The Islamic University
Collage of Medical Technology
Anesthesiology Techniques Department

Freshman Class

Medical Physics

Chapter Two

Human Eye Response

Assist.Lec. Ameer Ali

Human Eye Response

Receptors of the Human Eye: The human eye contains two types of retinal receptors, rods and cones.

Photopic Eye Response (Cone Vision) : Photopic response is that of the cones in the retina and occurs after the eye has been adapted to a field luminance equal to or greater than about 3 nt ($cd.m^{-2}$) (light-adapted state). After being dark adapted, the eye requires 'about two or three minutes to become light adapted when the luminance is raised.

Scotopic Eye Response (Rod Vision): Scotopic response is that of the rods in the retina and occurs after the eye has been adapted to field luminance equal to, or less than, about 3 $x10^{-5}$ nt ($cd.m^{-2}$). After being light adapted, the eye requires considerable time to become dark adapted when the luminance is lowered (See Fig.No.1). The rate of adaption depends on the initial luminance of the starting field with nearly complete dark adaption being approached in about 45 minutes. Because the rods and not the cones function in the dark-adapted state and because color vision is entirely a function of the cones, the increased responsivity of the eye in the dark-adapted state is accompanied by a loss in color vision. The central part of the retina known as the fovea contains only cones.

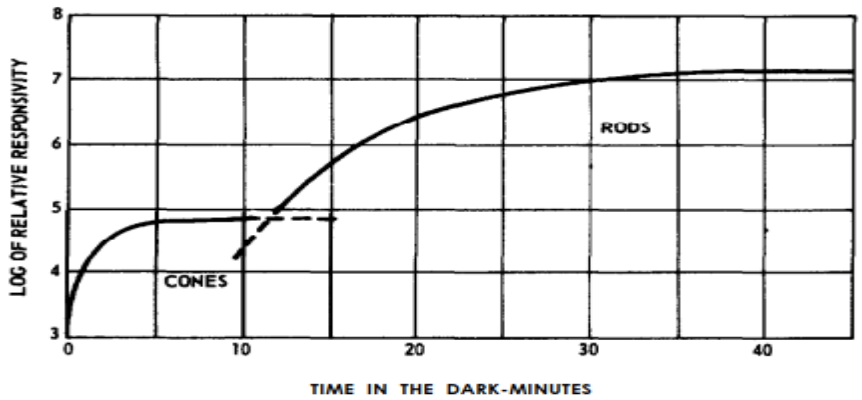

Figure No.1 Adaption of the eye to complete darkness after exposure to abright field. Light incident 12° above fovea.

The spectral responsivity of the eye in the dark-adapted (scotopic) state differs considerably from the light-adapted (photopic) state. Between these two states, the spectral response of the eye is continuously variable; this condition is known as the mesopic state.

Mesopic Eye Response As field luminance is lowered from about ($3\text{-}3x10^{-5}$) nt ($cd.m^{-2}$), the luminous efficacy curve of the eye shifts progressively from that of photopic vision to that of scotopic vision.

Rod cells are photoreceptor cells in the retina of the eye that can function in lower light than the other type of visual photoreceptor, cone cells. Rods are usually found concentrated at the outer edges of the retina and are used in peripheral vision. On average, there are approximately 92 million rod cells in the human retina. Rod cells are more sensitive than cone cells and are almost entirely responsible for night vision. However, rods have little role in color vision, which is the main reason why colors are much less apparent in dim light.

Cone cells, or cones, are photoreceptor cells in the retinas of vertebrate eyes (e.g. the human eye). They respond differently to light of different wavelengths, and are thus responsible for color vision and function best in relatively bright light, as opposed to rod cells, which work better in dim light. Cone cells are densely packed in the fovea centralis, a 0.3 mm diameter rod-free area with very thin, densely packed cones which quickly reduce in number towards the periphery of the retina. There are about six to seven million cones in a human eye and are most concentrated towards the macula. Cones are less sensitive to light thanthe rod cells in the retina (which support vision at low light levels), but allow the perception of color. They are also able to perceive finer detail and more rapid changes in images, because their response times to stimuli are faster than those of rods. Cones are normally one of the three types, each with different pigment, namely: S-cones, M-cones and L-cones. Each cone is

therefore sensitive to visible wavelengths of light that correspond to short-wavelength, medium-wavelength and longer-wavelength light. Because humans usually have three kinds of cones with different photopsins, which have different response curves and thus respond to variation in color in different ways, we have trichromatic vision. Being color blind can change this, and there have been some verified reports of people with four or more types of cones, giving them tetrachromatic vision.The three pigments responsible for detecting light have been shown to vary in their exact chemical composition due to genetic mutation; different individuals will have cones with different color sensitivity.

Scotopic vision is the vision of the eye under low-light levels. The term comes from Greek skotos, meaning "darkness", and -opia, meaning "a condition of sight". In the human eye, cone cells are nonfunctional in low visible light. Scotopic vision is produced exclusively through rod cells, which are most sensitive to wavelengths of around 498 nm (green–blue) and are insensitive to wavelengths longer than about 640 nm (reddish orange). This condition is called the Purkinje effect.

Photopic vision is the vision of the eye under well-lit conditions (luminance level 10 to 10^8 cd/m^2). In humans and many other animals, photopic vision allows color perception, mediated by cone cells, and a significantly higher visual acuity and temporal resolution than available with scotopic vision. The human eye uses three types of cones to sense light in three bands of color. The biological pigments of the cones have maximum absorption values at wavelengths of about 420 nm (blue), 534 nm (bluish-green), and 564 nm (yellowish-green). Their sensitivity ranges overlap to provide vision throughout the visible spectrum. The maximum efficacy is 683 lm/W at a wavelength of

555 nm (green). By definition, light at a frequency of 5.4×10^{14} hertz (λ = 555.17 nm) has a luminous efficacy of 683 lm/W.

Mesopic: This term refers to a range of human vision with both rods and cones active. There is no hard-line transition at either end, but for most intents and purposes the mesopic range is generally considered to be from 3 cd/m2 down to 0.01 cd/m2.

In visual physiology, **adaptation** is the ability of the retina of the eye to adjust to various levels of light. Natural night vision, or scotopic vision, is the ability to see under low-light conditions. In humans, rod cells are exclusively responsible for night vision as cone cells are only able to function at higher illumination levels.[1] Night vision is of lower quality than day vision because it is limited in resolution and colors cannot be discerned; only shades of gray are seen.[1] In order for humans to transition from day to night vision they must undergo a **dark adaptation** period of up to two hours [2] in which each eye adjusts from a high to a low luminescence "setting", increasing sensitivity hugely, by many orders of magnitude.[1] This adaptation period is different between rod and cone cells and results from the regeneration of photopigments to increase retinal sensitivity.[1] Light adaptation, in contrast, works very quickly, within seconds. Adaptation is much faster under photopic vision; it can occur in 5 minutes for photopic vision but it can take 30 minutes to transition from photopic to scotopic.[In photometry**, luminous flux** or **luminous power** is the measure of the perceived power of light. It differs from radiant flux, the measure of the total power of electromagnetic radiation (including infrared, ultraviolet, and visible light), in that luminous flux is adjusted to reflect the varying sensitivity of the human eye to different wavelengths of light. In physics, **power** is the rate of doing work or of transferring heat, i.e. the amount of energy transferred or converted per unit time. In the International System of

Units, the unit of power is the watt, equal to one joule per second. **The lumen** (symbol: lm) is the SI derived unit of luminous flux, a measure of the total quantity of visible light emitted by a source per unit of time. Luminous flux differs from power (radiant flux) in that radiant flux includes all electromagnetic waves emitted, while luminous flux is weighted according to a model (a "luminosity function") of the human eye's sensitivity to various wavelengths.

Questions

1. What is the difference between cones and rods?
2. What is scotopic eye response?
3. What is photopic eye response?
4. Who is responsible for the state of eye adaptation to lighting?
5. Who is responsible for the state of eye adaptation to darkness?
6. What are the receptors of the human eye?
7. What are the areas of vision distribution for the human eye?
8. Why is vision less in rods than in cones?