Al-Mustaqbal University

College of Science

Medical physics Department

Medical Physics II

Second Semester

3rd stage

Lesson 1

Physics of Vision

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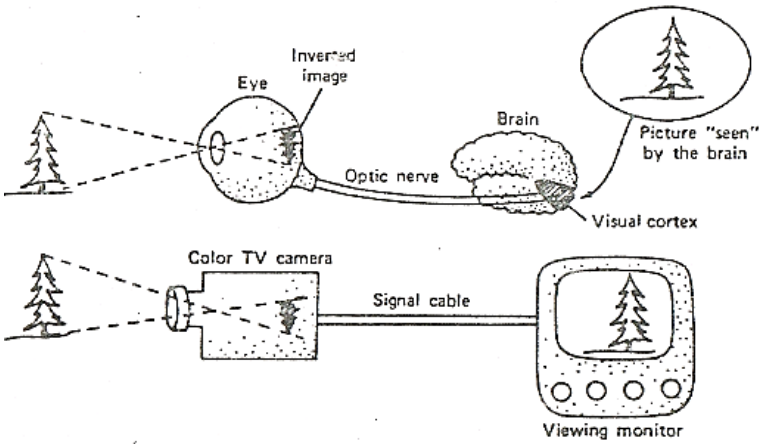
Introduction

Vision is one of the sensory systems that allows living beings to gather information about their surroundings. The visual system captures incident light either from an object emitting it or reflecting it, and the light is converted into an electrical signal after interacting with special cells in the eyes.

The sense of vision consists of three major components:

1. The ***eyes*** that focus an image from the outside world on the light-sensitive retina.
2. The system of millions of ***nerves*** that carries the information deep into the brain.
3. The visual ***cortex***-that part of the brain.

Blindness results if any one of the eye parts does not function.

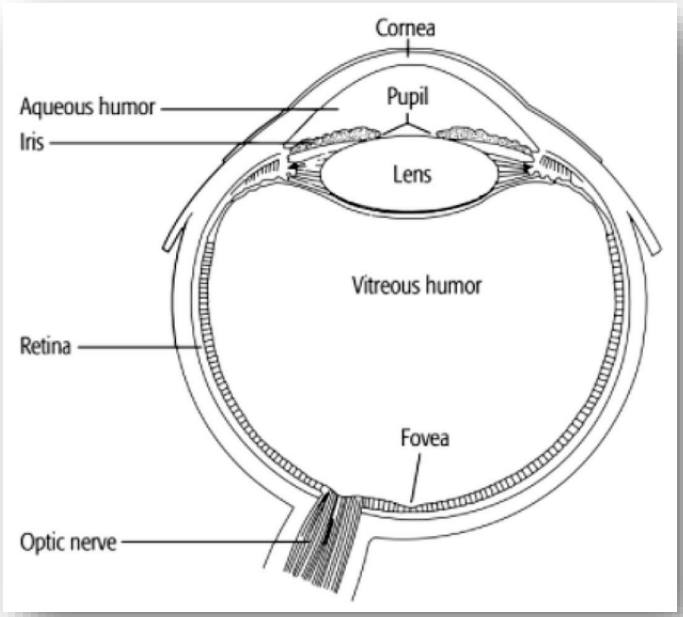


The eye has some striking similarities to camera

1. The lens of TV camera is analogous to the lens of the eye.
2. The signal cable is the optic nerve.
3. Viewing monitor is the visual cortex.

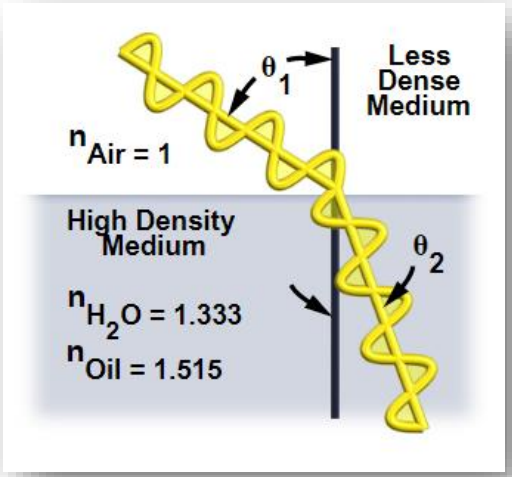
The main parts of an eye

- **Iris:** is the area around the eye's aperture, and it has a color depending on genetic factors. The iris aids the eye by increasing or decreasing incident light on the retina until the retina to adapt the new lighting condition.
- **Lens:** is a semitransparent structure located directly behind the main aperture of the eyes. Their unique function is to concentrate the rays of light to modify the focus of images at different distances.
- **Cornea:** is the front, crystalline part of the eye that allows light to enter.
- **Pupil:** is the black part located in the center of the eye and it is the aperture from which light enters.
- **Vitreous body:** This gel-like substance fills the eye and is found between the lenses and the retina.
- **Ciliary body and muscle:** is responsible for changing the size of the focus when the eye focuses on a near object. The ciliary body produces a liquid named aqueous humor which is responsible for eye pressure.



- **Retina:** is the surface behind the eye that is responsible for sensing, and it is filled with cone and rod cells.
- **Optical nerve:** is the nerve that sends the signal to the brain.

Refractive Index (n)



Refractive Index is a value calculated from the ratio of the speed of light in a vacuum (c) to that in a second medium of greater density (v). $n = \frac{c}{v}$

When light transfer between two media, refraction of light occur depending on the refractive index of both media.

The incident angle θ_1 is related to the refraction angle θ_2 by the simple relationship

known as Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$

There are several important points that can be drawn from this equation.

- When n_1 is greater than n_2, the angle of refraction is larger than the angle of incidence.
- When n_2 is greater than n_1 the angle of refraction is smaller than the angle of incidence.
- When the two refractive indices are equal, then the light is passed through without refraction.

Focusing Elements of Eye

The eye has two major focusing components: the ***cornea***, and the ***lens***.

The **cornea** focuses by bending (refracting) the light rays. The amount of bending depends on the curvatures of its surfaces and the speed of light in the lens compared with that in the surrounding material. The indexes of refraction of the cornea and other transparent parts of the eye are given as;

When the cornea is under-water it loses most of its focusing power because the index of refraction of the water (1.33) is close to that of the cornea (1.37). Divers keep air around the cornea by wearing a face mask.

Table of some parts of our eyes refractive index	
Part	n
Cornea	1.37
Aqueous humor	1.33
Lens cover	1.38
Lens center	1.41

The index of refraction is nearly constant for all corneas, but the curvature varies from one person to another and is responsible for most of our defective vision. If the cornea is curved too much the eye is **near-sighted**, not enough curvature results in **farsightedness**, and uneven curvature produces **astigmatism**.

The **lens** has focusing properties at both its front surface and its back surface. The lens is more curved in the back than in the front. It changes its focal strength by changing its curvature.

The lens is made up of layers somewhat like an onion, and all layers do not have the same index of refraction.

The lens has a flexible cover that is supported under tension by suspension fibers.

When the focusing muscle of the eye is relaxed, the lens flattened and adjusted to its lowest power and the eye is focused on distant objects. The point at which distant objects are focused when the focusing muscle is relaxed is called the *far point*.

For a *near-sighted* person the far point may be quite close to the eye.

To focus on closer objects, the circular muscle around the lens contracts causing spherical shape of the lens. The lens then has a greater focusing power. The closest point at which objects can be focused is called the *near point*.

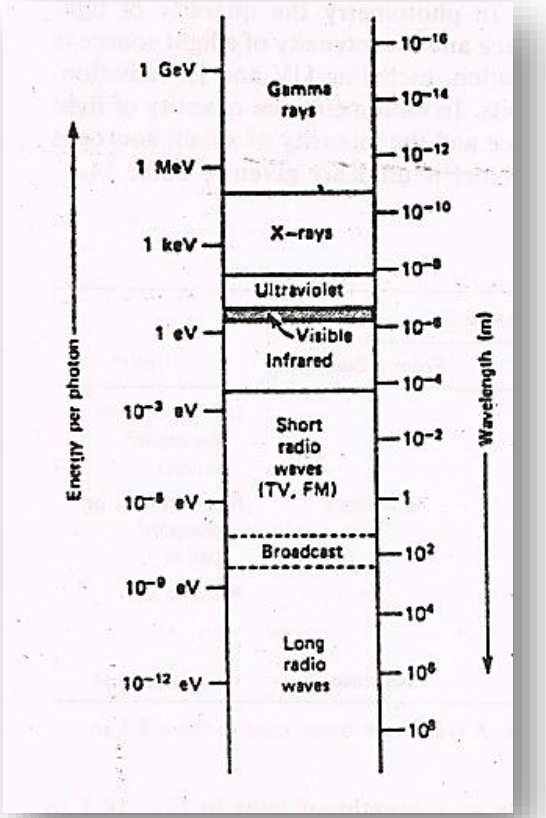
Young children have very flexible lenses and can focus on very close objects. The ability to change the focal power of the eye is called *accommodation*. As people get older, their lenses lose some accommodation. *Presbyopia* (old sight) results when lens has lost nearly all of its accommodation.

The cornea and lens can be damaged by ultraviolet and other forms of radiation.

The Retina (The light detector of the eye)

The retina, the light-sensitive part of the eye, converts the light images into electrical nerve impulses that are sent to the brain.

The absorption of a light photon in a *photoreceptor* triggers an electrical signal to the brain-an action potential. The energy of the photon is about 3 eV; the action potential has an energy millions of times greater. The light photon apparently causes a photochemical reaction in the photoreceptor which in some way initiates the action potential. The photon must be above a minimum energy to cause the reaction.

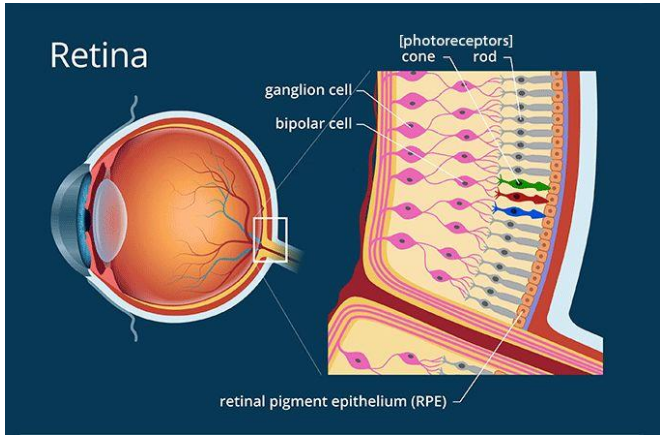


Infrared photons have insufficient energy and thus are not seen.

Ultraviolet photons have sufficient energy, but they are absorbed before they reach the retina and also are not seen.

Types of Receptors in the Retina

Rod cells



Specialized cells that help us see in the dark. They are sensitive to a wide range of wavelengths in the spectrum with a peak response at 500nm. They also have a low resolution and are much more sensitive to the incoming photons than cone cells. Despite this, they produce white and black colors.

Cone cells

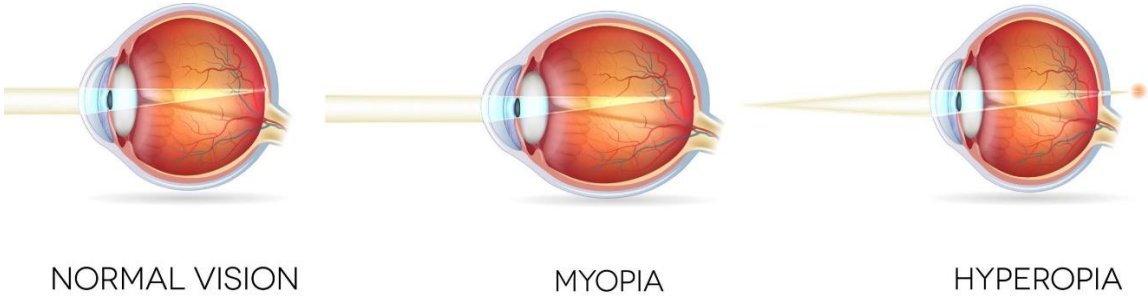
Contain one of three photo-pigments, each with a particular frequency/wavelength range of response with its own peak and reception. One of these photo-pigments in a cone cell may absorb a photon of light when it reaches the retina. The wavelength of the light influences the likelihood of absorption. A certain wavelength will excite one of the three types of cone cells in a specific ratio. This allows the brain to recognize wavelengths and generate the color sense.

Controlling the amount of light

A certain amount of light is needed in order for us to see. An aperture called the pupil regulates the amount of light entering the eye. This aperture is circular, and you can see it as black when you look at your eyes in the mirror. The radius of the aperture is regulated by the iris, which is connected to the ciliary muscle. The muscle will expand and contract depending on the light conditions. When the intensity is higher, the muscles will contract, and when it is lower, the muscles will expand.

Vision Defects

A normal eye can focus by accommodation on any object more than about 25cm away. In cases where an eye cannot focus on an object, the image is formed either behind or in front of the retina, resulting in blurred vision. This can be caused by the eye being too short or too long.



Near-sightedness (Myopia) A person affected by myopia has an eye ball that is too long, making the distance from the lens system to the retina too large. *This causes the image of distant objects to be formed in front of the retina*.

Far-sightedness (Hyperopia) A person affected by hyperopia has an eye ball that is too short, making the distance from the lens system to the retina too small. *This causes the image of near objects to be formed behind the retina*.

Exercises

1 The light is converted into ---------- after interacting with special cells in the eyes.

(a) Mechanical wave (b) Infrared (c) Ultraviolet (d) Electrical signal (e) Black and white

2 ----------is the aperture from which the light enter to the eye.

(a) Cornea (b) Iris (c) Pupil (d) Lens (e) Cortex

3 When light transfers between two media, if n_1 is greater than n_2, the angle of refraction is -------- than the angle of incidence

(a) Larger than (b) Smaller than (c) The same as (d) Not effected in comparison to (e) None of them

4 When the cornea is under-water it loses most of its focusing power because the index of refraction of the water is ------that of the cornea;

(a) Quite larger than (b) Quite smaller than (c) Close to (d) Exactly the same of (e) None of them

5 In the myopia disease, the image of distant objects is formed in front of the retina.

(a) Because of the eye ball is long (b) Because of the eye ball is short (c) Because of the eye ball is normal

(d) Because of the liquid is lost (e) Because of the color blindness