Visual System

conversion of light energy into neural signal

EM spectrum

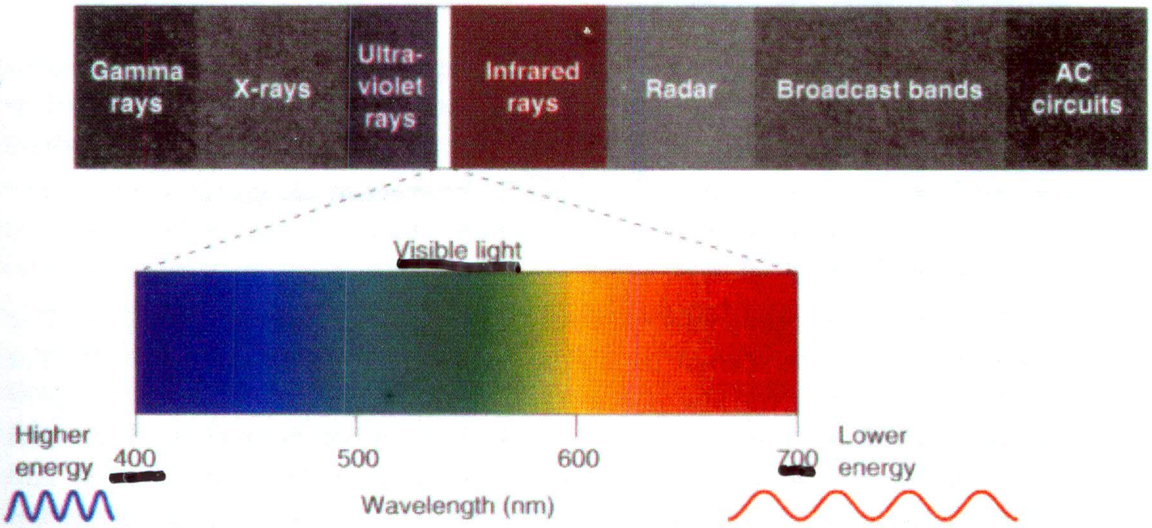


Figure 9.2
The electromagnetic spectrum. Only electromagnetic radiation with wavelengths of 400–700 nm is visible to the naked human eye. Within this visible spectrum, different wavelengths appear as different colors.

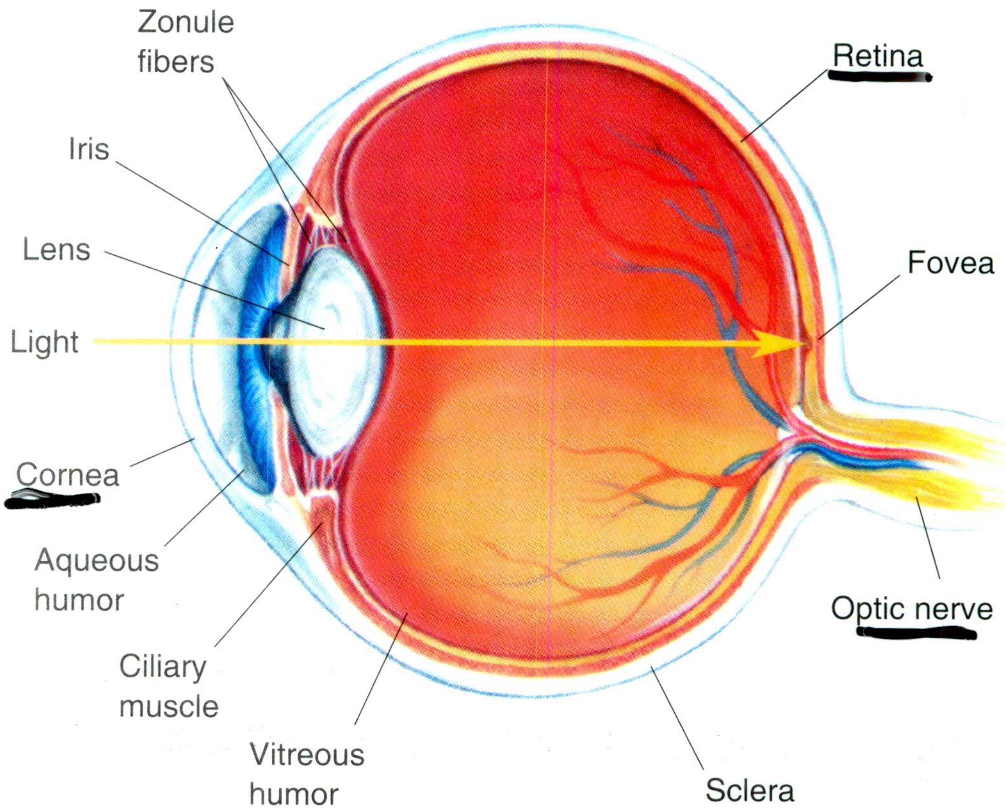


Figure 9.6
The eye in cross section.

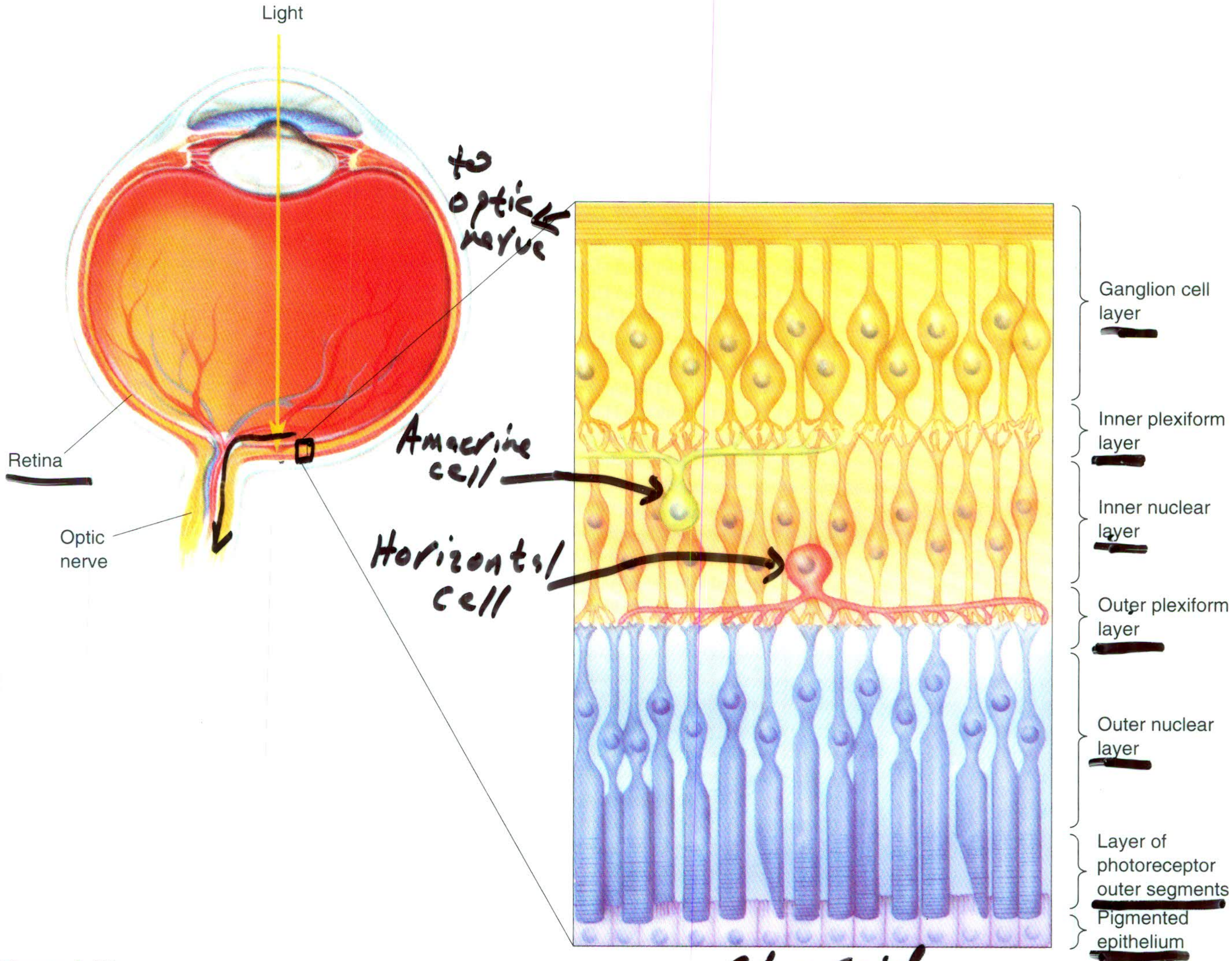


Figure 9.12
Laminar organization of the retina. Notice how light must pass through several cell layers before it reaches the photoreceptors at the back of the retina.

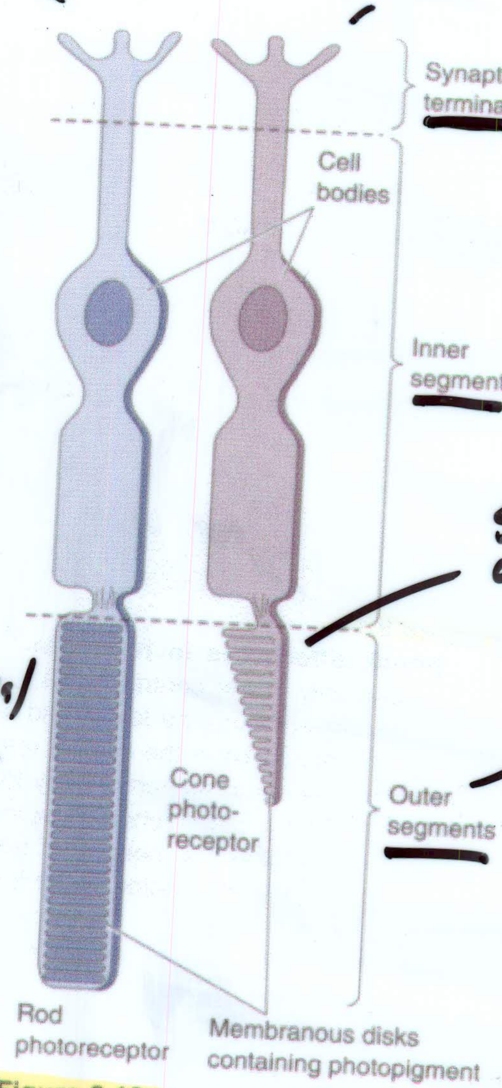
Two types of photoreceptors:
- Rods
- Cones

Differ in morphology + function.

Figure 9.12
Neuroscience: Exploring the Brain

Rod

Cone



Synaptic terminals – synapse with bipolar + horizontal cells

Inner segments – cell body with nucleus + organelles

short + tapering outer segment

Long + cylindrical outer segment –

Outer segments – membranous disks have the photo pigment of the receptor embedded in the cell membrane of the disks

Figure 9.13
A rod and a cone.

Rods have many more membranous disks making the 1000× more sensitive to light than the cones.

Rods are active under scotopic light conditions (low light). Under these conditions the rod receptors are used for vision.

Under normal light conditions (photopic light conditions) rods stop responding, and the less sensitive cones are used for vision

Rods + cones also differ in terms of wavelengths of light they are sensitive to.

Rods have a photopigment called Rhodopsin – consists of a protein called opsin that is conjugated with a non-protein called retinal (derived from vitamin A). Retinal is the light energy absorbing part of the rhodopsin

Absorbs light energy 400nm – 650nm in wave lengths, with maximum sensitivity at 525nm.

Photopigment in cones is structurally similar to rhodopsin. Has an opsin protein associated with retinal. Differ in the type of opsin part of the photopigment.

3 types of cones:

<u>Blue cones</u>: sensitive to light wavelengths between 350nm – 500nm
maximum sensitivity at 430nm
light perceived as blue in color

<u>Green cones</u>: sensitive to light wavelengths between 450nm – 575nm
maximum sensitivity at 530nm
light perceived as green in color

Red cones: sensitive to light wavelengths 500 – 610nm maximum sensitivity at 560nm

light perceived as red in color

Helmholtz Trichromacy Theory:
The brain interprets the relative inputs from the three cone receptor types in perceiving the color of an object.

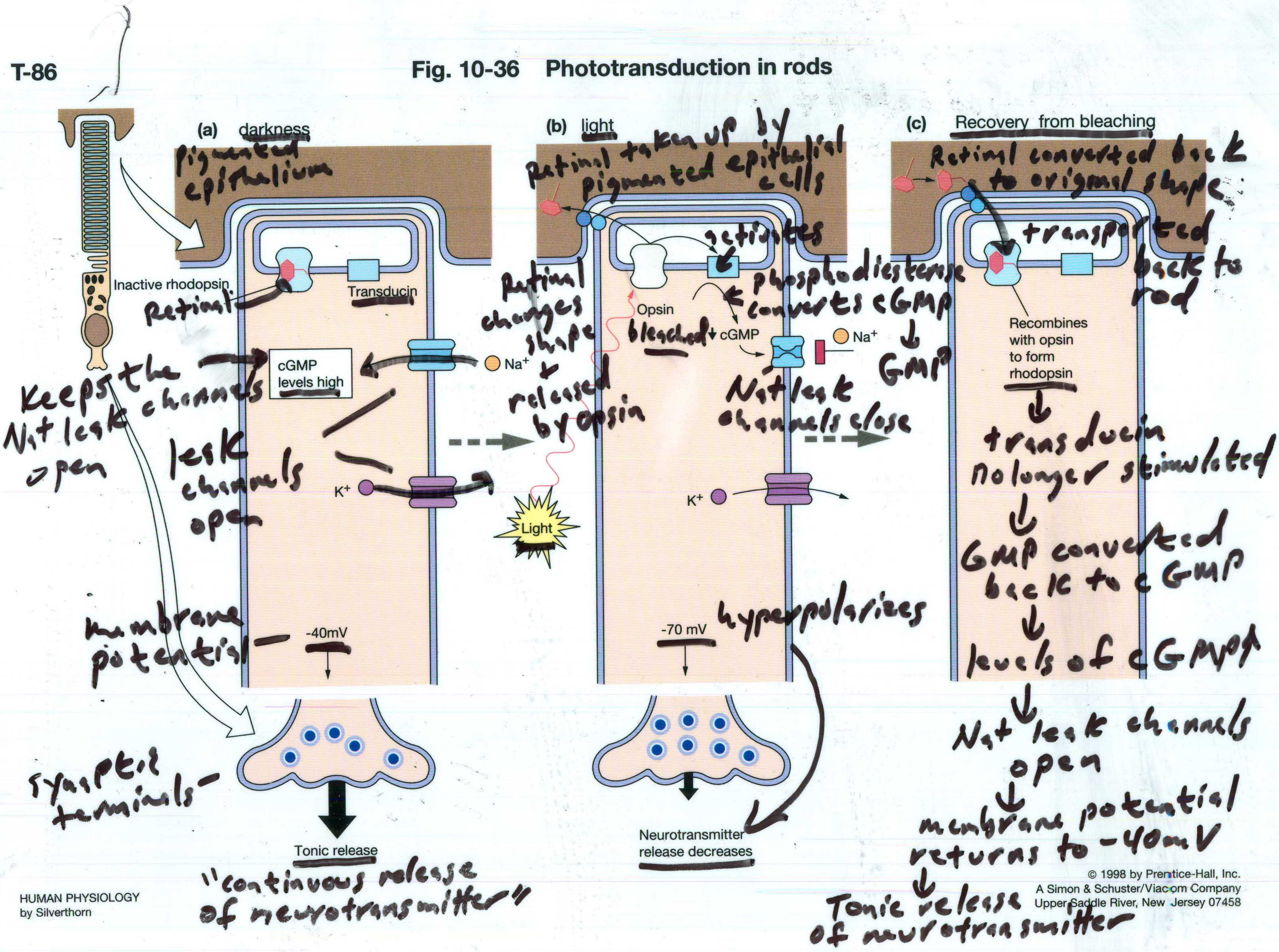
Ex. If all three types of cones are equally stimulated, The brain perceives the color of the light as white.

Another example of population coding in a sensory system.

Phototransduction – process by which light energy is converted into neural signal.

T-86

Fig. 10-36 Phototransduction in rods



HUMAN PHYSIOLOGY
by Silverthorn

The decrease in neurotransmitter release is related to the intensity of the light falling on the photoreceptor.

Brighter the light

↓

The more rhodopsin bleached

↓

The more transducin that is activated

↓

The more phosphodiesterase activated

↓

The more cGMP → GMP (The lower the cGMP levels fall)

↓

The more Na^+ channels that close

↓

The greater the hyperpol. of membrane potential

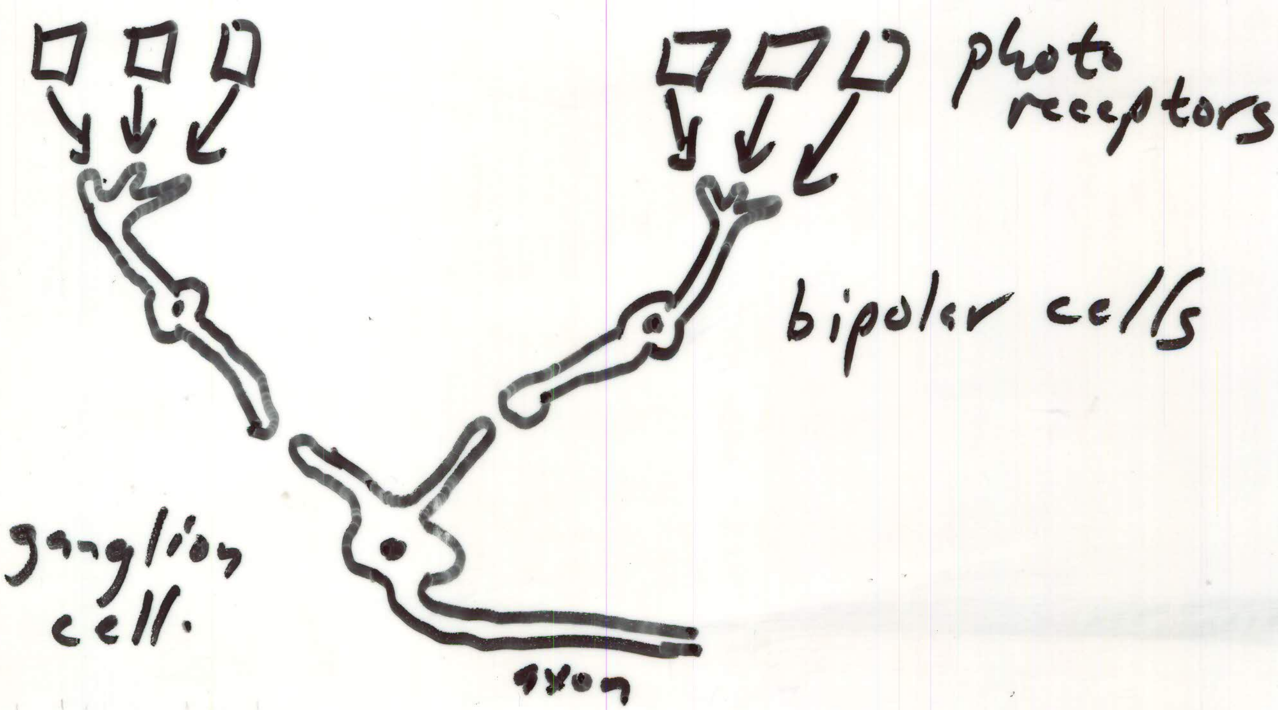
↓

The less neurotransmitter released.

In the retina

photoreceptor → bipolar cells → Ganglion cells

In most of the retina there is convergence such that multiple photoreceptors synapse onto single bipolar cells + multiple bipolar cells synapse onto a single ganglion cell.



In the fovea there is a 1:1:1 relationship between the photoreceptors: bipolar cells: ganglion cells.

Also, in the fovea the ganglion cells + bipolar cells are displaced towards the sides of the fovea so light falling on the photoreceptors has direct access to the to the receptors

These characteristics give the fovea the highest visual acuity (sharpest vision)

when you focus your visual attention on an object you are positioning the image of that object so that it falls on the fovea.

Antagonist Center - Surround Receptive Field Arrangement.

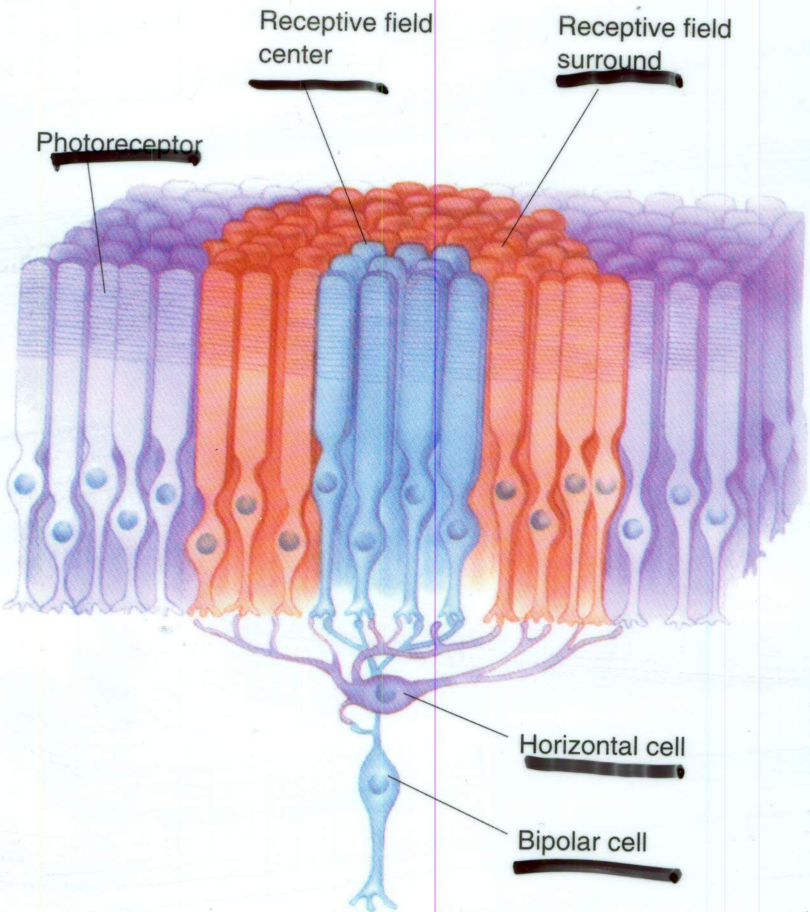


Figure 9.22
Direct and indirect pathways from photoreceptor to bipolar cell. Bipolar cells receive direct synaptic input from a cluster of photoreceptors, constituting the receptive field center. In addition, they receive indirect input from surrounding photoreceptors via horizontal cells.

There are two types of bipolar cells in terms of how they respond to the inputs from the different parts of their receptive field.

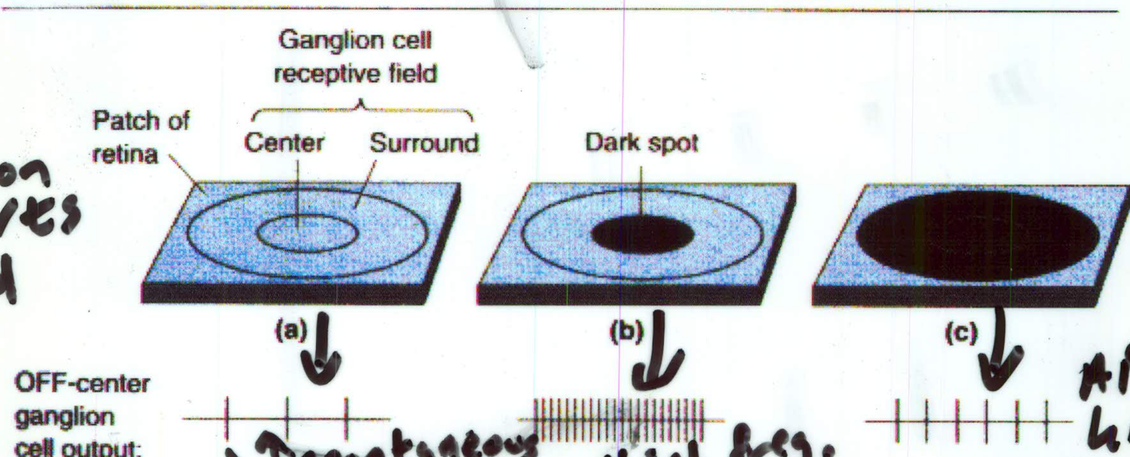
- On-center off-surround bipolar cell:
  Responds to a spot of light on the center of its receptive field by depolarizing, and to a spot of light on the surround part of its receptive field by hyperpolarizing.

- Off-center on-surround bipolar cell:
  Responds to a spot of light on the center of its receptor field by hyperpolarizing, and to a spot of light on the surround part of its receptive field by depolarizing

Off-center, On-surround ganglion cell

Light on both parts of field

Response of ganglion cell —



AP ↑ spontaneous activity

High freq. of APs

AP freq. higher than spont. level, lower than in (b)

Figure 9.23

A center-surround ganglion cell receptive field. (a, b) An OFF-center ganglion cell responds with a barrage of action potentials when a dark spot is imaged on its receptive field center. **(c)** If the spot is enlarged to include the receptive field surround, the response is greatly reduced.

Light on center, dark on the surround of the field, This ganglion cell will hyper polarize → AP frequency will decrease (lowest AP frequency)

Dark on center, light on surround of the field, this ganglion cell will depolarize → AP frequency will increase.

Ganglion cells are most responsive in terms of AP frequency to differences in illumination within their receptive field.

The center surround arrangement of the receptive fields of ganglion cells emphasizes contrast.

Allows the visual system to distinguish individual objects and borders between objects (i.e. details) of the visual world.

Two major groups of ganglion cells

M ganglion cells — magnocellular ganglion cells

P ganglion cells — parvocellular ganglion cells

95% of ganglion cells are either M or P type

5% non-M non-P ganglion cells

	M cells	P cells
Appearance	Large cell bodies & large diameter axons	Small cell body & small diameter axons
size of receptive field	Large receptive fields	small receptive fields
Stimulus	movement across receptive field	specific wavelengths of light

P cells have center-surround receptive fields in which the center is sensitive to one wavelength of light and the surround is sensitive to another wavelength of light.

Color pairings are red-green and blue-yellow

Red on-center green off-surround
p cell.

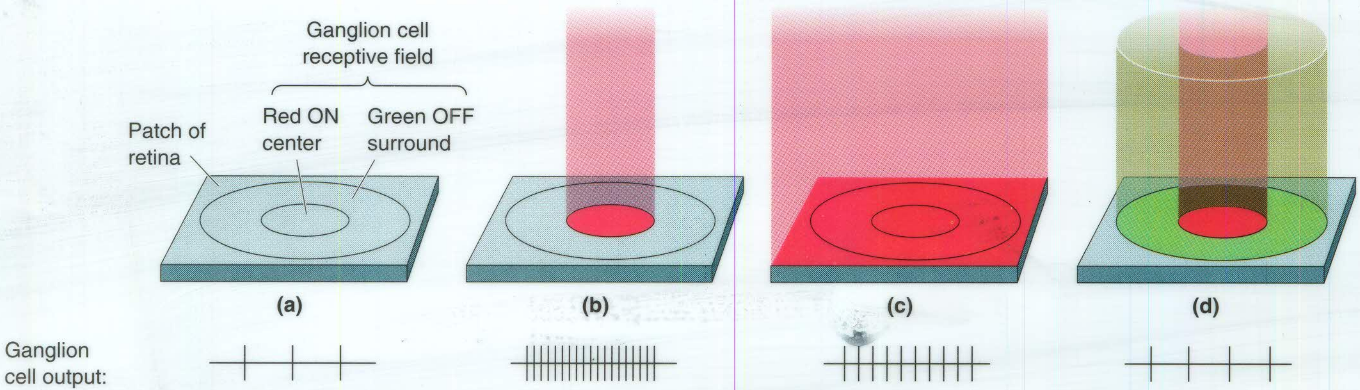
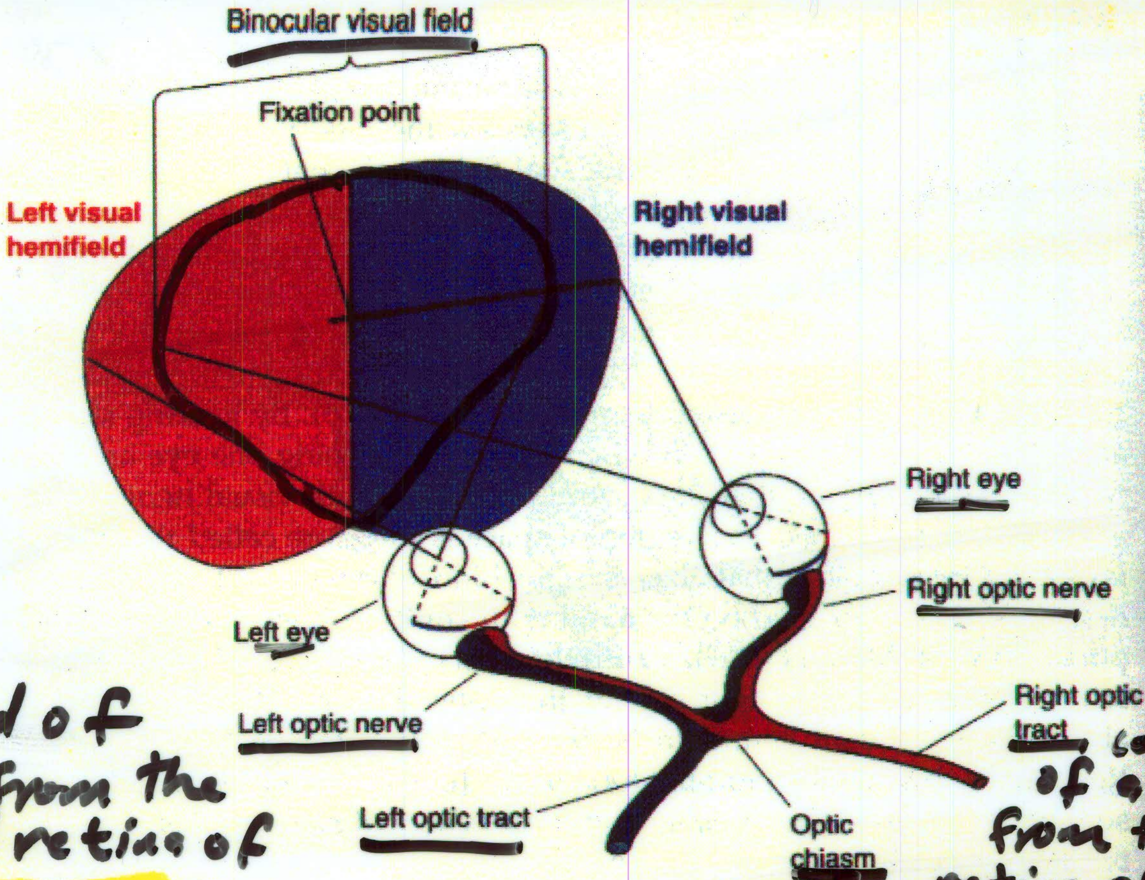


Figure 9.28
A color-opponent center-surround receptive field of a P-type ganglion cell.

Emphasis is again on contrast between the center + surround in the receptive field.

Figure 9.27



composed of axons from the temporal retina of left and nasal retina of right eye

composed of axons from temporal retina of R. eye and nasal retina of left eye

Figure 10.3

Right and left visual hemifields. Ganglion cells in both retinas that are responsive to visual stimuli in the right visual hemifield project axons into the left optic tract. Similarly, ganglion cells "viewing" the left visual hemifield project into the right optic tract.

Visual field that is viewed by the temporal retina on one side is partially over lapped by the visual field viewed by the nasal retina of the opposite eye. This area of over lap is called the binocular field