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VISION PHOTOCHEMISTRY

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ABSTRACT

Vision is no doubt the most important of all our senses. 40% of all the sensory information about the world comes to us through our eyes. But how do we see is one of the old scientific questions. The eye is the most extraordinary sensory organ. The wavelength response is 400-800 nm but its degree of sensitivity is such that the eye can clearly detect an object in light so dim to correspond to a light input over the retina of only about 1000 quanta per second. Retina contains a series of light sensitive cells known as Rods and Cones or Photoreceptor cells which respond to light and convert it into electrical impulses that create image. In this review, we discuss about the chemistry behind vision.

KEYWORDS: Vision, rod and cone cells, rhodopsin, isomerization.

INTRODUCTION

In Mammals, the organ responsible for vision is the "Eye." Light enters the eye and it is then focused on the Retina by the Lens. The Retina is a layer of cells that cover the interior surface of the Eye. The Retina contains molecules that undergo chemical changes upon absorbing light but it is the Brain that makes sense of visual information to create an image. Retina contains a series of light sensitive cells known as Rods and Cones or Photoreceptor cells which respond to light. Therefore, light image is mapped on the surface of Retina. The light impulses are converted to electrical impulses by rod and cone cells. These are then transmitted to the brain via nerve fibers. The brain then determines, which nerve fibers carried the impulse activated by light at certain Photoreceptors, and then creates an image.

EYE

There are three million cone cells and hundred million rod cells in human eye. Each of these types of cell performs a different function. Some people cannot tell some colors from others. These people are colorblind. A colorblind person has low count of cone cells in the retina. The cone cells require high levels of light to operate and are responsible for **colored vision** and sharpness of images. The cone cells are concentrated at the center of the back of the eye, at its most sensitive region, Fovea. The cone cells are sensitive to different wavelengths of light; they are yellow, blue and green. The rod cells are responsible for seen in dim light and they operate in black and white. Rod cells are extremely sensitive to detecting white light to provide night vision. The Rod cells are spread throughout the Retina.

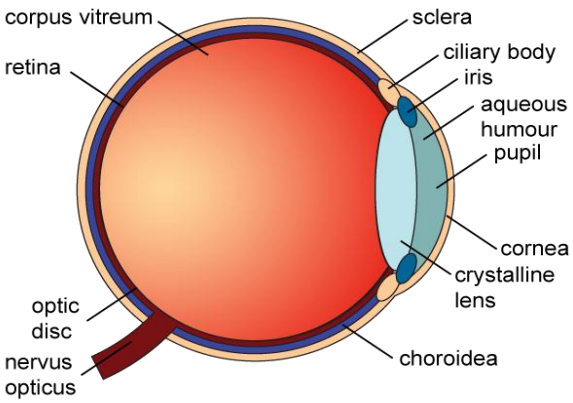

Fig. 1: Diagram of eye.

Chemical Changes In Eye

Rod cells and cone cells contain similar chemicals to allow them to operate. There is a chemical called Rhodopsin, a light sensitive substance formed from a protein called opsin and which is bonded to a pigment called 11-cis retinal. 1-cis retinal is synthesized in the liver from dietary vitamin A, and it is the key substance. The tops of the rod cells and cone cells contain a region filled with membrane-bound discs, which contain the molecule cis-retinal bound to a protein called opsin. The resulting complex is called rhodopsin or "visual purple".

Structure of Rhodopsin

The structure of opsin is unknown, but its prosthetic group (11-*cis*-retinal) is bonded to it through an imine (Schiff base) function formed between the aldehyde group of the retinal and the side-chain amino function of a lysine unit of opsin. The molecule cis-retinal can absorb light at a specific wavelength. When light hits the retinal, the energy is used to break a double bond contained in the molecule. Once the bond has been broken, the molecule can then rotate. The rotation results in an **isomerization** and thus changes the shape of the molecule from the cis to the trans arrangement and the retinal molecule physically separates from the opsin. As the protein changes its geometry, it initiates a series of biochemical reactions that result in changes in charge so that a large potential difference builds up across the plasma membrane. This potential difference is passed along to an adjoining nerve cell as an electrical impulse. The nerve cell carries this impress to the brain, where the visual information is interpreted as our vision.

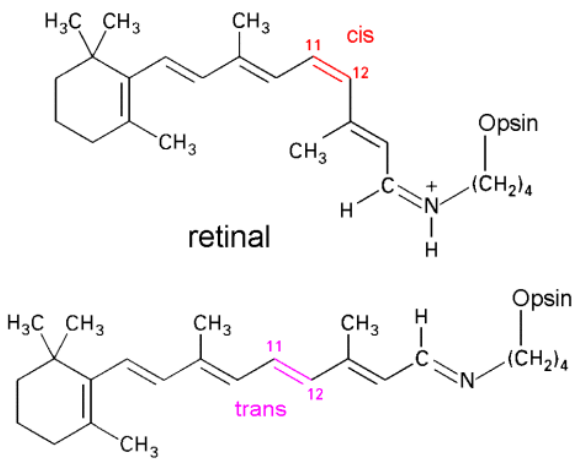

Fig. 2: Isomerization of Cis-Retinal To Trans-Retinal.

To overcome this spontaneous change, five adjacent rod cells or cone cells must all transmit a signal to the brain at the same time before it is interpreted as vision. Each cell can be stimulated by photon. As a direct result, the smallest amount of light that will effectively stimulate our vision is five photons. When light is absorbed by rhodopsin, the double bond electrons are promoted to pi*-orbital, which allows the bond to free rotate and the molecule, is converted into trans-retinal molecule. The trans retinal molecule is bleached and cannot respond to more light until it isomerizes back to the cis- form and attaches to the protein opsin again.

Due to this conversion, the bond between opsin and the trans retinal molecule breaks. As a result, the active site of the opsin molecule becomes free. The opsin molecule thus catalyses the transformation of GDP to GTP. GTP molecule bonds with the alpha subunit attached to the phosphodiesterase and removes it. As a result, the phosphodiesterase molecule becomes free. This phosphodiesterase catalyses the conversion of cyclic GMP molecule into the GMP molecule. This results in the closing of the ion channels and thereby inhibits the movement of the sodium ions into the cell resulting in hyperpolarization. This stops the release of the inhibitory neuro-transmitter and thereby results in the generation of the nerve impulses which is carried to the brain by the nerves for interpretation.

Once a cell has been stimulated, the molecules have to return to their original form. The opsin reattaches itself to the retinal and reforms the double bond to remake the rhodopsin molecule. The temporary blindness that occurs when looking at bright light is caused by cell overload and rhodopsin breakdown. As the molecules slowly return to their natural form and some are then disassociated, vision returns.

When visible light hits the cis-retinal, the cis-retinal undergo an isomerization, or change in molecular arrangement to all-trans-retinal. The new form of trans-retinal does not fit as well into protein, so a series of geometrical changes in the protein begin. The resulting complex is referred to as Bathrhodopsin. Sometimes the change in the rhodopsin molecule can occur spontaneously, creating random flashes of light. The pigment in the cones is less easy to break down and it is harder and slower for it to regenerate than the pigment in the rods. Color vision needs brighter conditions.

CONCLUSION

Photoisomerization reaction occurs as the first step in the chemistry of vision. Cis Trans isomerization is believed to be caused by weakening of the C-C12bond of the rhodopsin due to the absorption of a photon.The pi-pi* electron transition loosens the bond, the bond swings around into a new conformation forming all-trans-retinal. The electron returns to the ground state locking the molecule in the trans conformation. The new trans-retinal conformation requires more space than the cis-retinal conformation. The molecules press against the opsin stimulating the rods and cones. The time required for this is 0.25-050 microseconds.

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