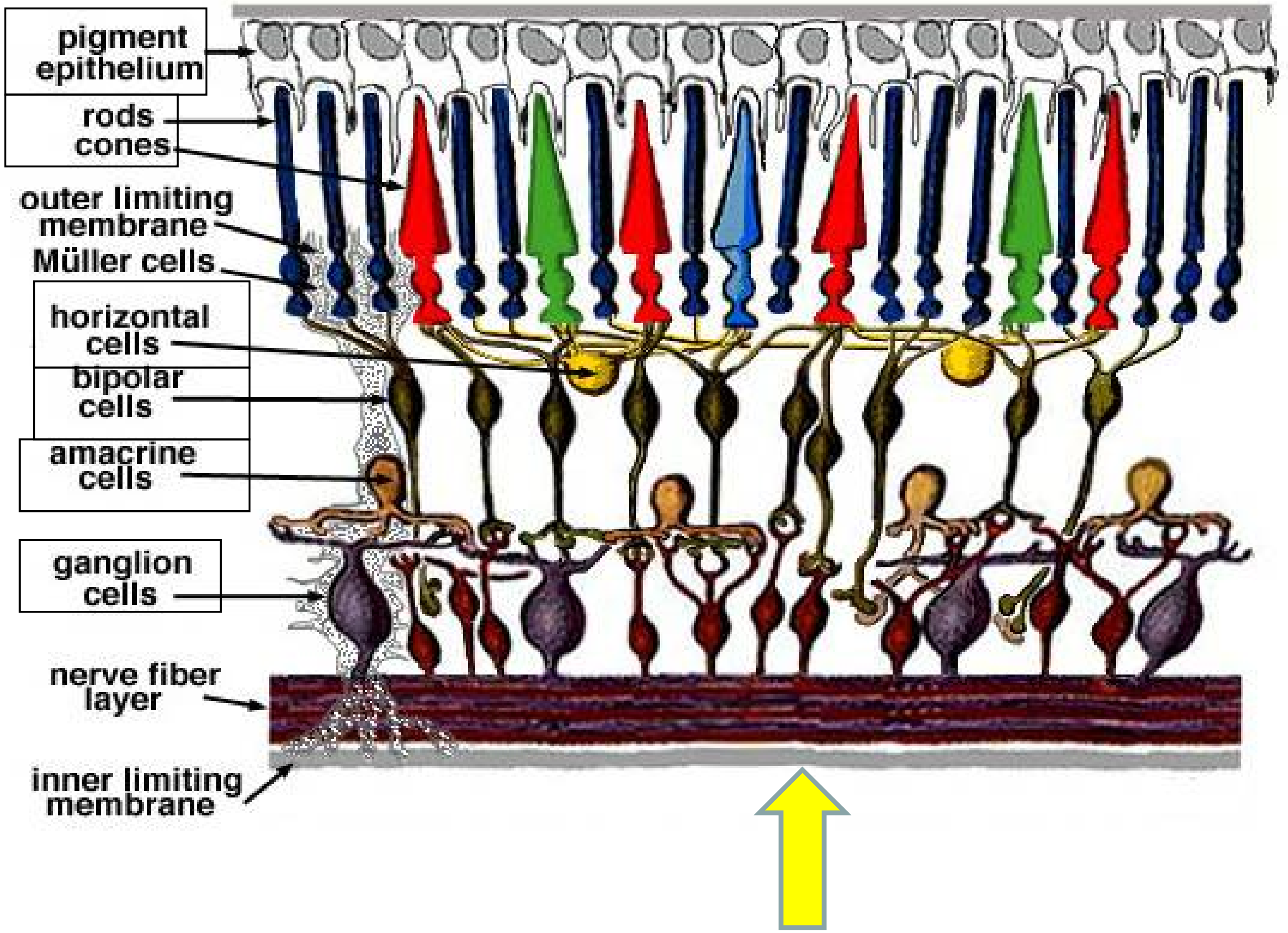
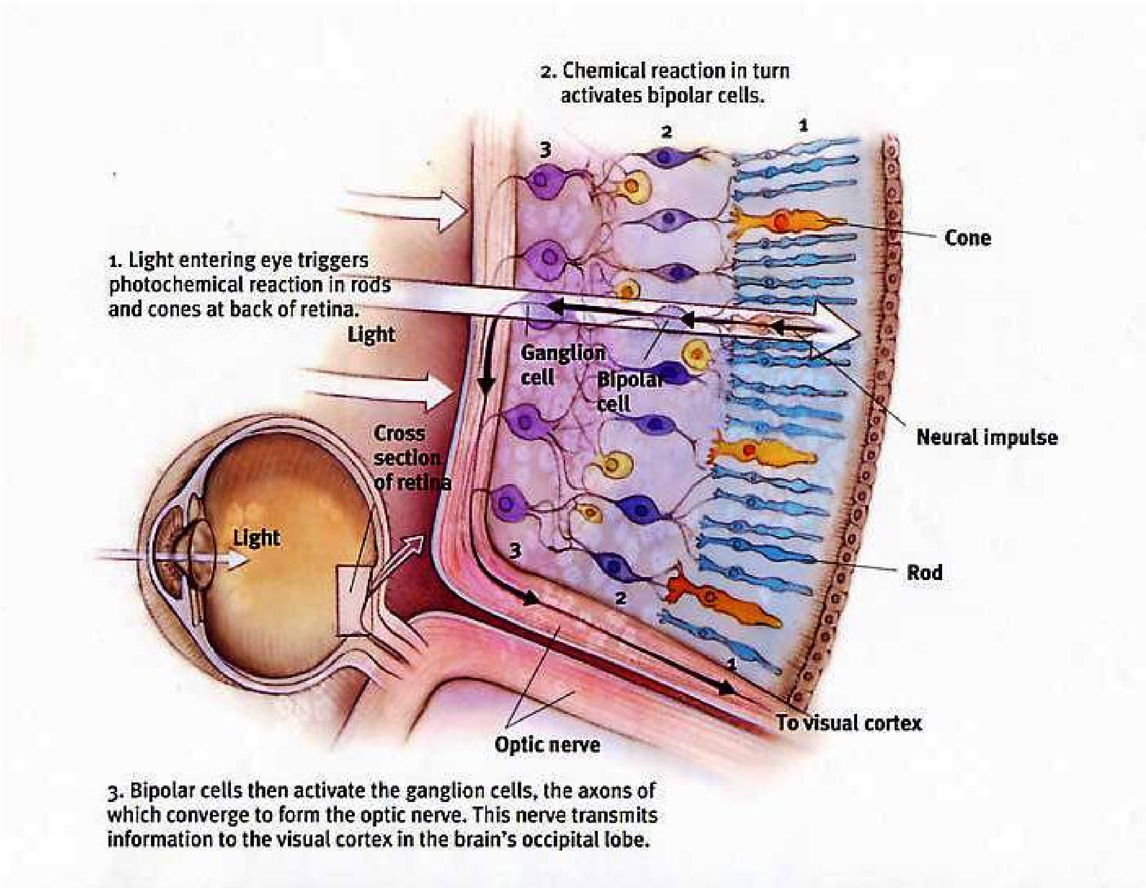
The Retina

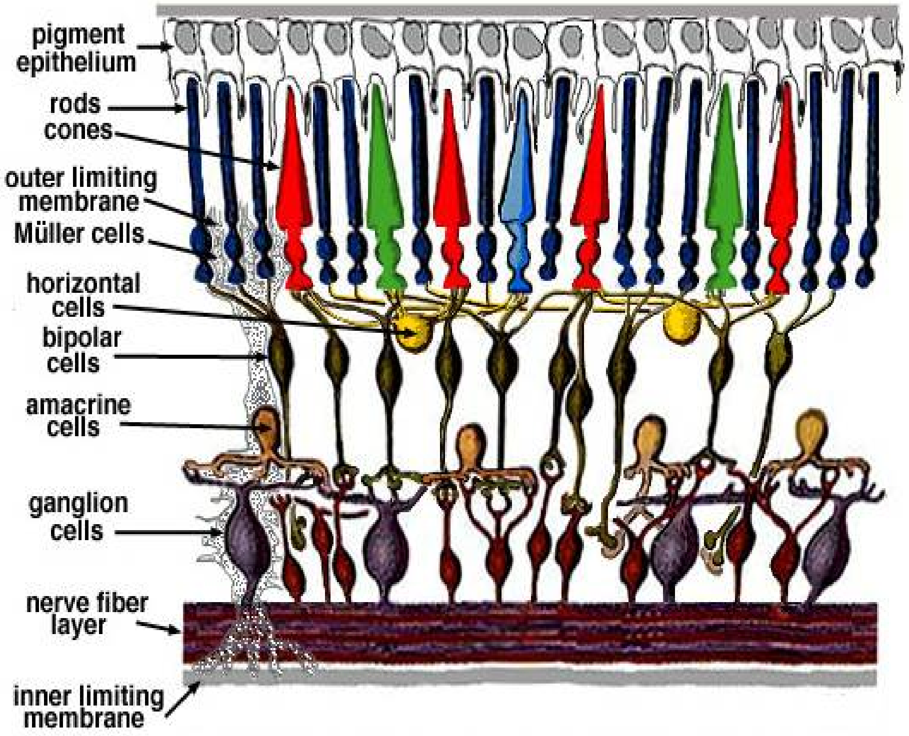
The retina



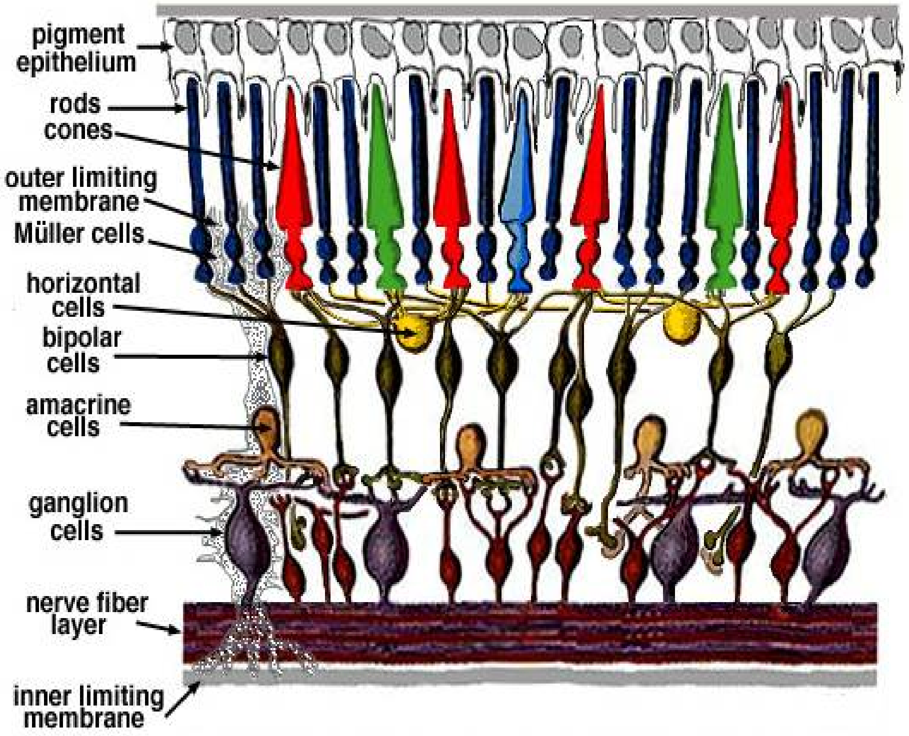
pigment epithelium
rods
cones
outer limiting membrane
Müller cells
horizontal cells
bipolar cells
amacrine cells
ganglion cells
nerve fiber layer
inner limiting membrane



2. Chemical reaction in turn activates bipolar cells.
3
2
1
Cone
1. Light entering eye triggers photochemical reaction in rods and cones at back of retina.
Light
Ganglion cell
Bipolar cell
Neural impulse
Cross section of retina
Light
3
2
Rod
1
To visual cortex
Optic nerve
3. Bipolar cells then activate the ganglion cells, the axons of which converge to form the optic nerve. This nerve transmits information to the visual cortex in the brain's occipital lobe.

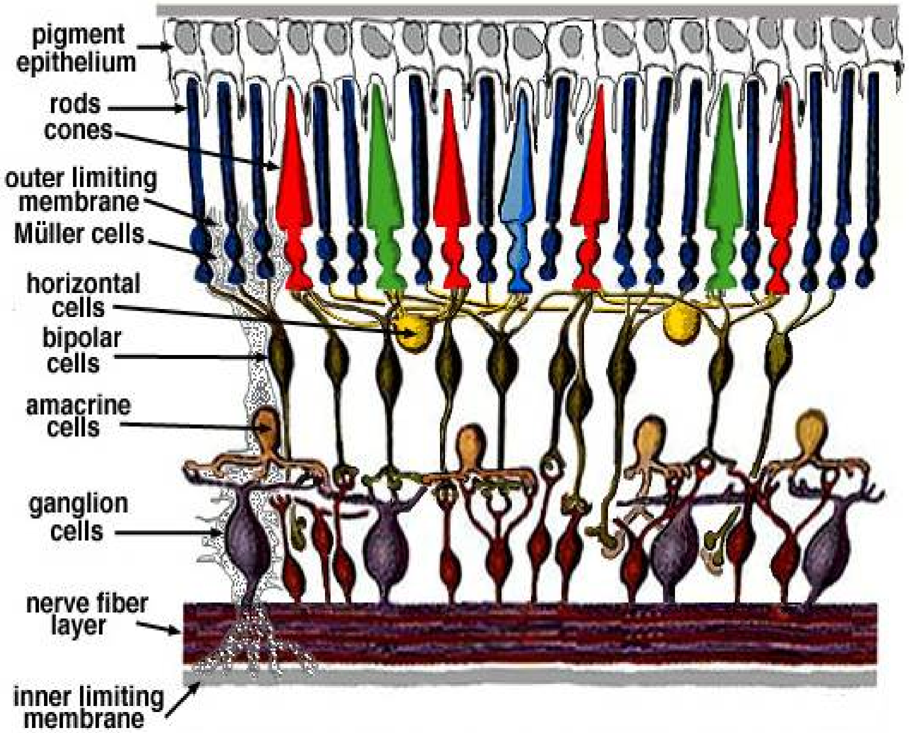


The pigment layer contains melanin that prevents light reflection throughout the globe of the eye. It is also a store of Vitamin A.



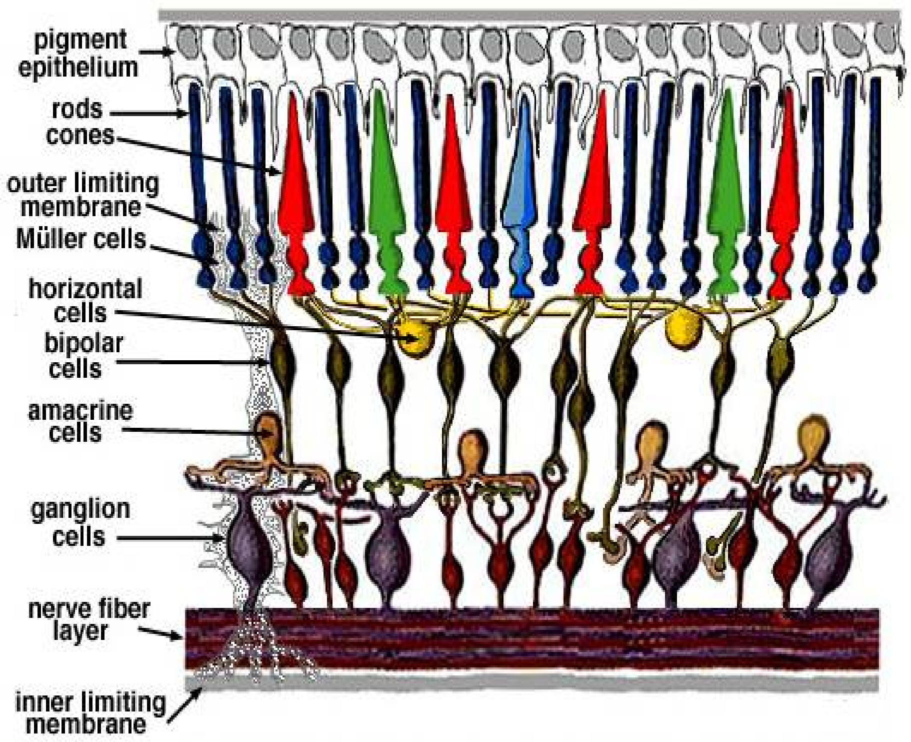
Rods and Cones

Photoreceptors of the nervous system responsible for transforming light energy into the electrical energy of the nervous system.



Bipolar cells

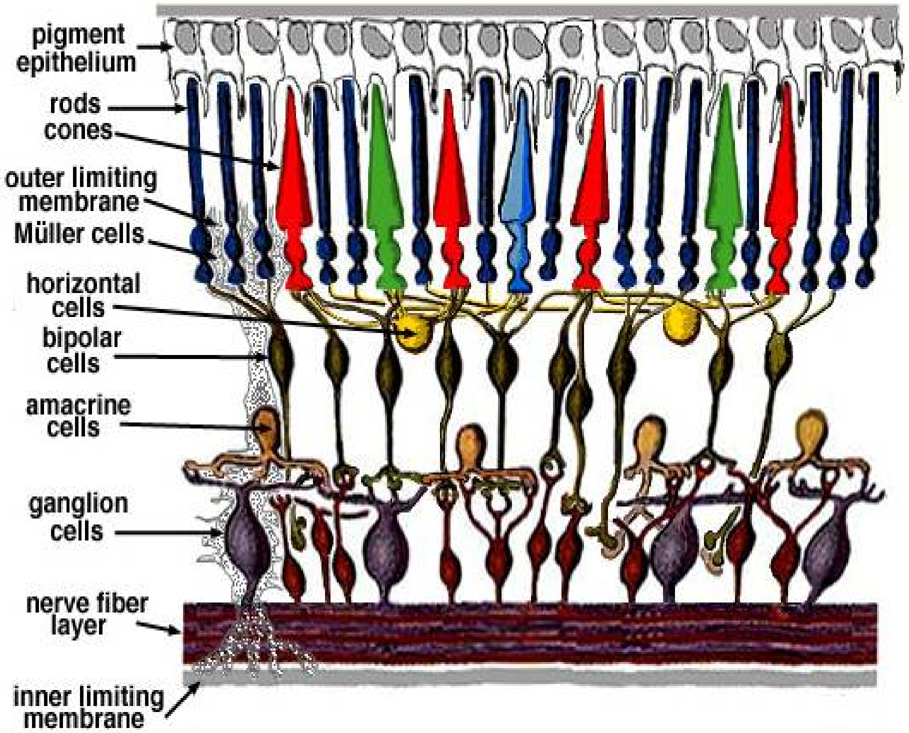
Link between photoreceptors and ganglion cells.



Horizontal cells

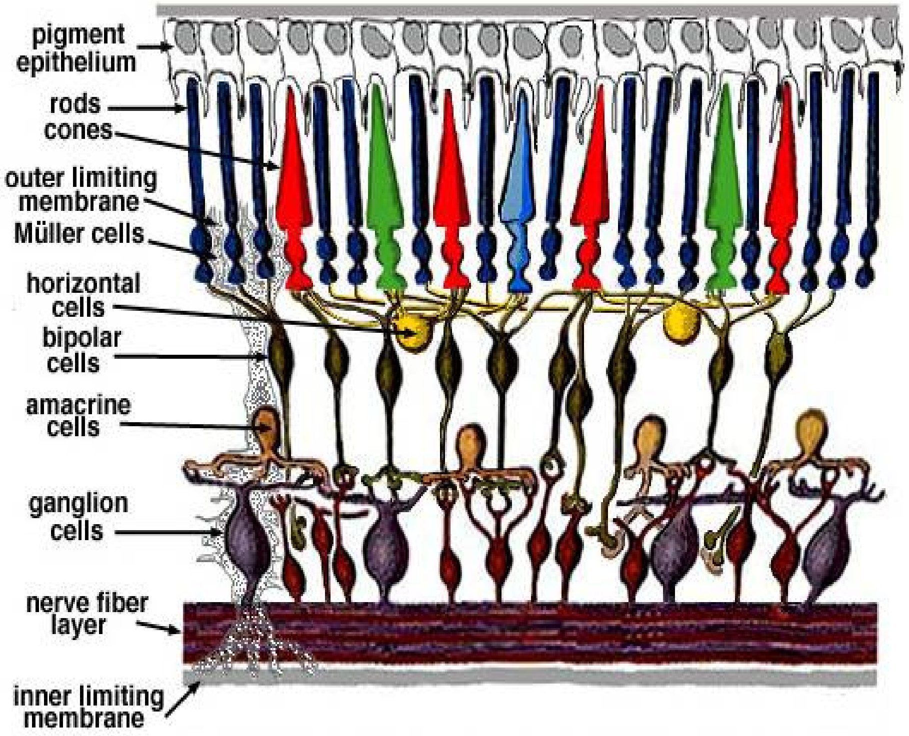
Provide inhibition between bipolar cells. This is the mechanism of lateral inhibition which is important to edge detection and contrast enhancement.

Lateral inhibition – capacity of an excited neuron to reduce the activity of its neighbour



Amacrine cells

Transmit excitatory signals from bipolar to ganglion cells. Thought to be important in signalling changes in light intensity.



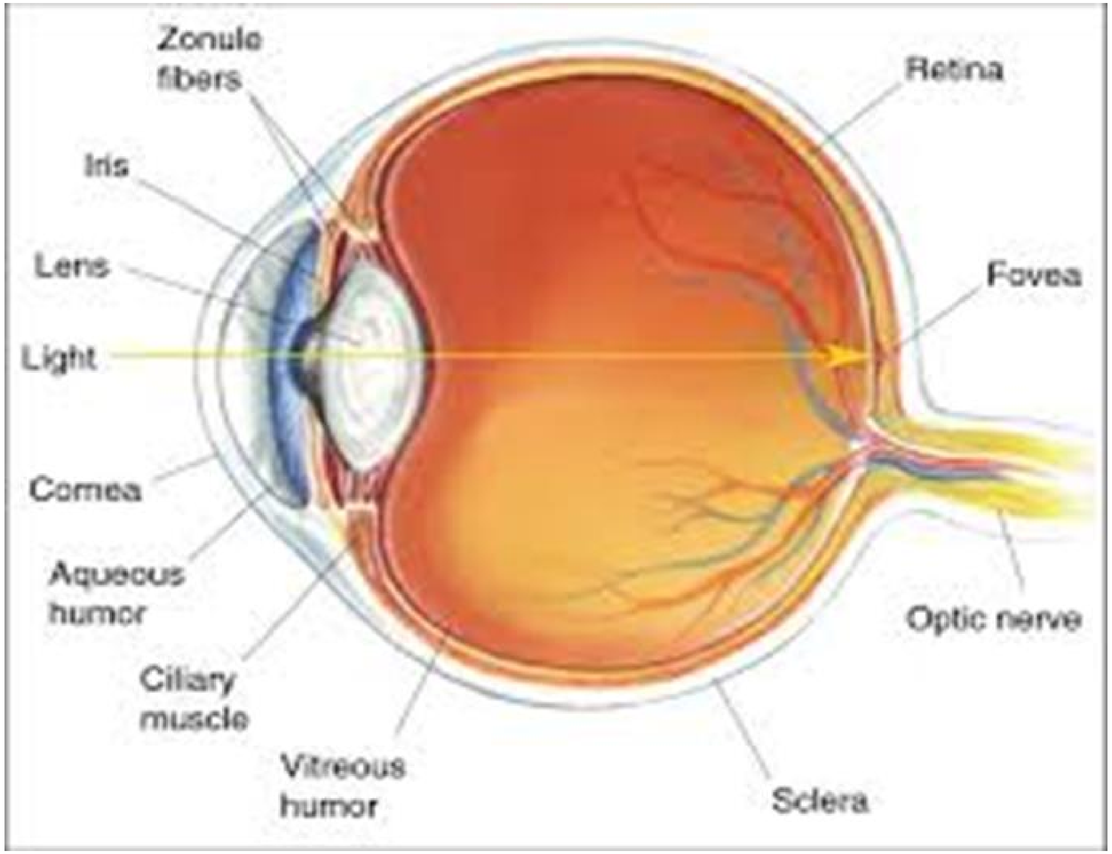
Ganglion cells

Output neurons of the eye that transmit light information to the brain. These axons bundle together to create the optic nerve and the blind spot.

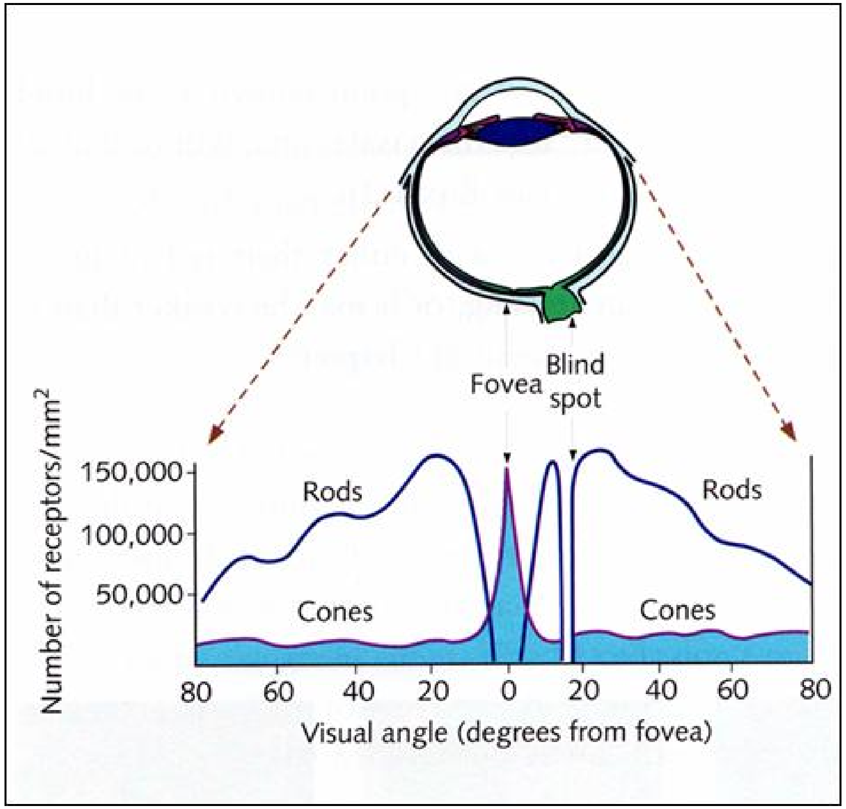
Neural circuitry

About 125 rods and 5 cones converge on each optic nerve fibre.

In the central portion of the fovea there are no rods. The ratio of cones to optic nerves in the fovea is one. This increases the visual acuity of the fovea.

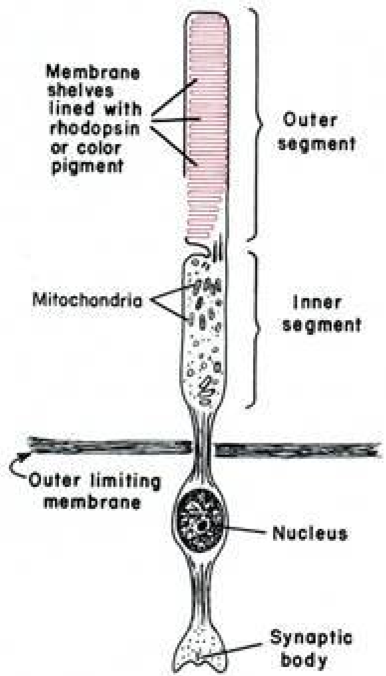


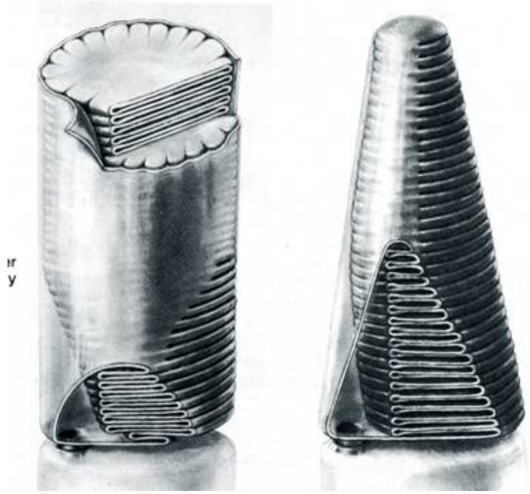
Zonule fibers
Retina
Iris
Lens
Fovea
Light
Cornea
Aqueous humor
Ciliary muscle
Optic nerve
Vitreous humor
Sclera



Fovea
Blind spot
Number of receptors/mm²
150,000
100,000
50,000
Rods
Cones
Rods
Cones
80
60
40
20
0
20
40
60
80
Visual angle (degrees from fovea)

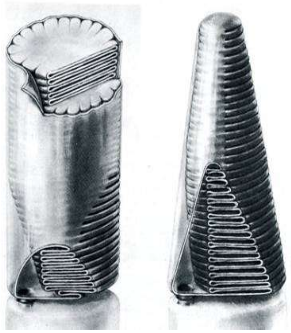
Rods and Cones





Photosensitive substance in rods is called rhodopsin and in cones is called iodopsin.

The Photochemistry of Vision



Rhodopsin and Iodopsin

Cis-retinal +Opsin

Light sensitive

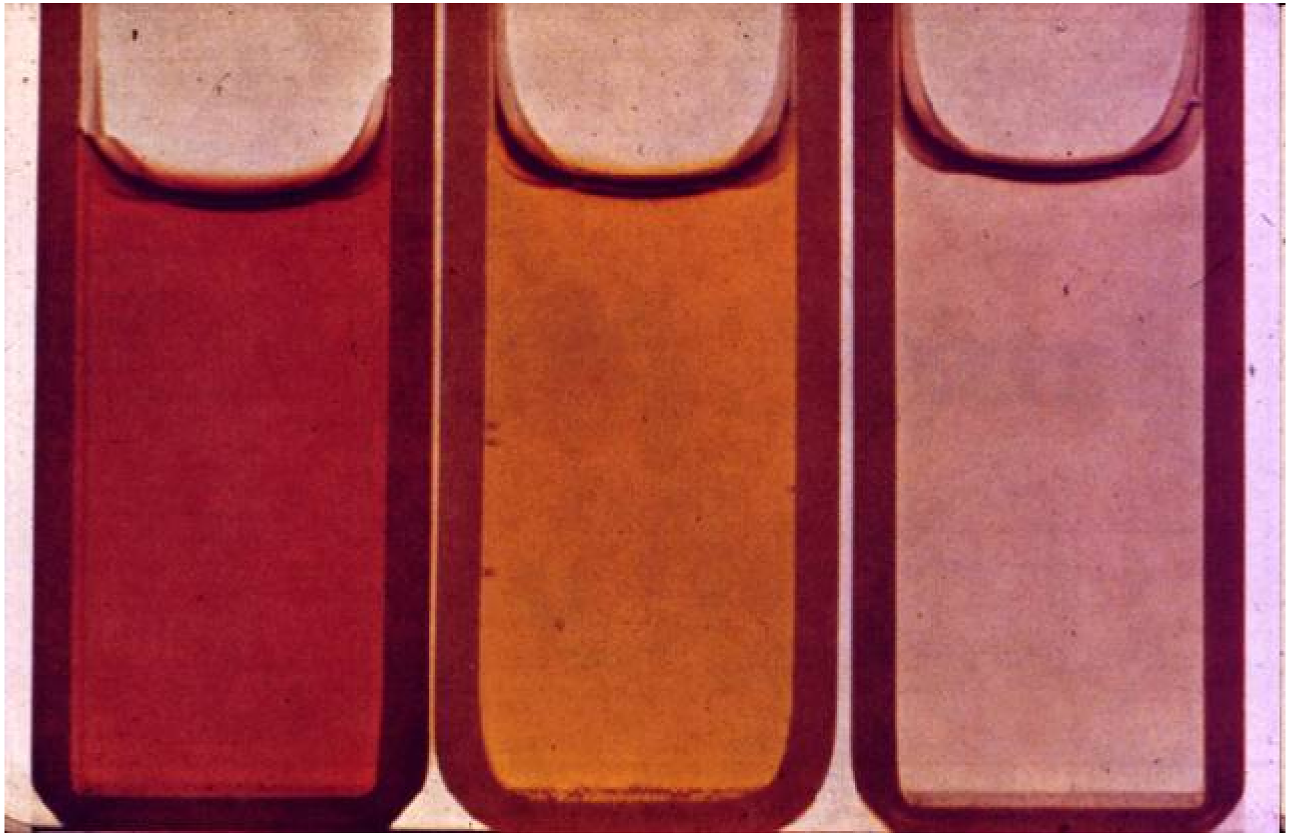
Light

Trans-retinal

Light insensitive

Opsin

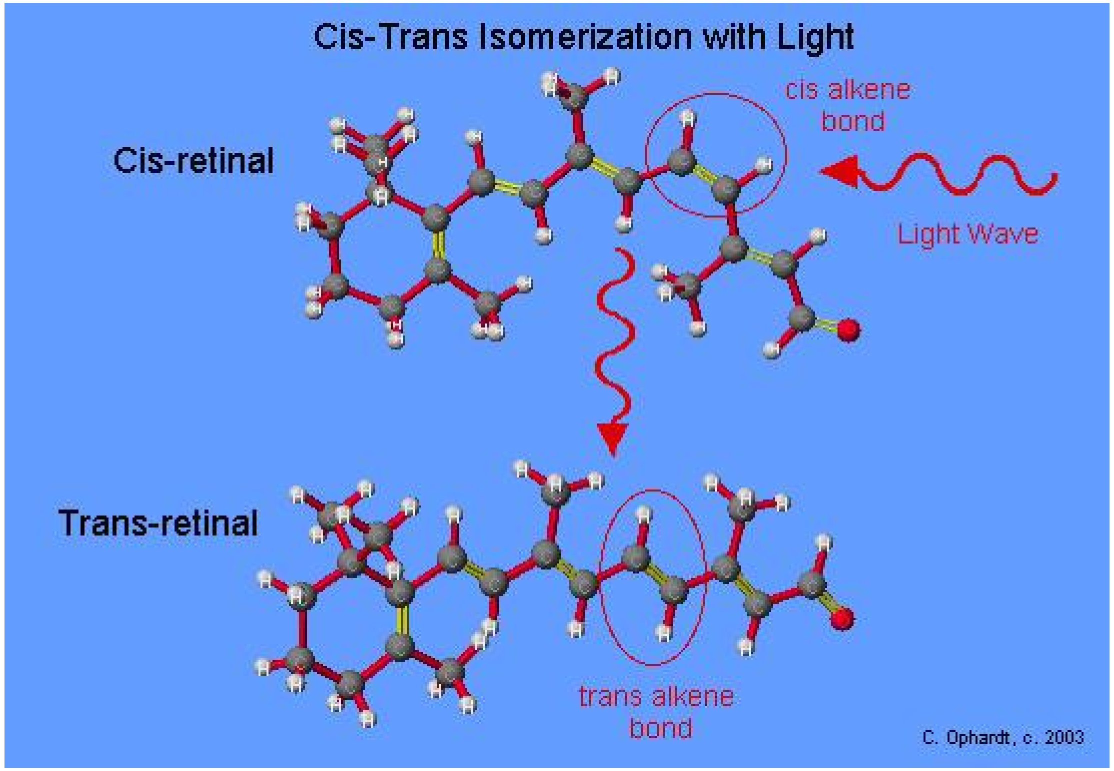
This is a reversible reaction

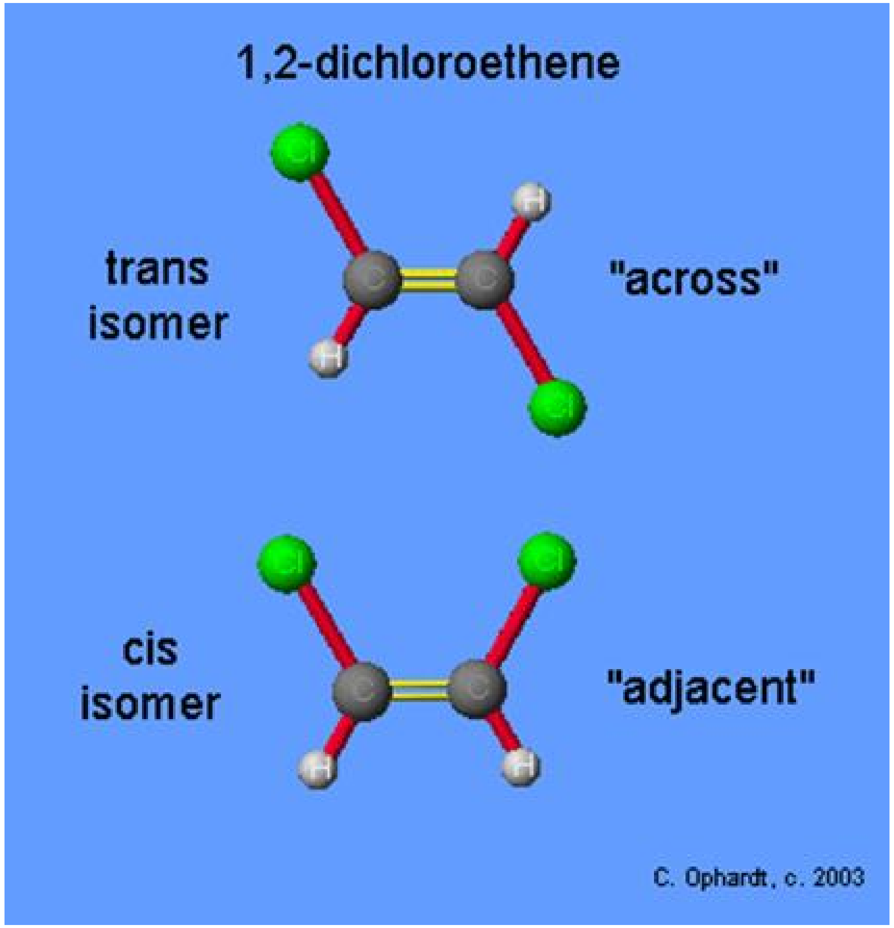


Cis-retinal +Opsin

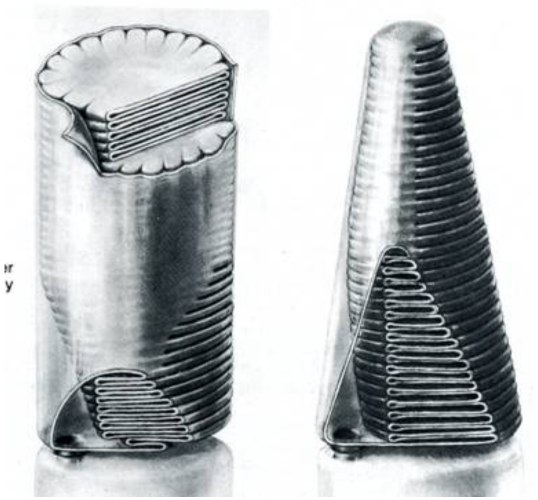
Light sensitive

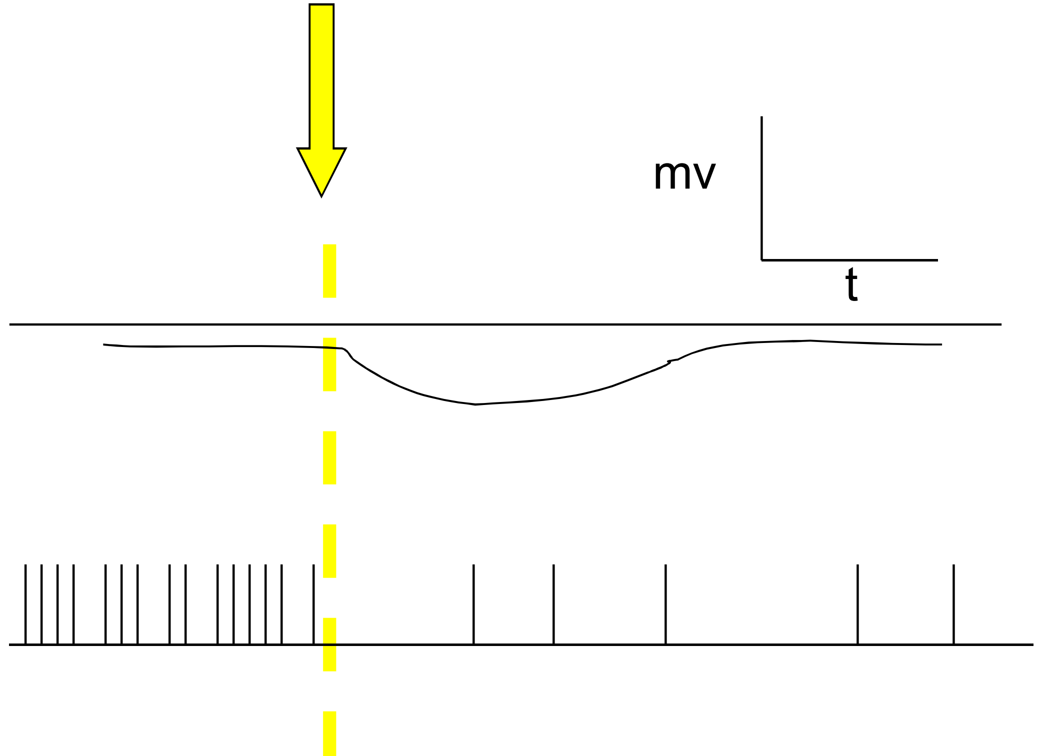
Vitamin A


Cis-Trans Isomerization with Light
Cis-retinal
cis alkene bond
Light Wave
Trans-retinal
trans alkene bond
C. Ophardt, c. 2003


1,2-dichloroethene
trans
isomer
"across"
cis
isomer
"adjacent"
C. Ophardt, c. 2003

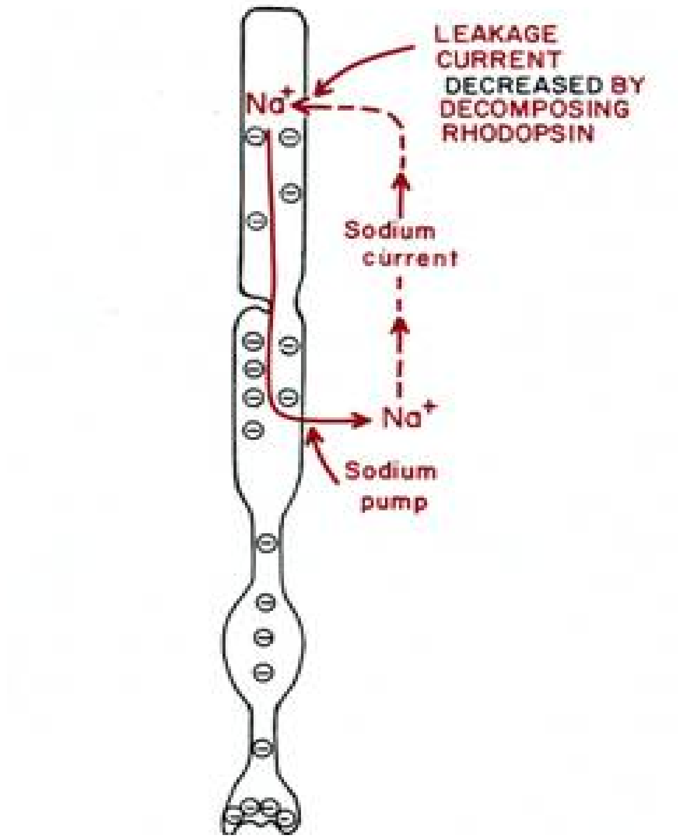
In the presence of light, the rods and cones are hyperpolarized



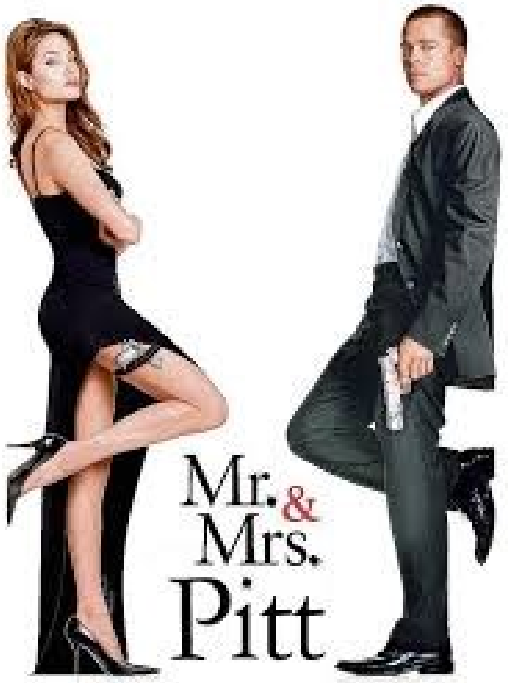


Hyperpolarizing potential (receptor potential) lasts for upto half a second, leading to the perception of fusion of flickering lights.

Receptor potential – rod and cone potential



Hyperpolarizing receptor potential caused by rhodopsin decomposition.



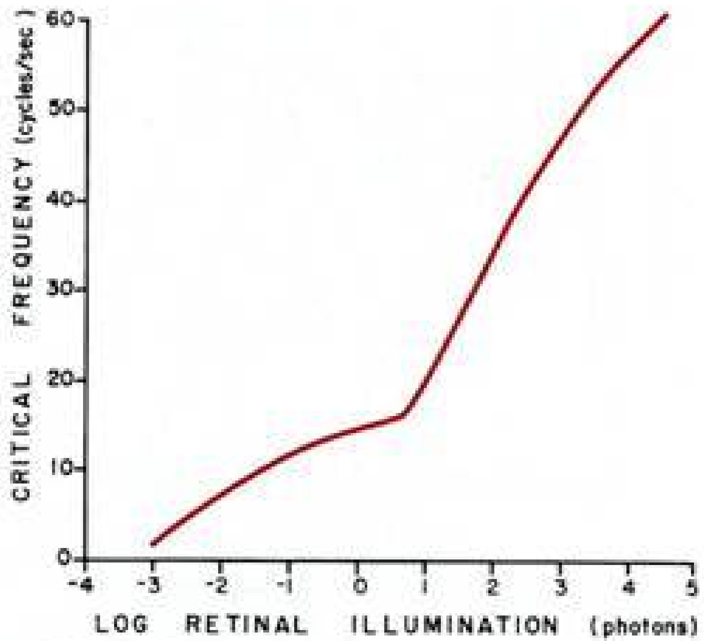
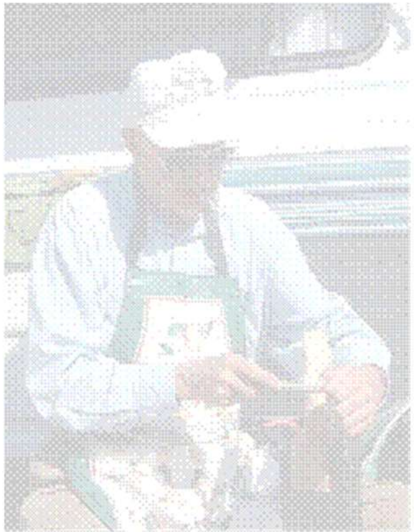


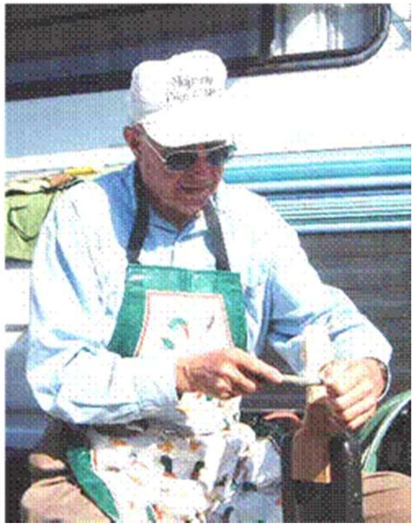
Figure 23–9. Relationship of intensity of illumination to the critical frequency for fusion.

Light and dark adaptation in the visual system

The eye is capable of vision in conditions of light that vary greatly in intensity

The eye adapts dynamically to lighting conditions

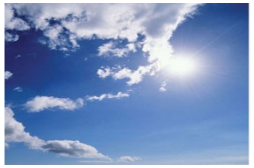




Light and Dark Adaptation

We are able to see in light intensities that vary greatly. The visual system is able to adapt dynamically to changes in light intensity. This is accomplished by

- Alterations in the size of the pupil
- Alterations in the concentration of rhodopsin
- Neural factors



Alterations in the concentration of rhodopsin

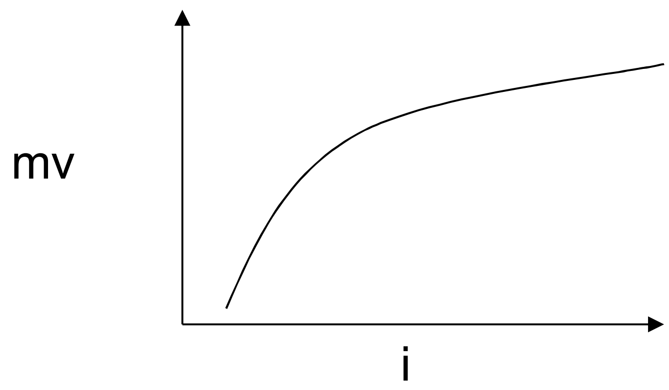
Cis-retinal +Opsin

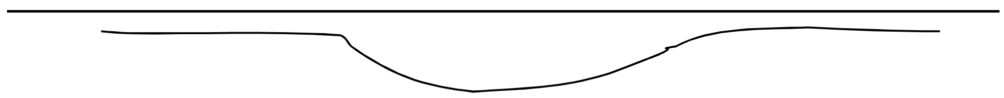
Light sensitive

Vitamin A

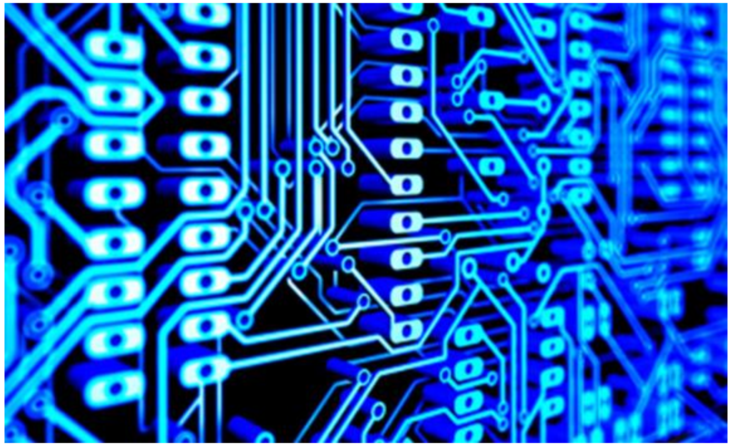
Neural factors

• Logarithmic relationship of receptor potential and light intensity



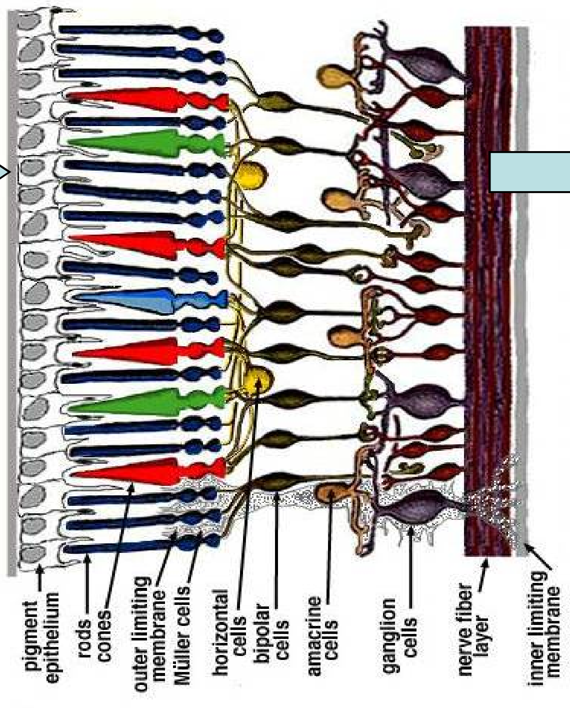


The retinal filter

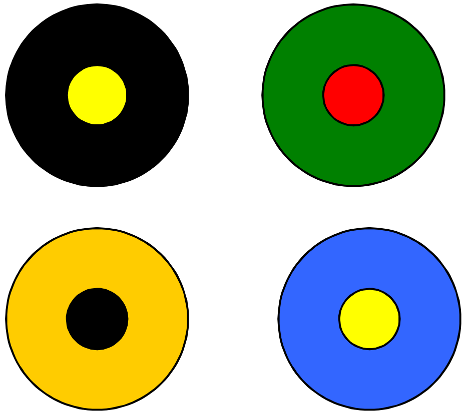
 

The retinal filter

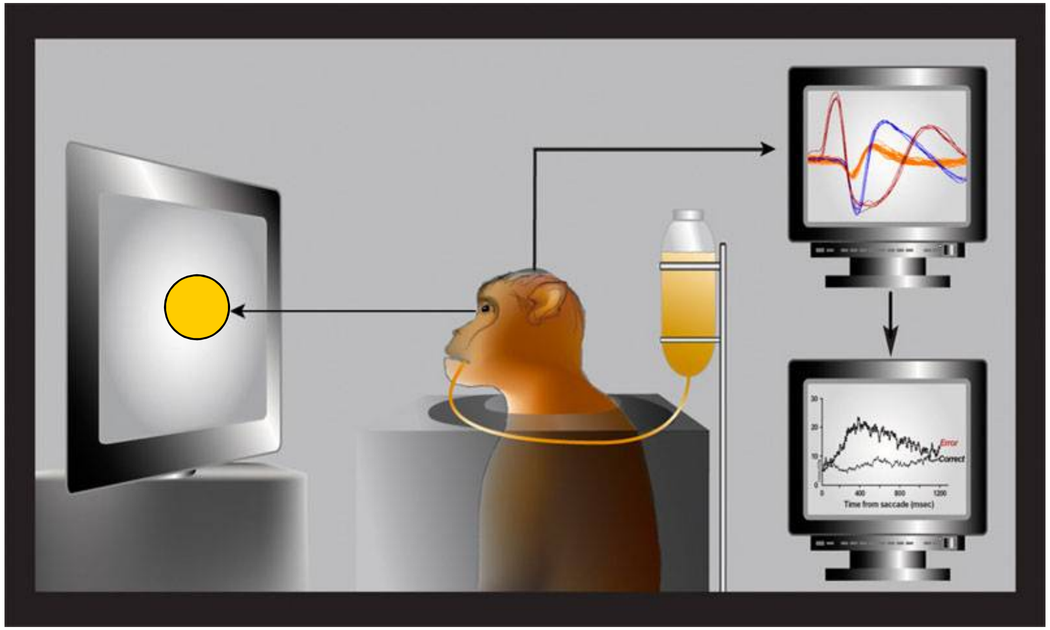
Image



To the brain



Receptive fields of ganglion cells



Electrophysiological recordings

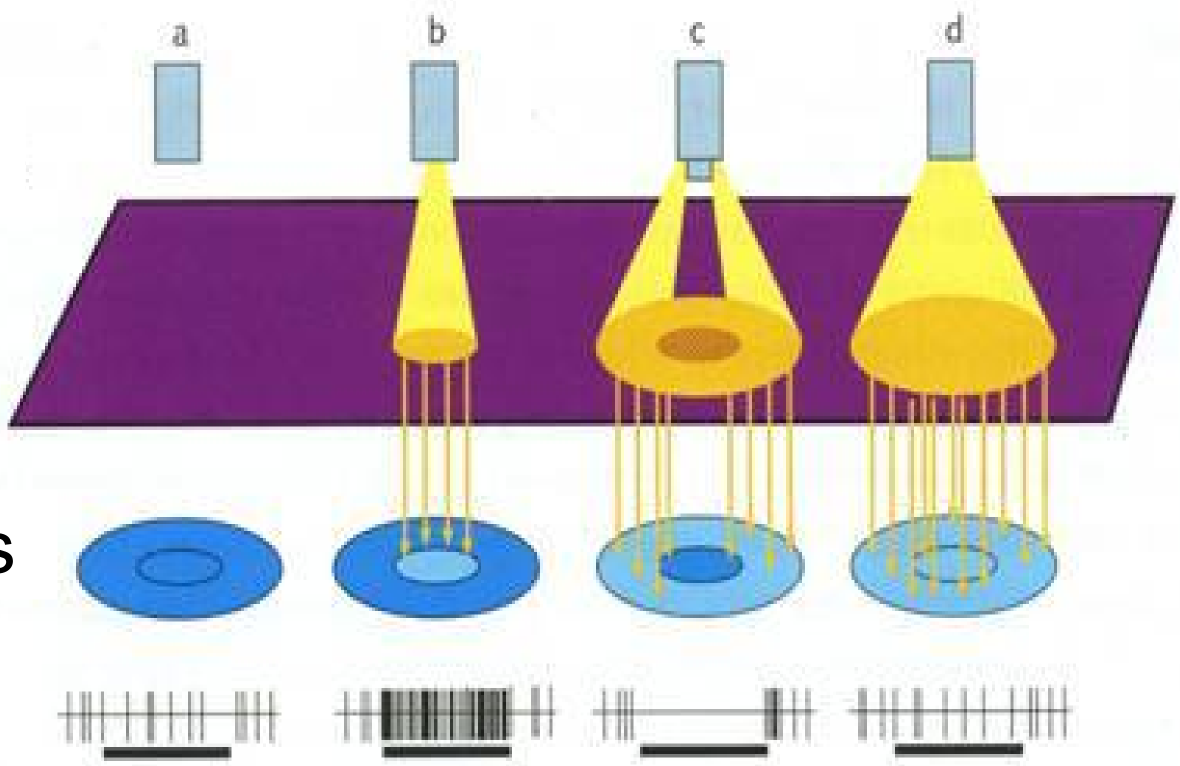
Electrophysiological recordings of the retinal ganglion cells reveal receptive fields that are concentric and antagonist center surround.

ON-centre cells

Stimulus

ON-centre cells

Response



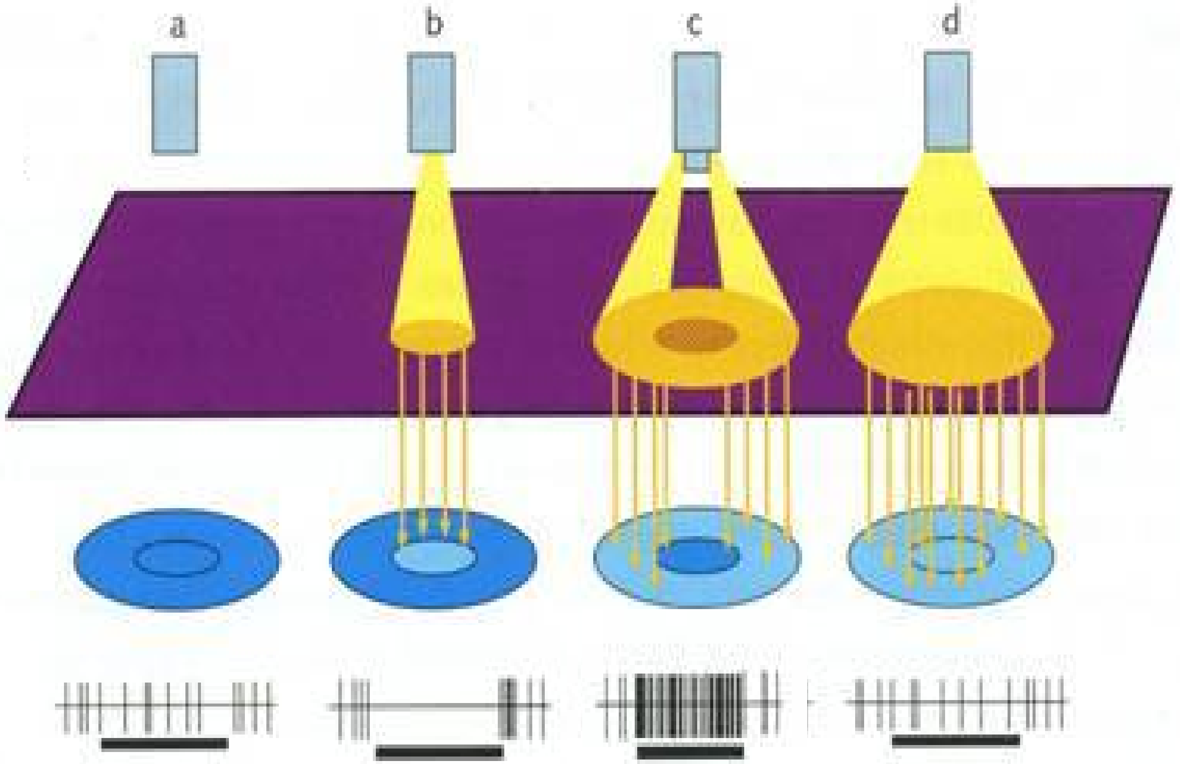
The visual system favors contrasts

OFF-centre cells

Stimulus

OFF-centre cells

Response



The visual system favors contrasts

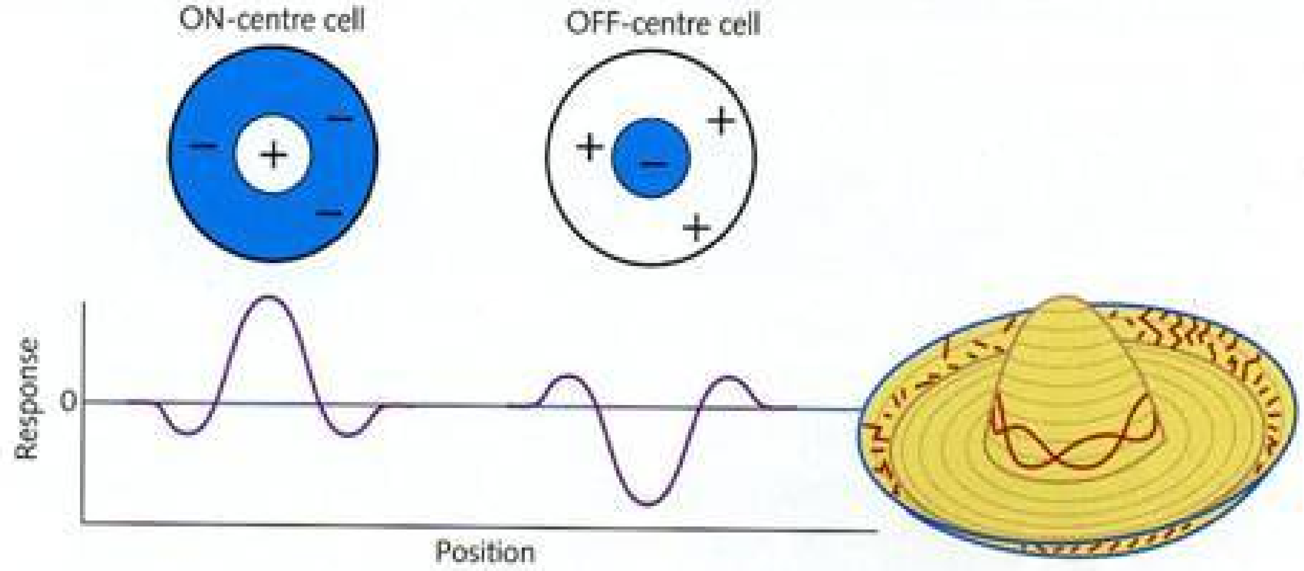
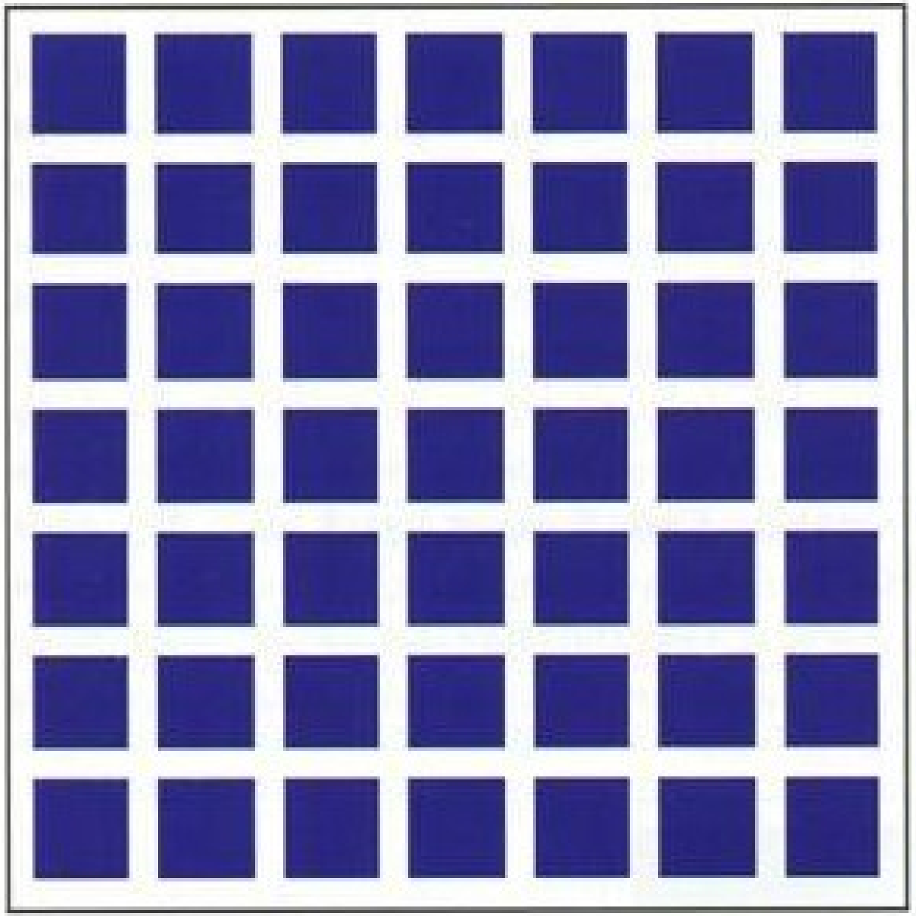


Fig. 2.2. Representations of ON- and OFF-centre receptive fields. The 'fried eggs' in the upper part of the figure show the maps of areas of excitation and inhibition in an ON-centre cell (left) and an OFF-centre cell (right). The traces below show the response of each cell to a spot of light presented at various positions across the centre of each cell. In 3-D we can think of the receptive field looking like a Mexican hat, pictured here for anyone who hasn't seen one before.

The inhibition of one part of the receptive field, in this case, the antagonist serround, is called **lateral inhibition**. It is important for edge detection and contrast enhancement.

The Hermann grid illusion



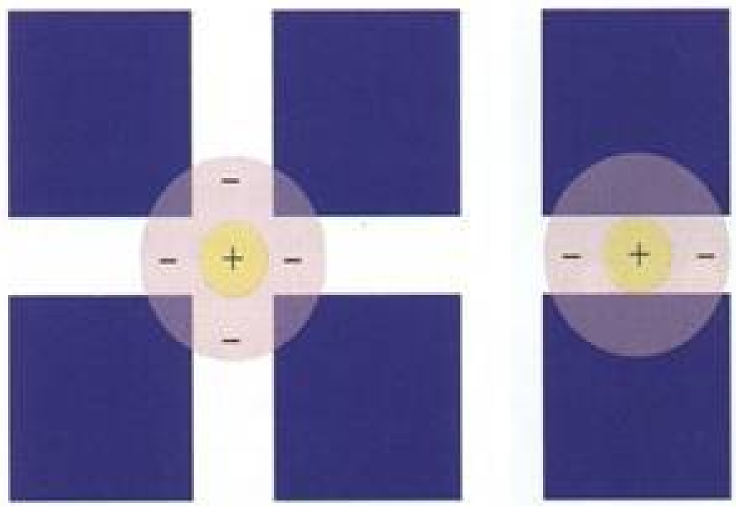


Fig. 2.10. An explanation of the Hermann grid in terms of the responses of ganglion cells.

Lateral inhibition and edge detection

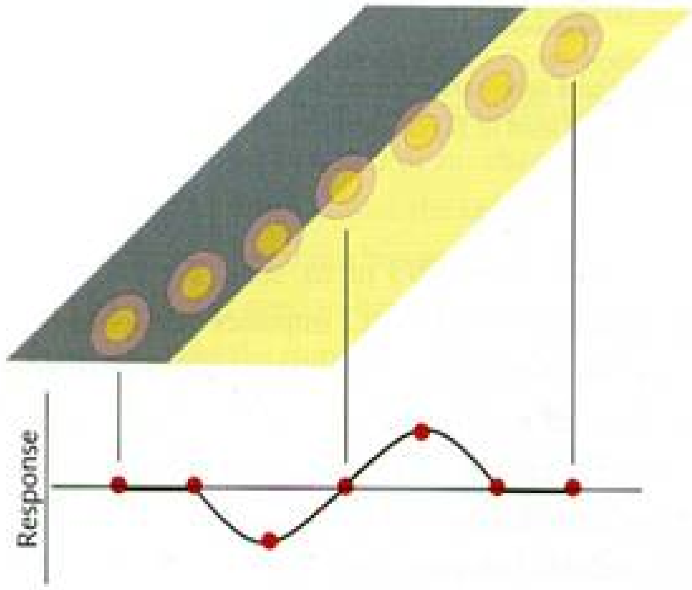
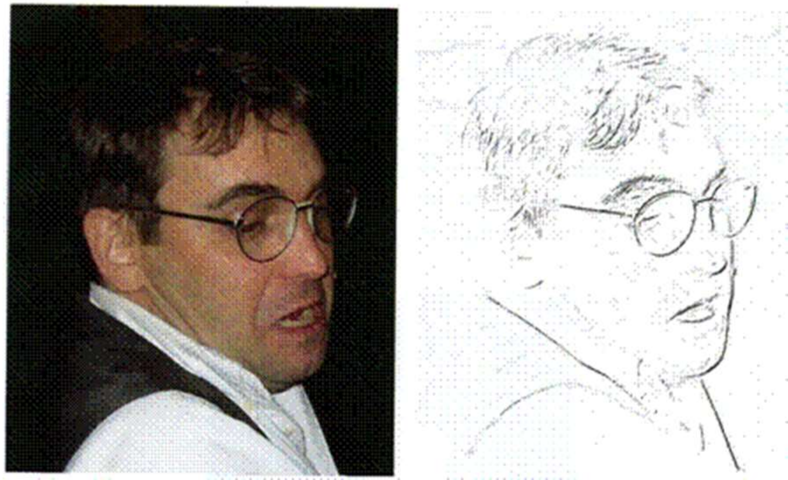


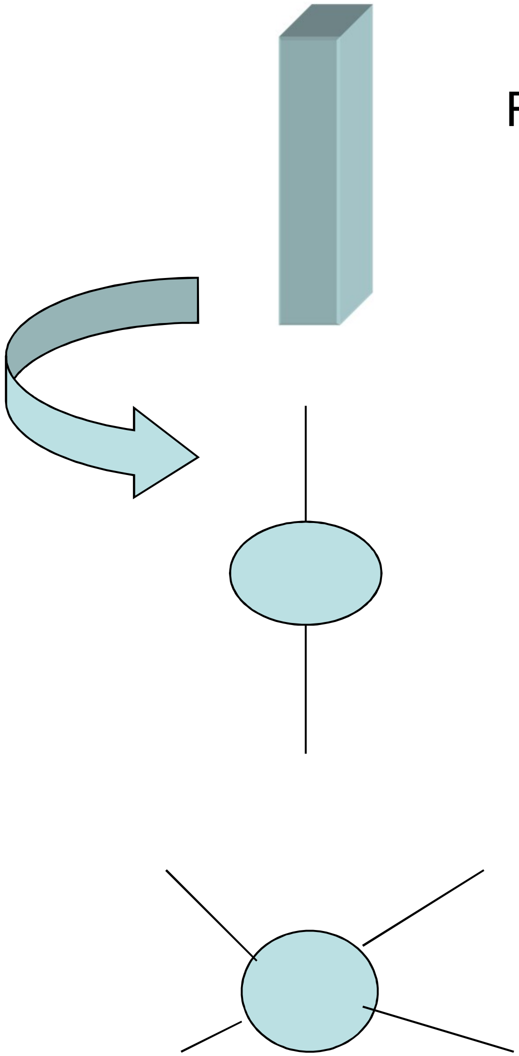
Fig. 2.5. The responses of various ON-centre ganglion cells that lie close to a dark–light edge. The cells that lie just on the dark side of the edge are inhibited, while those just to the bright side are excited.

Edges are important in visual recognition



Retinal circuitry:
We start with the
simple story!!

In the dark

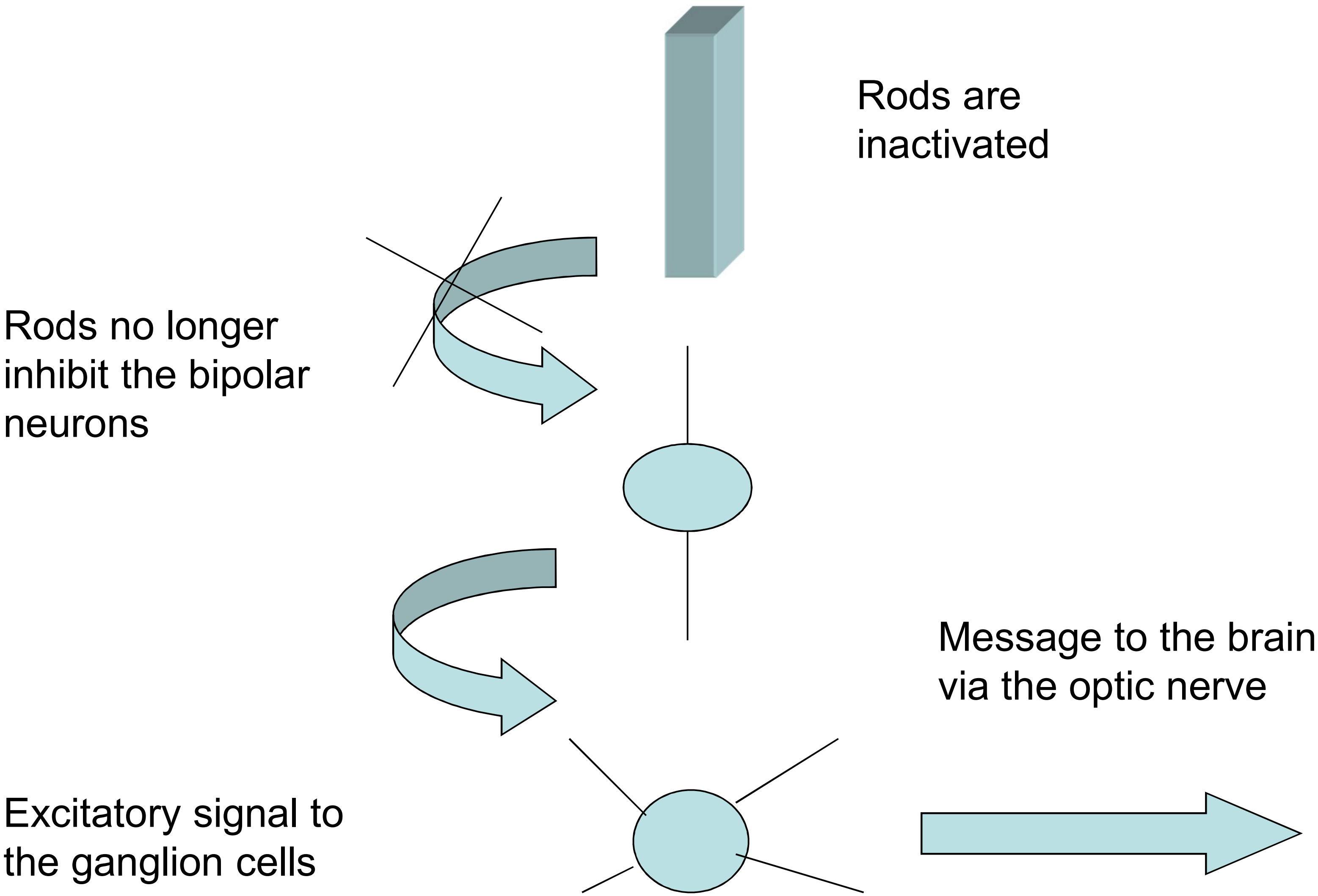


Rods are activated

Rods inhibit the
bipolar neurons

No signal to the
ganglion cells

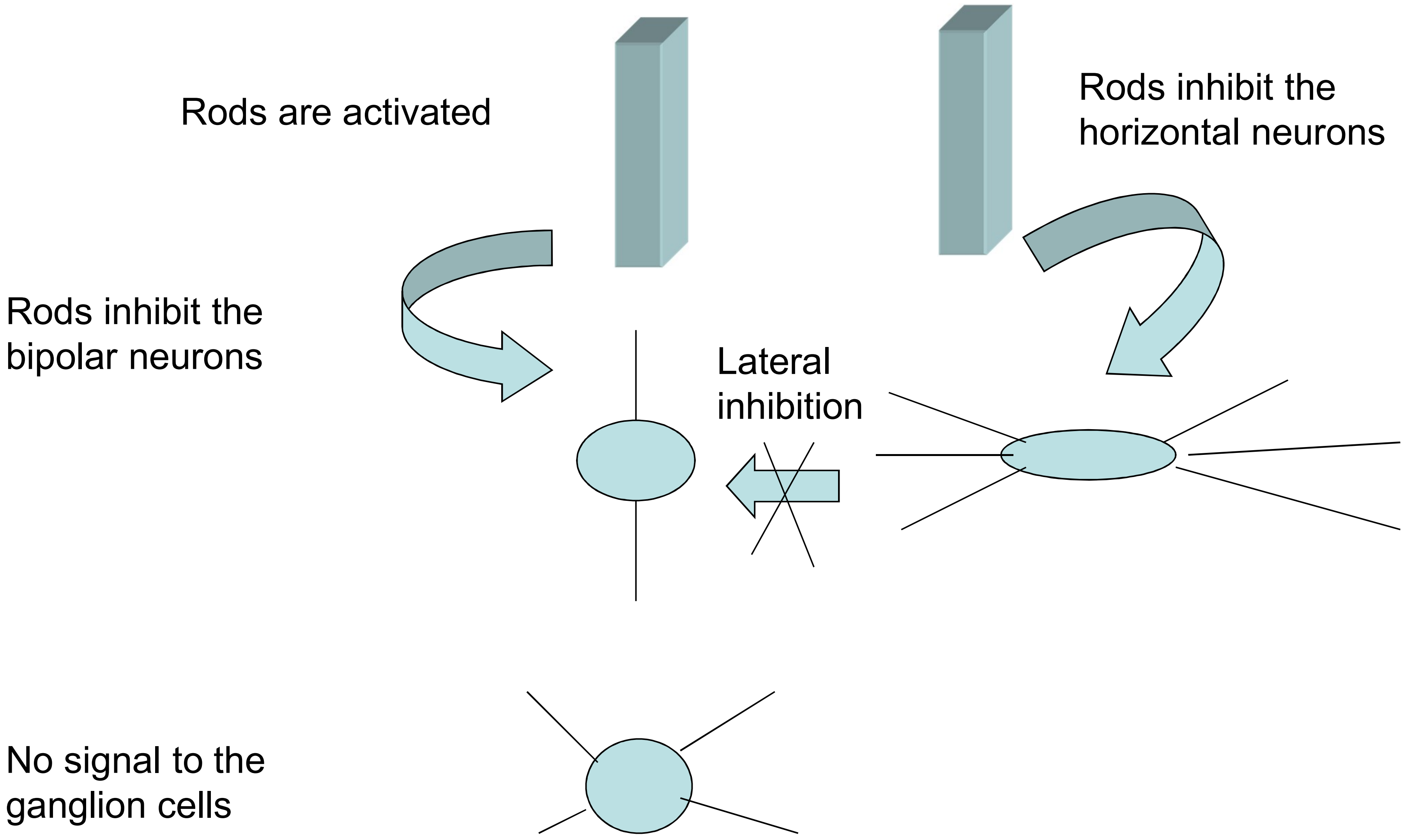
In the light

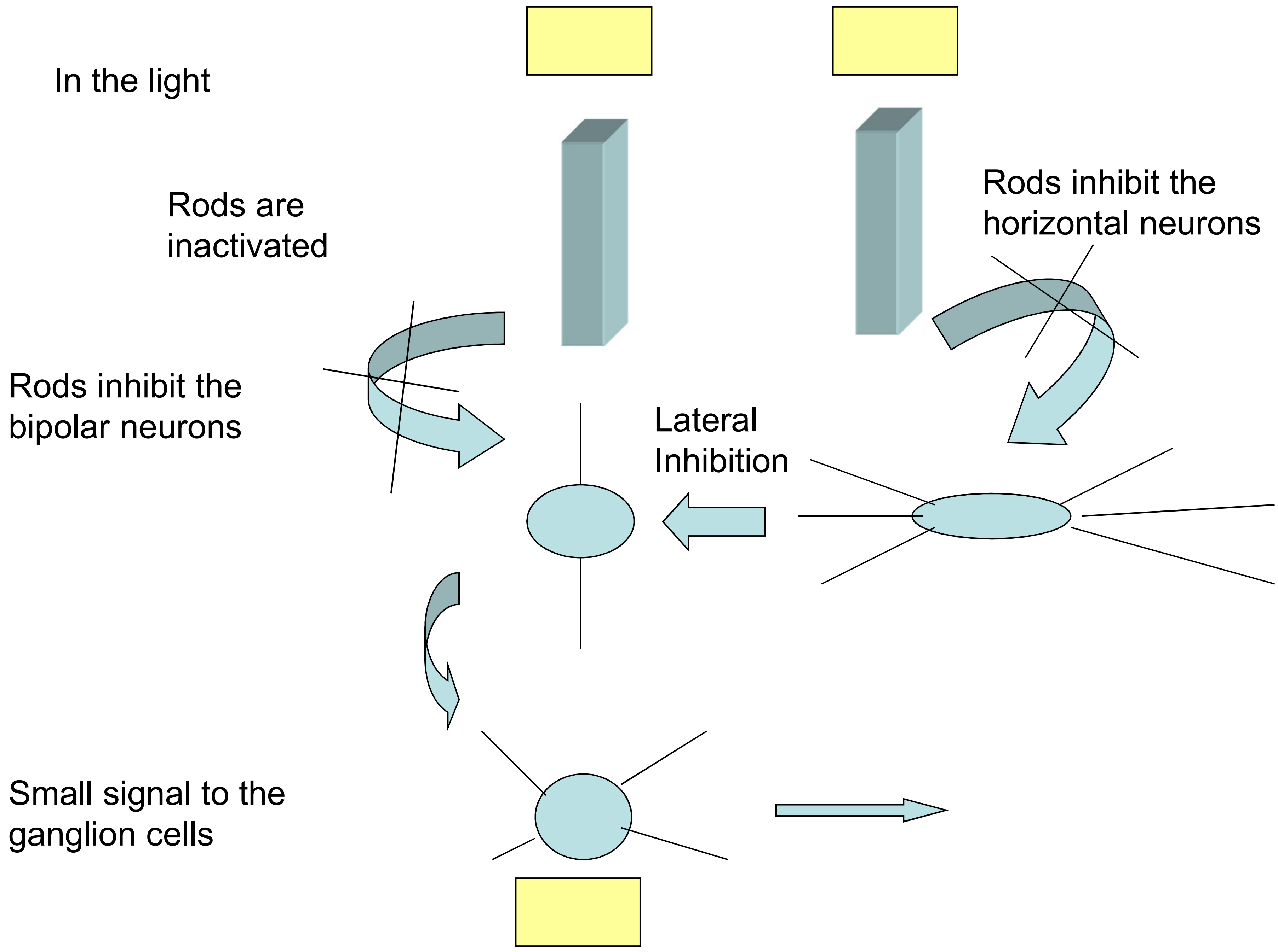


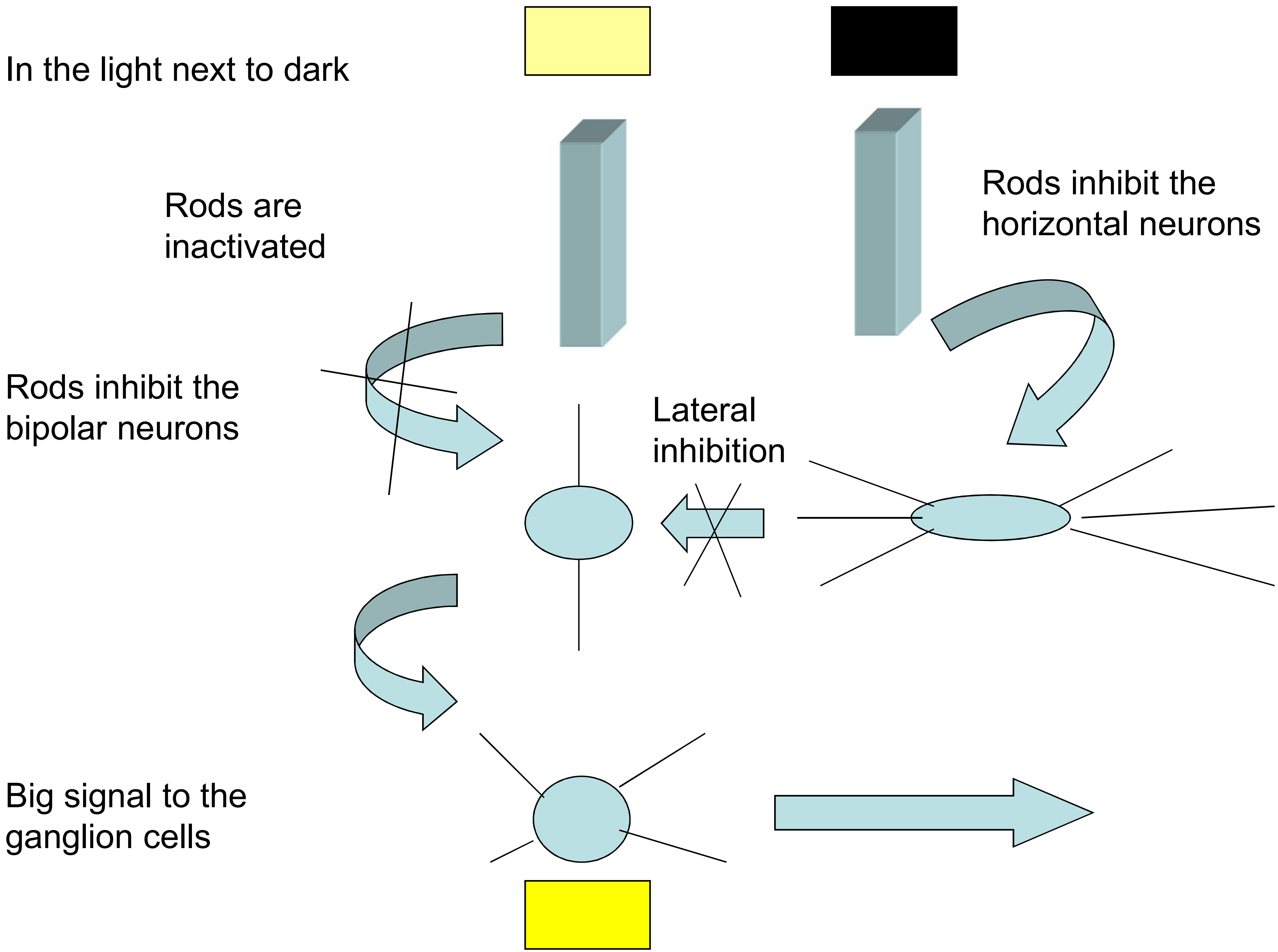
Rods are inactivated
Rods no longer inhibit the bipolar neurons
Excitatory signal to the ganglion cells
Message to the brain via the optic nerve

Retinal circuitry: The story gets a little more complicated with lateral inhibition

In the dark


Rods are activated
Rods inhibit the horizontal neurons
Rods inhibit the bipolar neurons
Lateral inhibition
No signal to the ganglion cells

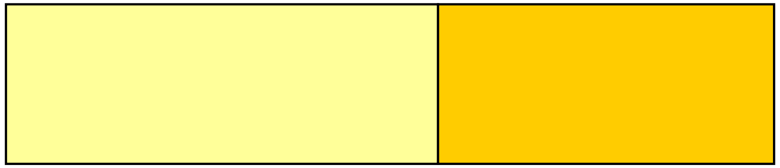

In the light
Rods are inactivated
Rods inhibit the horizontal neurons
Rods inhibit the bipolar neurons
Lateral Inhibition
Small signal to the ganglion cells



In the light next to dark
Rods are inactivated
Rods inhibit the horizontal neurons
Rods inhibit the bipolar neurons
Lateral inhibition
Big signal to the ganglion cells

Light contrast illusion created by lateral inhibition

Lateral inhibition & Contrast Enhancement

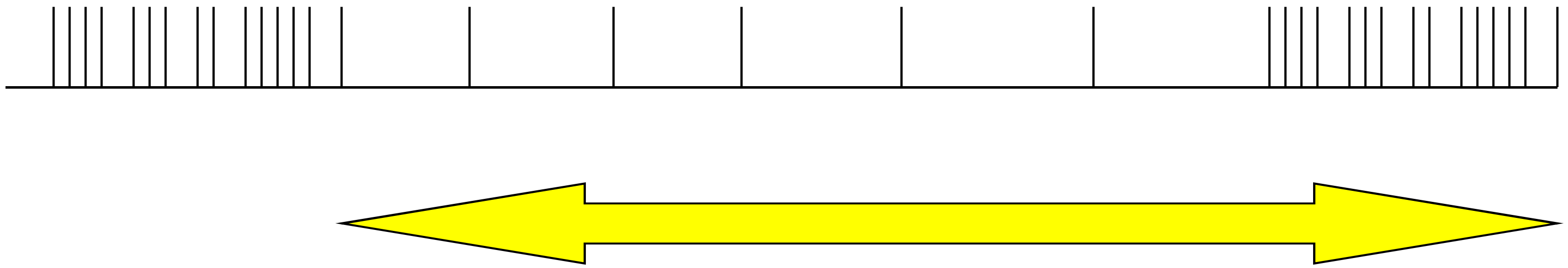


The horizontal cells between the bipolar cells can create an inhibition that increases the difference in their responses hence enhancing the perception of contrast.

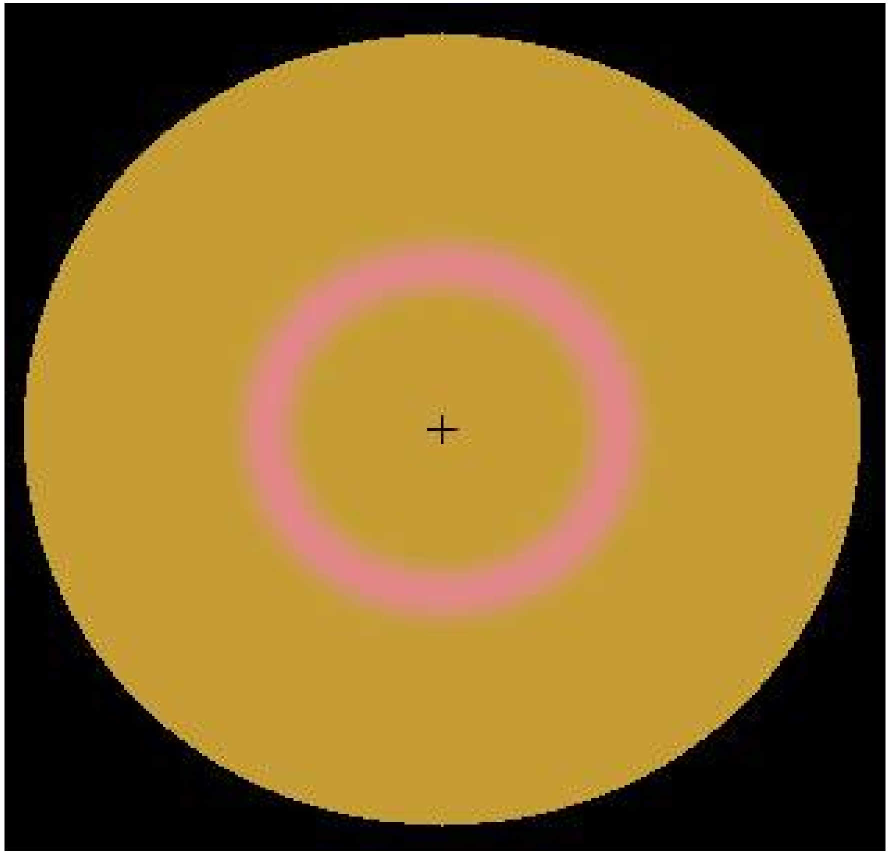
The retina detects changes

Most neurons after a sustained exposure to a stimulus will stop responding to it. This is so even if the initial response was positive. In fact our eyes are constantly moving in our heads, producing small random movements called tremor. This constantly produces small changes in the stimulus that reaches the retina. If we stop these modifications, it impairs our vision. This is the basis of illusions like the Troxler effect.

Adaptation

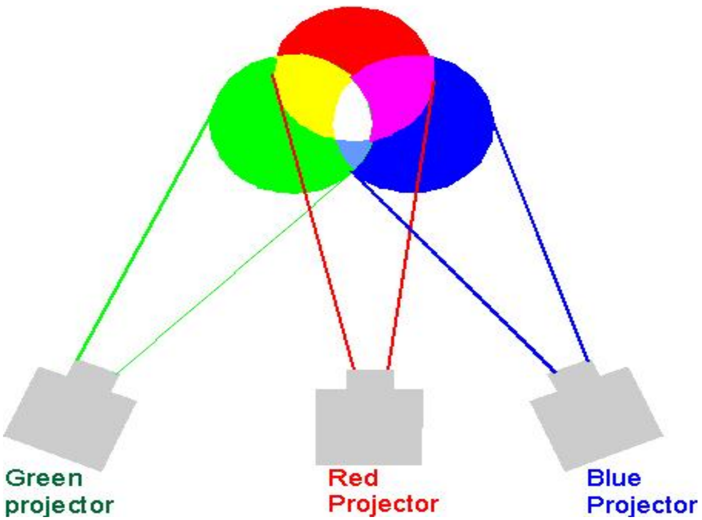


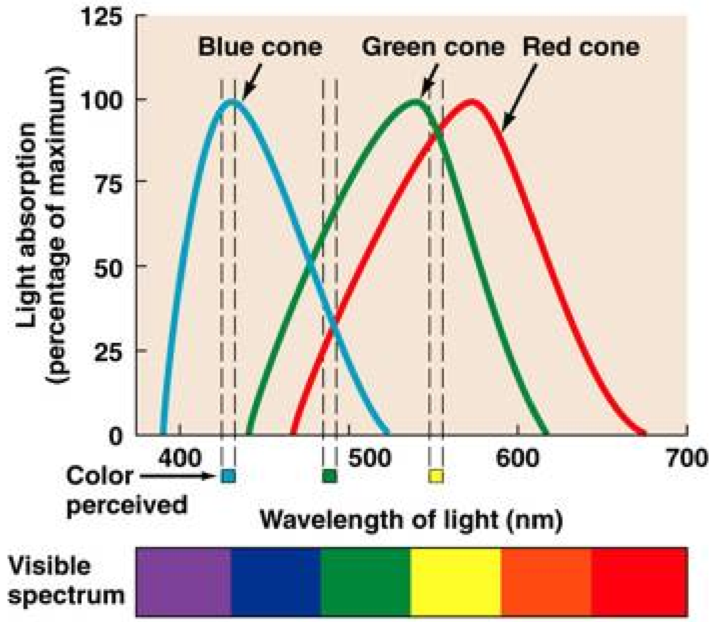
Troxler effect

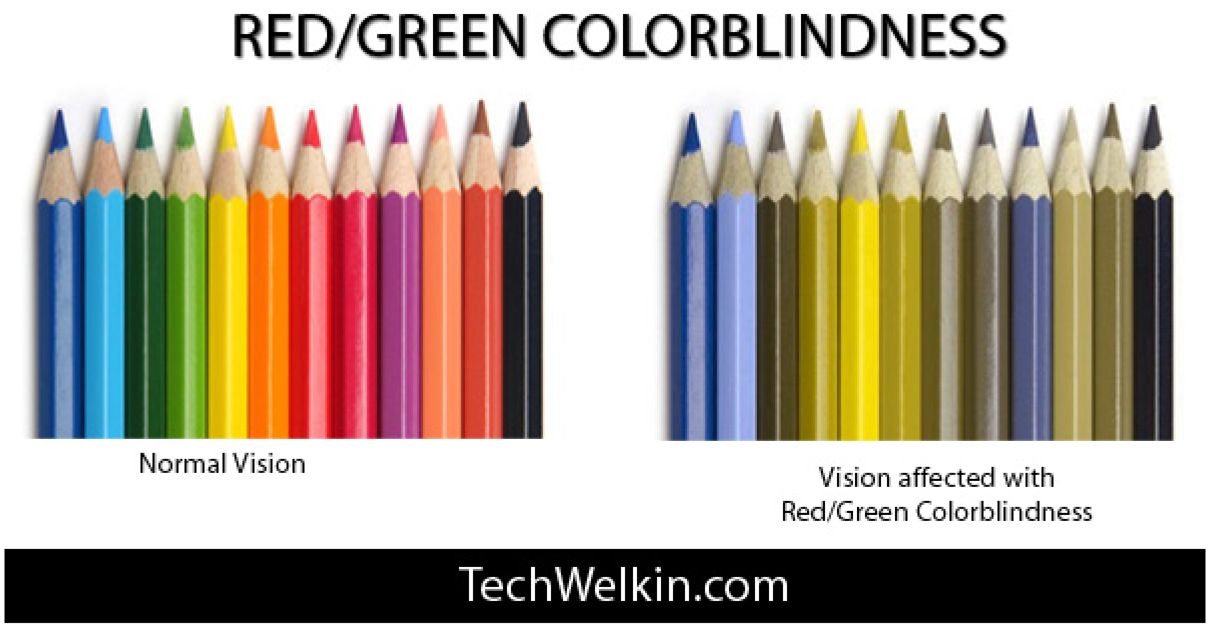


Color perception

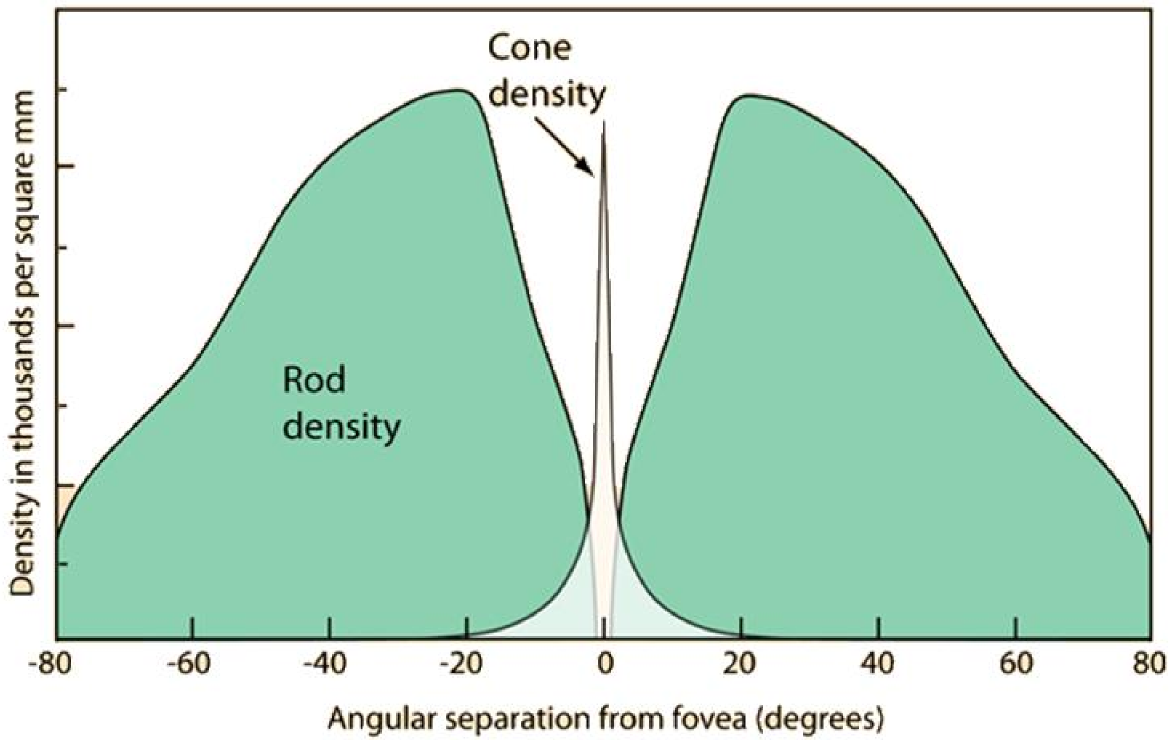
Young Helmholtz trichromacy theory







Red-green color blindness is the most common, followed by blue-green color blindness. A complete absence of color vision —total color blindness — is rare.



Cone
density
Rod
density
Density in thousands per square mm
-80
-60
-40
-20
0
20
40
60
80
Angular separation from fovea (degrees)

Less color in the dark

The cones have a higher stimulation threshold than the rods. As a consequence, our night vision takes place through the rods and we do not preceive color very well.

Cats have better night vision but poorer color vision.