Neurophysiology

Vision III

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Cones

- photochemicals in the cones have almost exactly the same chemical composition as that of rhodopsin in the rods.

- The only difference is that the protein portions, or the opsins—called photopsins in the cones—are slightly different from the scotopsin of the rods.

- The retinal portion of all the visual pigments is exactly the same in the cones and rods.

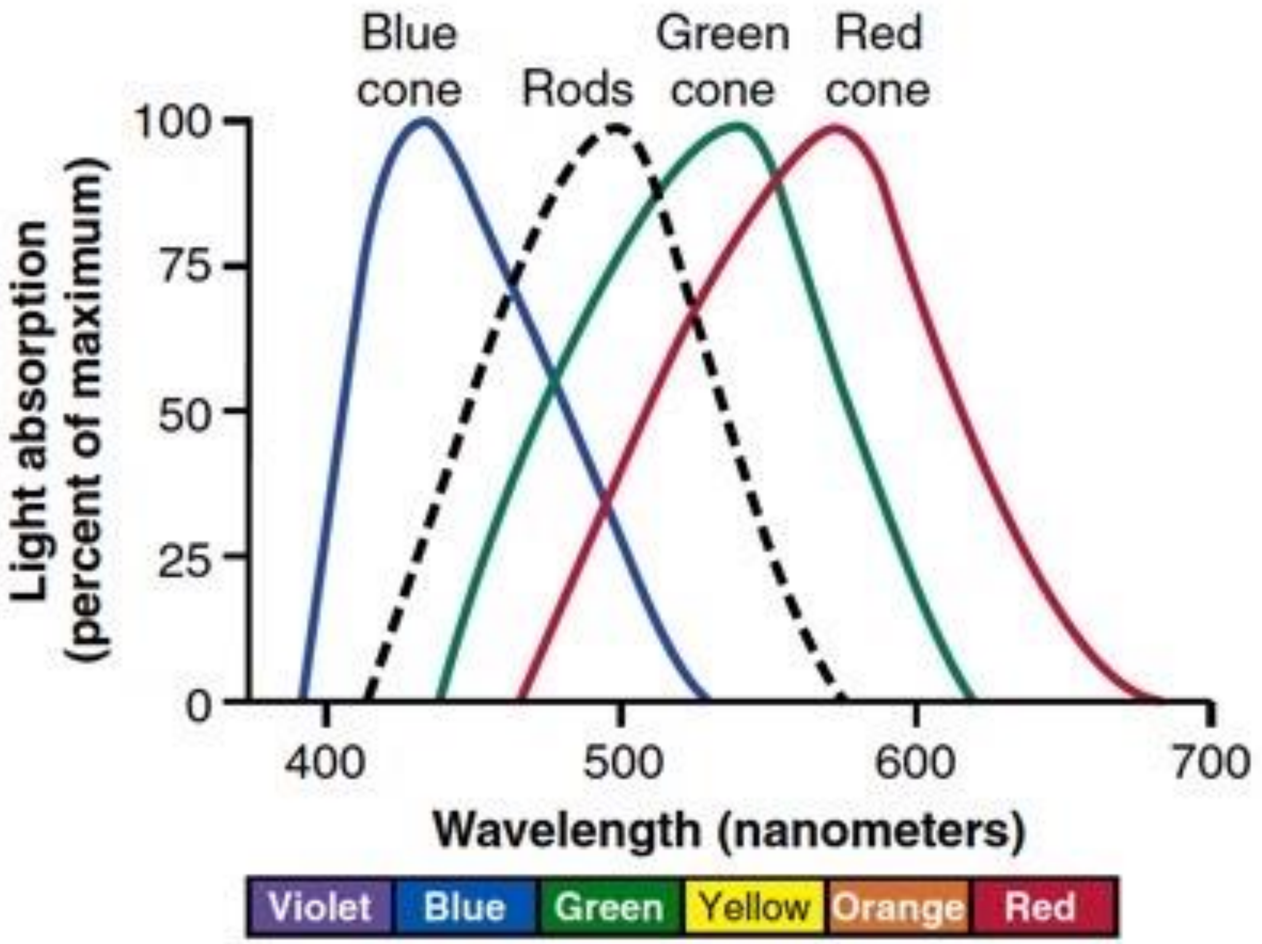
Color vision

- Each photopigment maximally absorbs a particular wavelength but also absorbs a range of wavelengths shorter and longer than this peak absorption.

- The farther a wavelength is from the peak wavelength absorbed, the less strongly the photopigment responds.

- The absorption curves for the three cone types overlap so that two or three cones may respond to a given wavelength but to a different extent.

Color vision

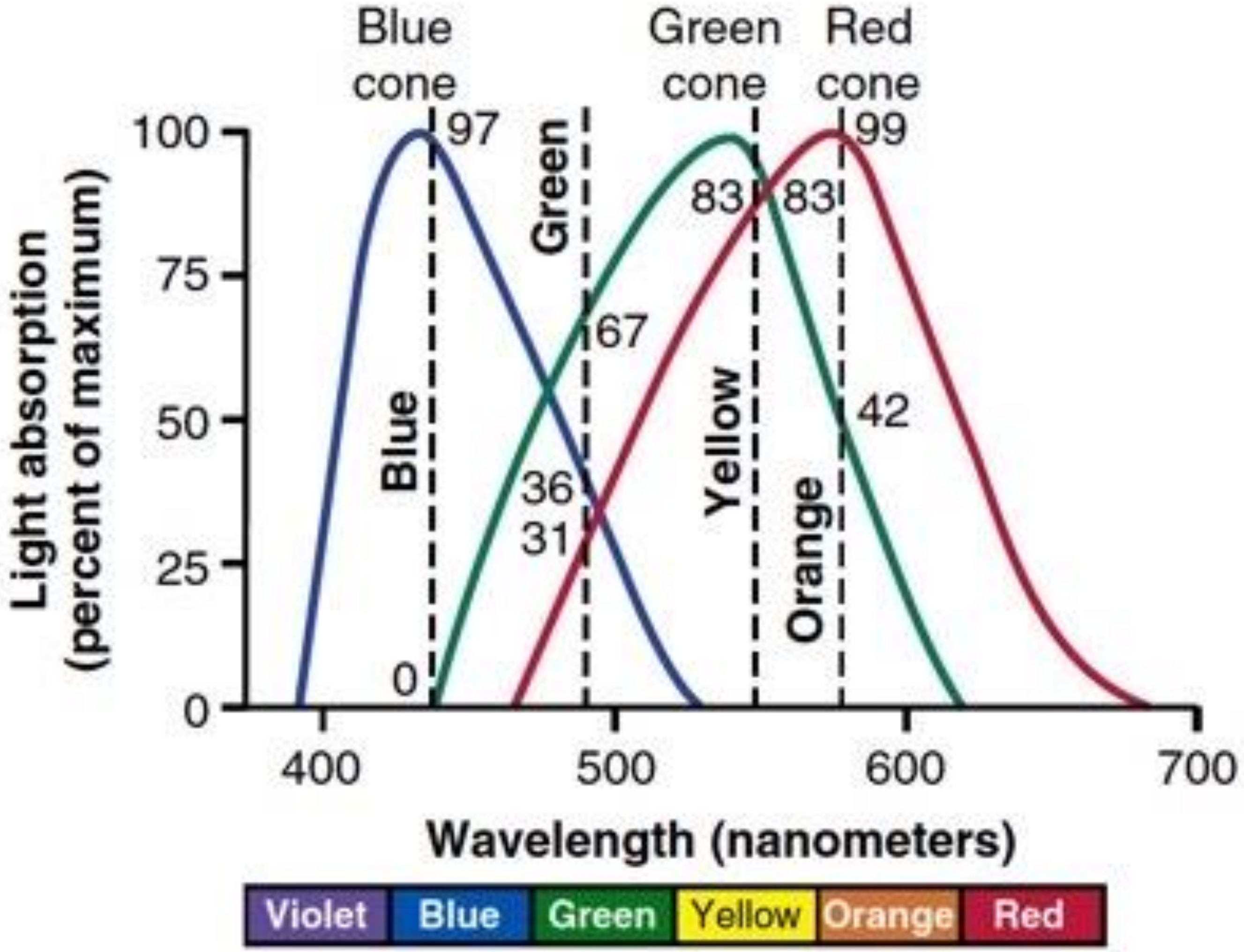


Color vision

- Each cone type is most effectively activated by a particular wavelength of light in the range of color indicated by its name.

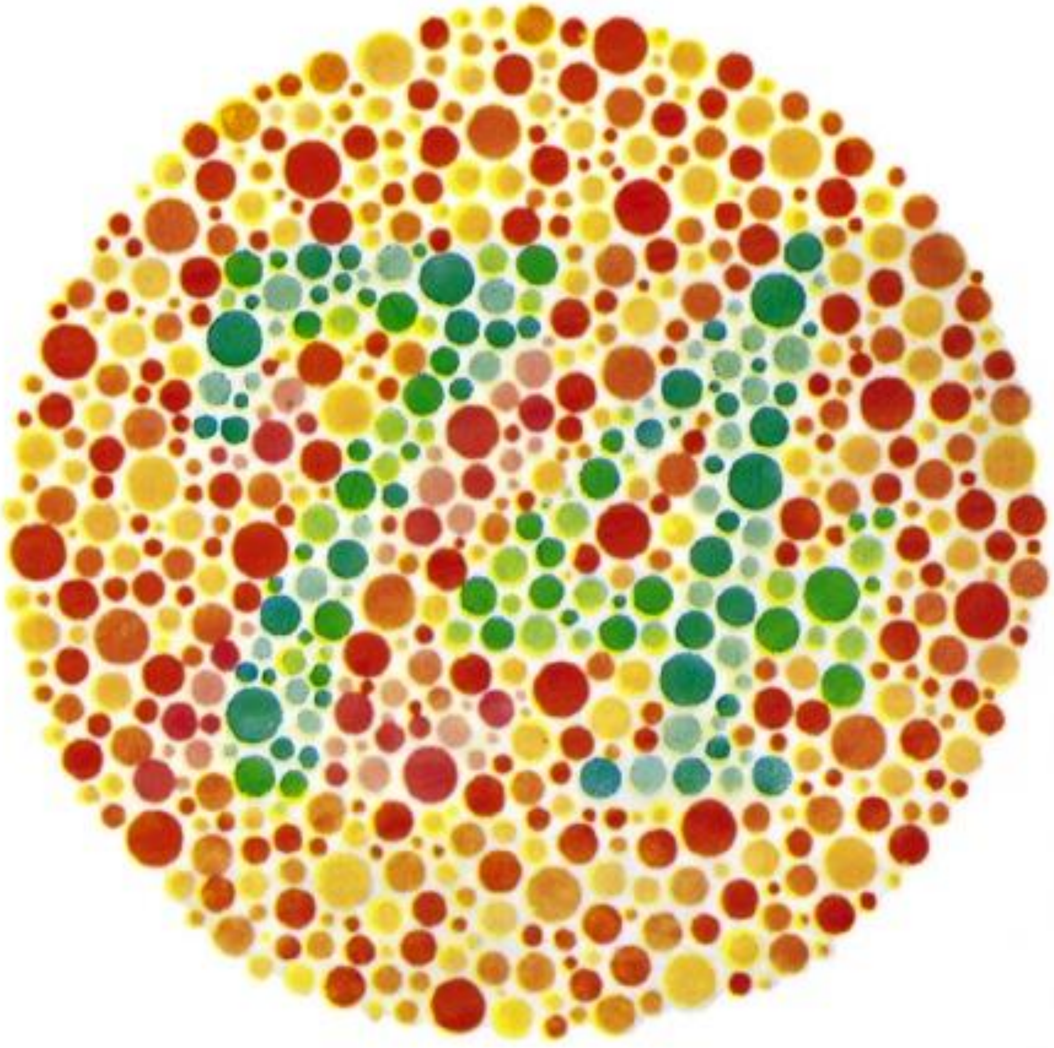
- cones also respond in varying degrees to other wavelengths.

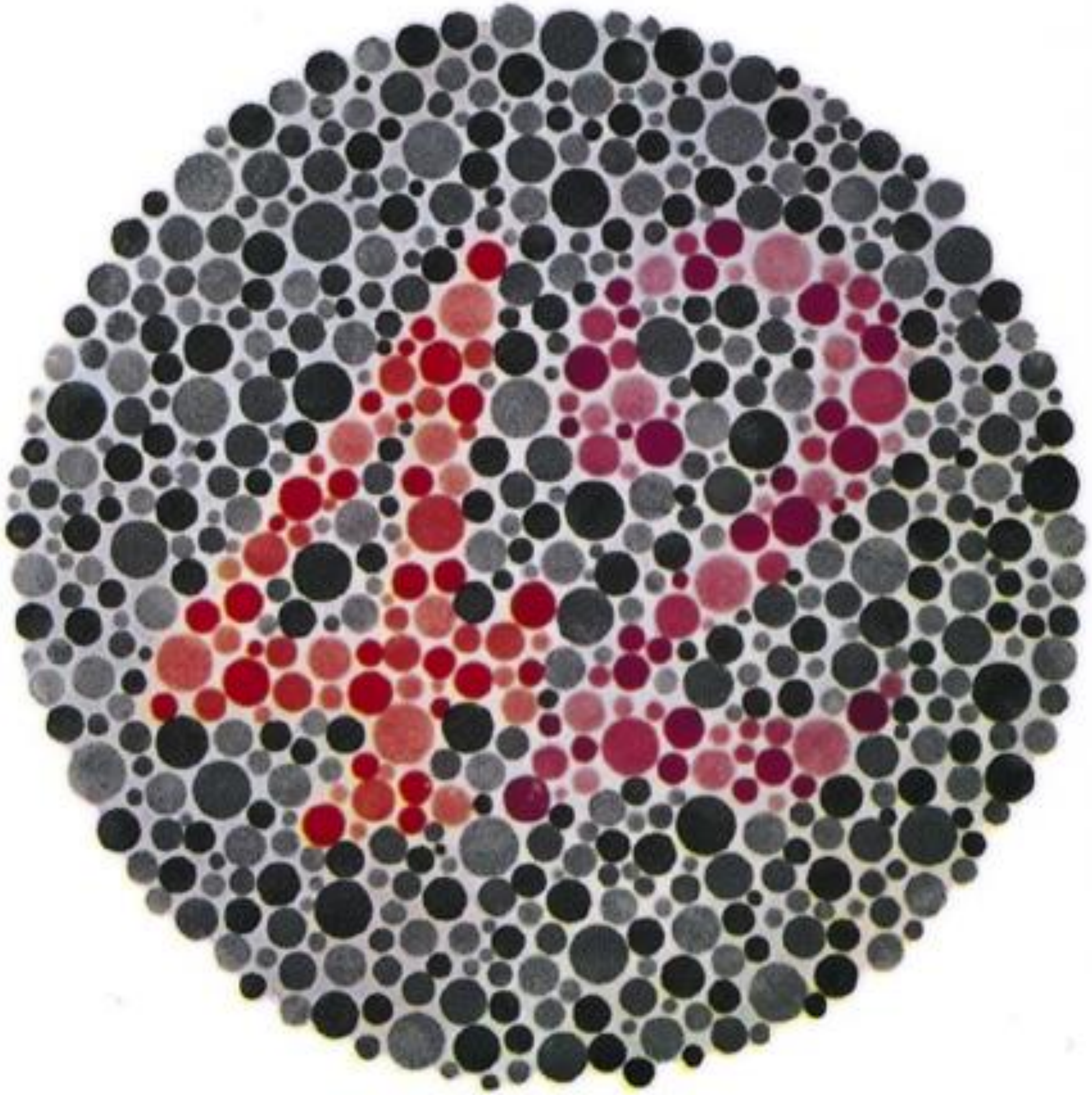
- According to the trichromatic theory of color vision, the perception of the many colors of the world depends on the three cone types' various ratios of stimulation in response to different wavelengths.



the ratios of stimulation of the three types of cones.

About equal stimulation of all the red, green, and blue cones gives one the sensation of seeing white.

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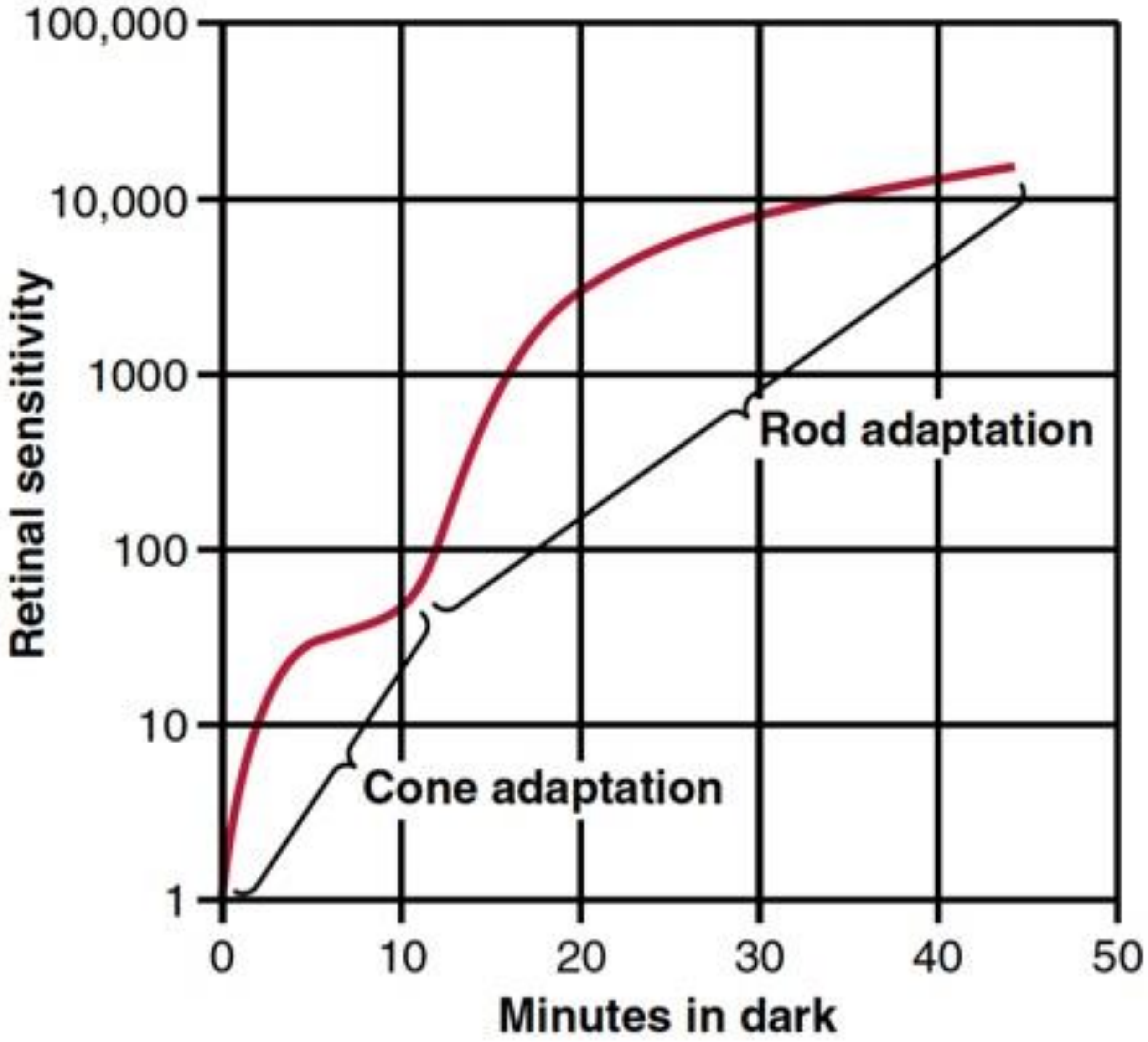
Photoreceptor	Sensitivity to Light	Acuity	Dark Adaptation	Color Vision
Rods	Low threshold Sensitive to low-intensity light Night vision	Low acuity Not present on fovea	Adapt late	No
Cones	High threshold Sensitive to high-intensity light Day vision	High acuity Present on fovea	Adapt early	Yes

Dark adaptation

- In the dark, the photopigments broken down during light exposure are gradually regenerated.

- As a result, the sensitivity of your eyes gradually increases so that you begin to see in the darkened surroundings.



100,000
10,000
1000
100
10
1
Retinal sensitivity
0
10
20
30
40
50
Minutes in dark
Rod adaptation
Cone adaptation

Light adaptation

- Conversely, when you move from the dark to the light, at first your eyes are very sensitive to the dazzling light.

- As some of the photopigments are rapidly broken down by the intense light, the sensitivity of the eyes decreases and normal contrasts can again be detected, a process known as light adaptation.

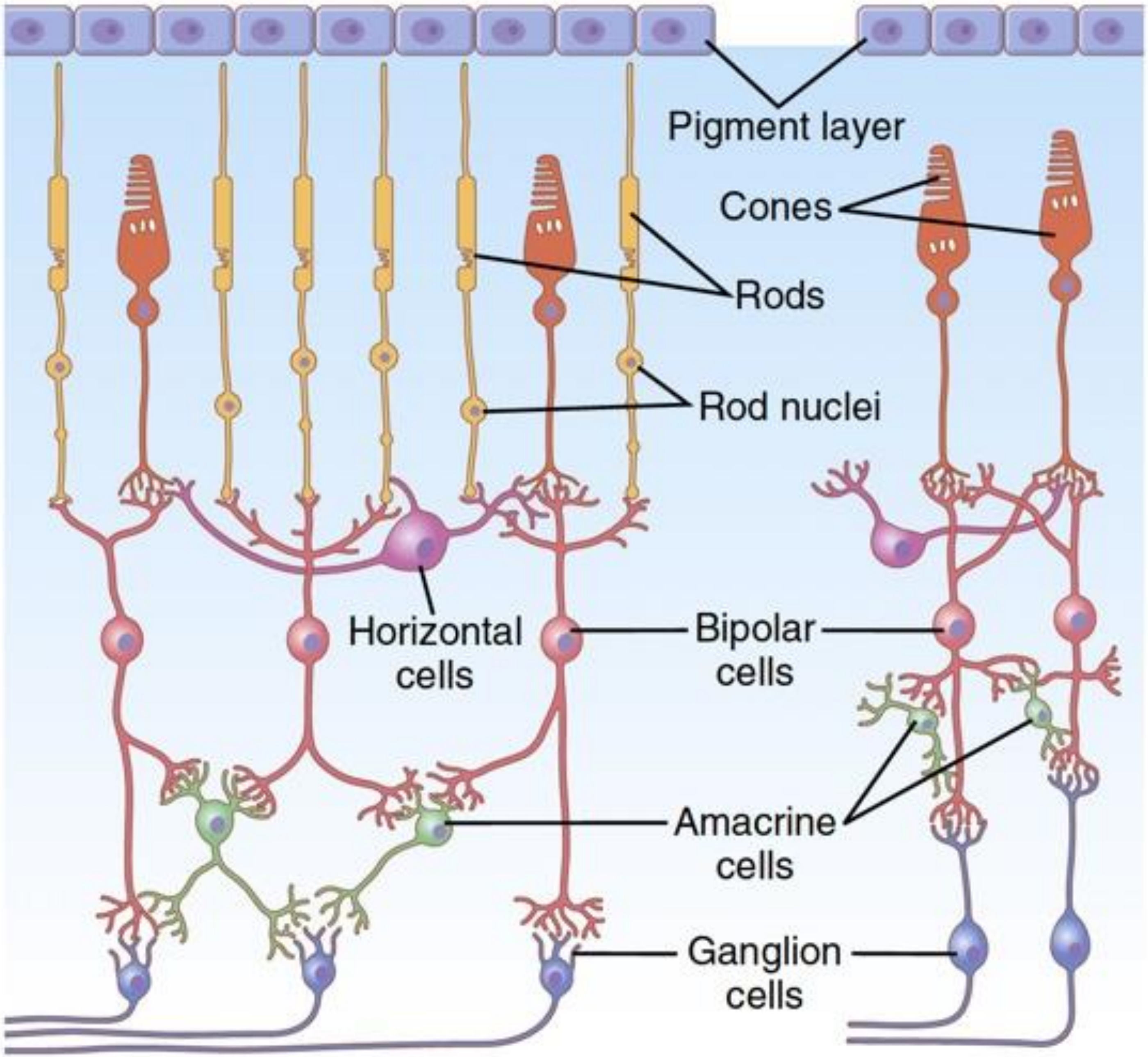
Adaptation

- These adaptive measures are also enhanced by **pupillary reflexes** that adjust the amount of available light permitted to enter the eye.
- The other mechanism is **neural adaptation**, involving the neurons in the successive stages of the visual chain in the retina and in the brain.

Central vs peripheral retina

- major differences exist between the peripheral retina and the central retina.
- As one approaches the fovea, fewer rods and cones converge on each optic fiber, which increases the acuity of vision in the central retina.

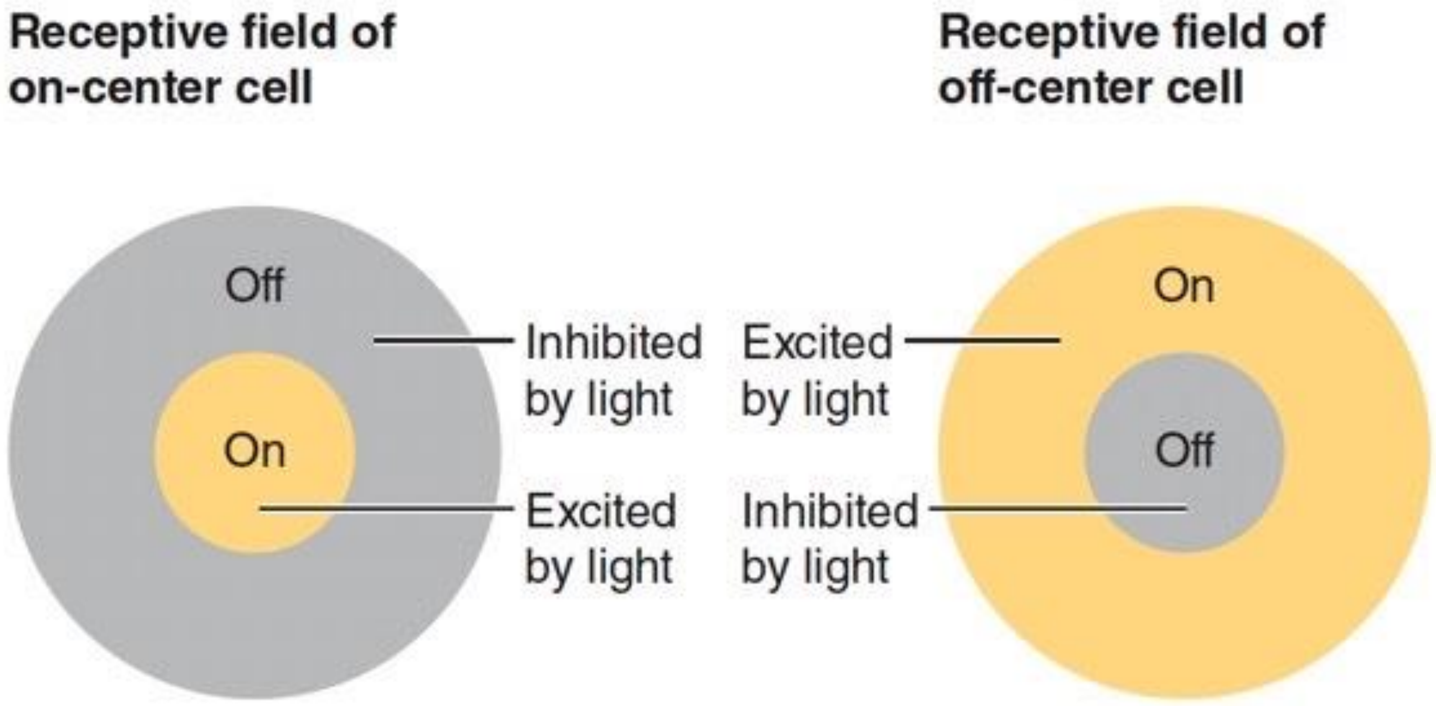
- Another difference between the peripheral and central portions of the retina is the much greater sensitivity of the peripheral retina to weak light, that as many as 200 rods converge on a single optic nerve fiber in the more peripheral portions of the retina.



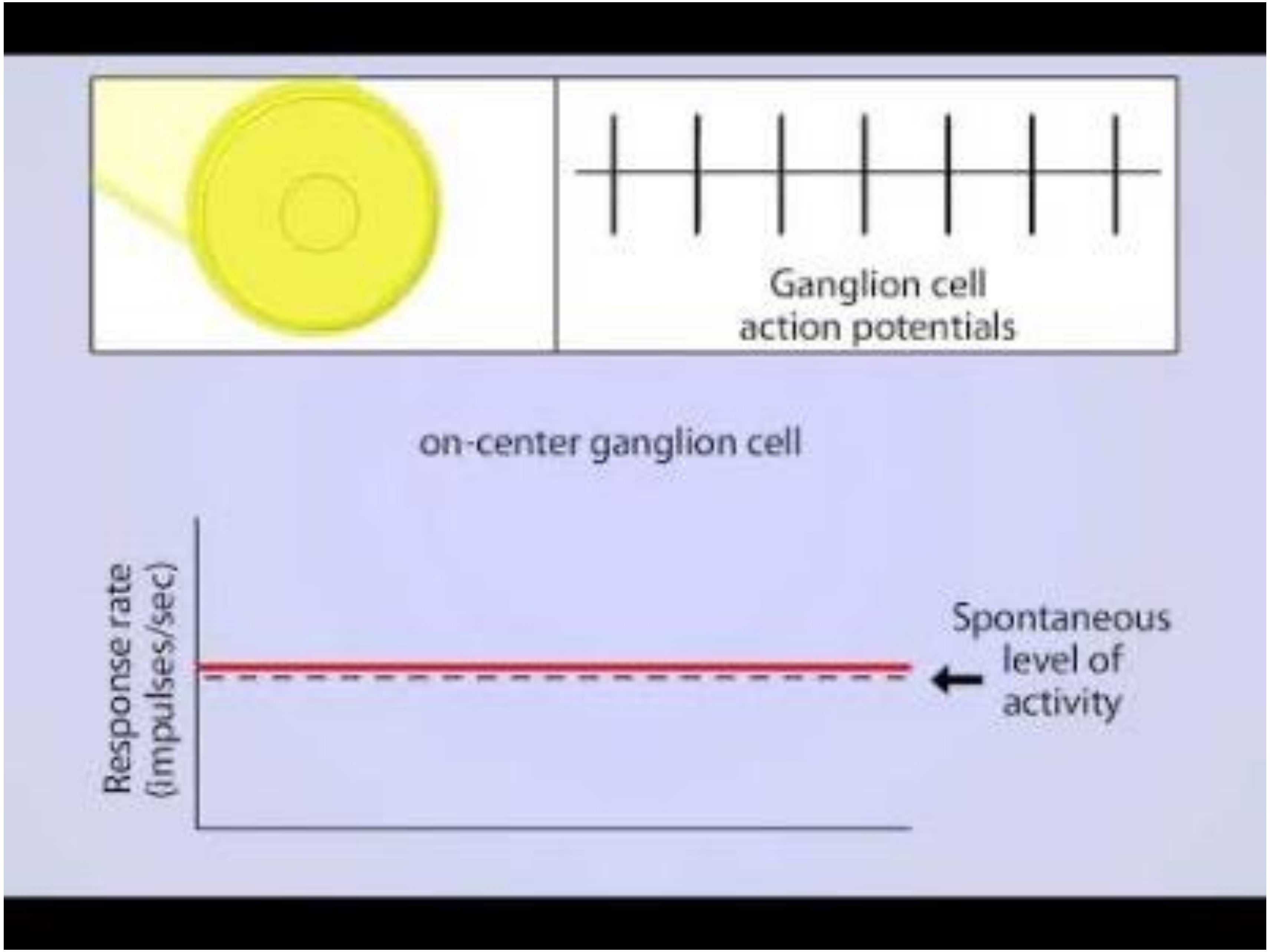
Pigment layer
Cones
Rods
Rod nuclei
Horizontal cells
Bipolar cells
Amacrine cells
Ganglion cells

Action potential in the retina

- The only retinal neurons that always transmit visual signals via action potentials are the ganglion cells.
- The importance is that it allows graded conduction of signal strength.
- Thus, for the rods and cones, the strength of the hyperpolarizing output signal is directly related to the intensity of illumination; the signal is not all or none, as would be the case for each action potential.



Receptive field of
on-center cell
Off
On
Inhibited
by light
Excited
by light
Receptive field of
off-center cell
On
Off
Excited
by light
Inhibited
by light


Ganglion cell
action potentials
on-center ganglion cell
Response rate
(impulses/sec)
Spontaneous
level of
activity

Horizontal cells

- The outputs of the horizontal cells are always inhibitory. Therefore, this lateral connection provides the same phenomenon of lateral inhibition that is important in helping to ensure transmission of visual patterns with proper visual contrast.

- This process is essential to allow high visual accuracy in transmitting contrast borders in the visual image.

Amacrine cells

- Some of the amacrine cells probably provide additional lateral inhibition and further enhancement of visual contrast in the inner plexiform layer of the retina as well.

Retinal Ganglion cells

- Even when unstimulated, ganglion cells still transmit continuous impulses at various rates.
- Two general classes of retinal ganglion cells that have been studied most, are designated as magnocellular (M) and parvocellular (P) cells.
- The P cells, in the central retina, project to the parvocellular (small cells) layer of the lateral geniculate nucleus of the thalamus.
- The M cells project to the magnocellular (large cells) layer of the lateral geniculate nucleus.

Retinal Ganglion cells

- The main functions of M and P cells are obvious from their differences:
- The **P cells** are highly sensitive to visual signals that relate to fine details and to different colors but are relatively insensitive to low-contrast signals.

- the **M cells** are highly sensitive to low-contrast stimuli and to rapid movement visual signals.

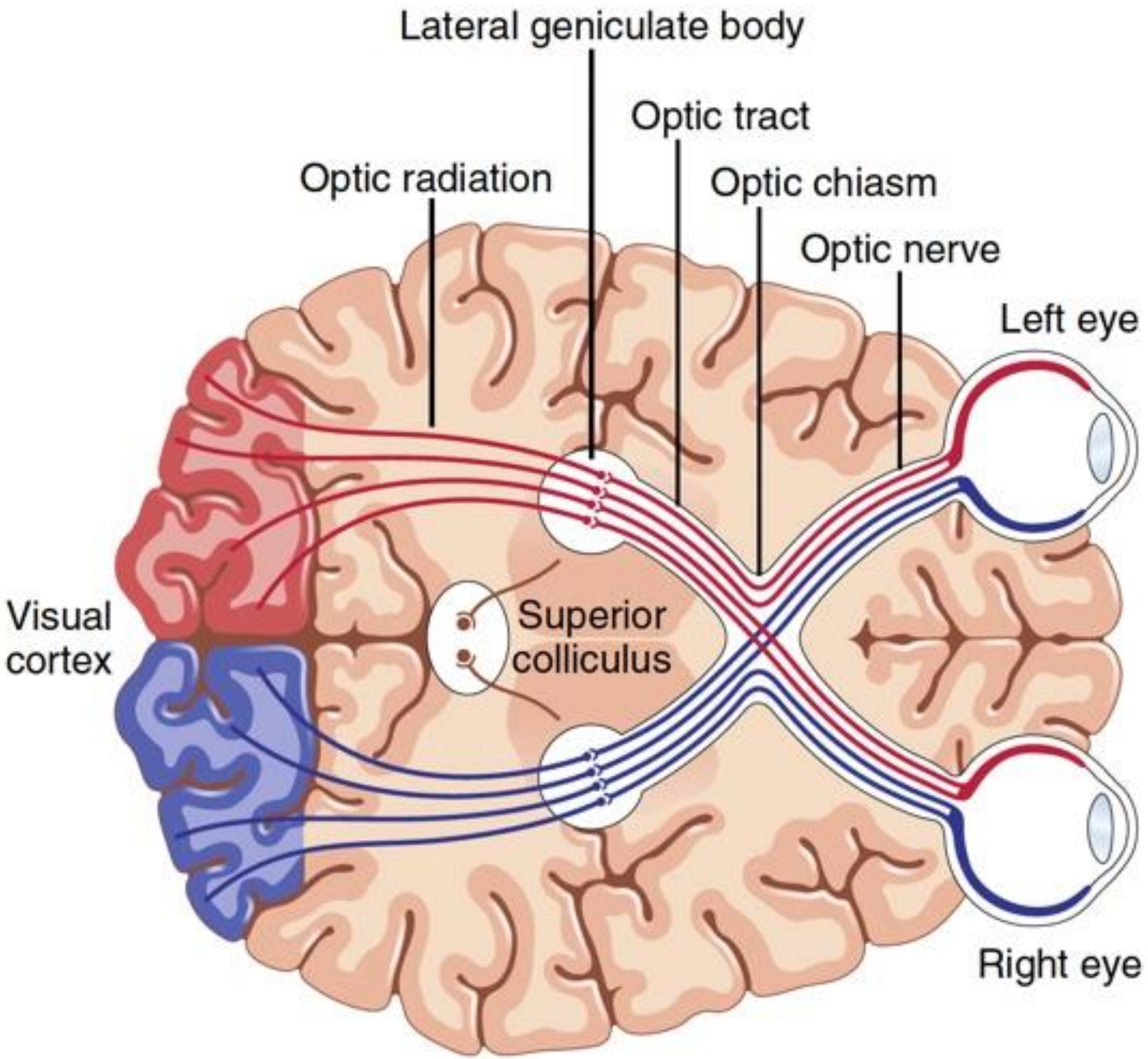
Retinal Ganglion cells

- A third type of photosensitive retinal ganglion cell has been described that contains its own photopigment, melanopsin.

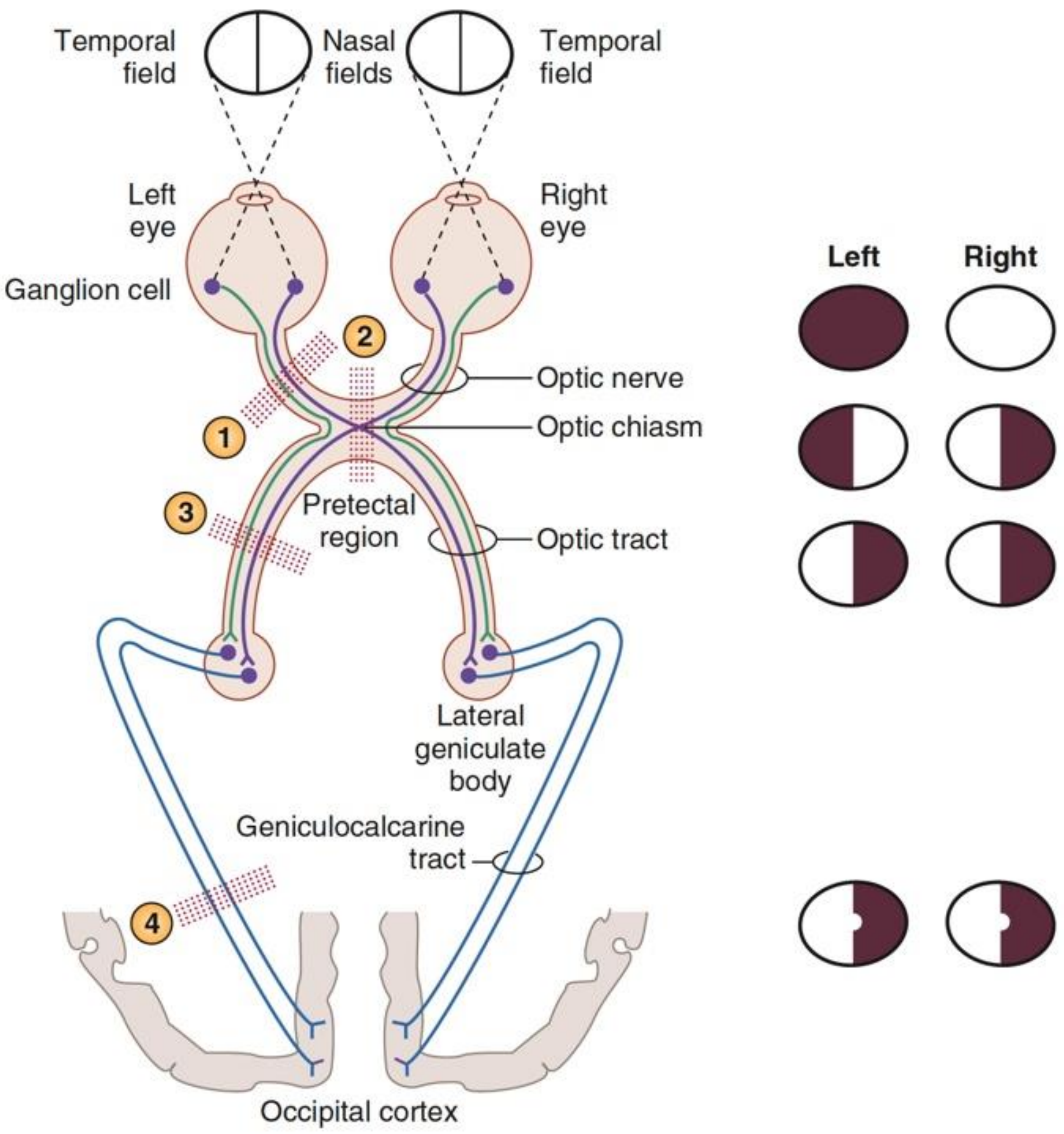
- These cells appear to send signals mainly to nonvisual areas of the brain, particularly the suprachiasmatic nucleus of the hypothalamus, the master circadian pacemaker.

Retinal ganglion cells

- Some of the ganglion cells are excited by only one color type of cone but are inhibited by a second type.
- The importance of these color contrast mechanisms is that they represent a means whereby the retina begins to differentiate colors.
- Thus, each color contrast type of ganglion cell is excited by one color but inhibited by the “opponent” color. Therefore, color analysis begins in the retina.


Lateral geniculate body
Optic tract
Optic radiation
Optic chiasm
Optic nerve
Left eye
Visual cortex
Superior colliculus
Right eye

LESIONS OF OPTIC PATHWAYS



Visual pathways

- the visual pathways can be divided roughly into an old system to the midbrain and base of the forebrain and a new system for direct transmission of visual signals into the visual cortex located in the occipital lobes.

Visual pathways

- Visual fibers also pass to several older areas of the brain:
- (1) from the optic tracts to the suprachiasmatic nucleus of the hypothalamus, presumably to control circadian rhythms that synchronize various physiological changes of the body with night and day.
- (2) into the pretectal nuclei in the midbrain to elicit reflex movements of the eyes to focus on objects of importance and activate the pupillary light reflex.
- (3) into the superior colliculus to control rapid directional movements of the two eyes.

Superior colliculus

- a sudden visual disturbance in a lateral area of the visual field often causes immediate turning of the eyes in that direction.

- This turning does not occur if the superior colliculi have also been destroyed.

- To support this function, the various points of the retina are represented topographically in the superior colliculi in the same way as in the primary visual cortex, although with less accuracy.

Thalamus

- After passing the optic chiasm, half the fibers in each optic tract are derived from one eye and half are derived from the other eye, representing corresponding points on the two retinas.
- However, the signals from the two eyes are kept apart in the dorsal lateral geniculate nucleus.
- This nucleus is composed of six nuclear layers.

Dorsal lateral geniculate nucleus

- 1. magnocellular layers because they contain large neurons. These neurons receive their input almost entirely from the large type M retinal ganglion cells.

- This magnocellular system provides a rapidly conducting pathway to the visual cortex.
- However, this system is color blind, transmitting only black-and-white information.

Dorsal lateral geniculate nucleus

- 2. parvocellular layers because they contain large numbers of small to medium-sized neurons.

- These neurons receive their input almost entirely from the type P retinal ganglion cells that transmit color and convey accurate point to point spatial information, but at only a moderate velocity of conduction rather than at high velocity.

Thalamus

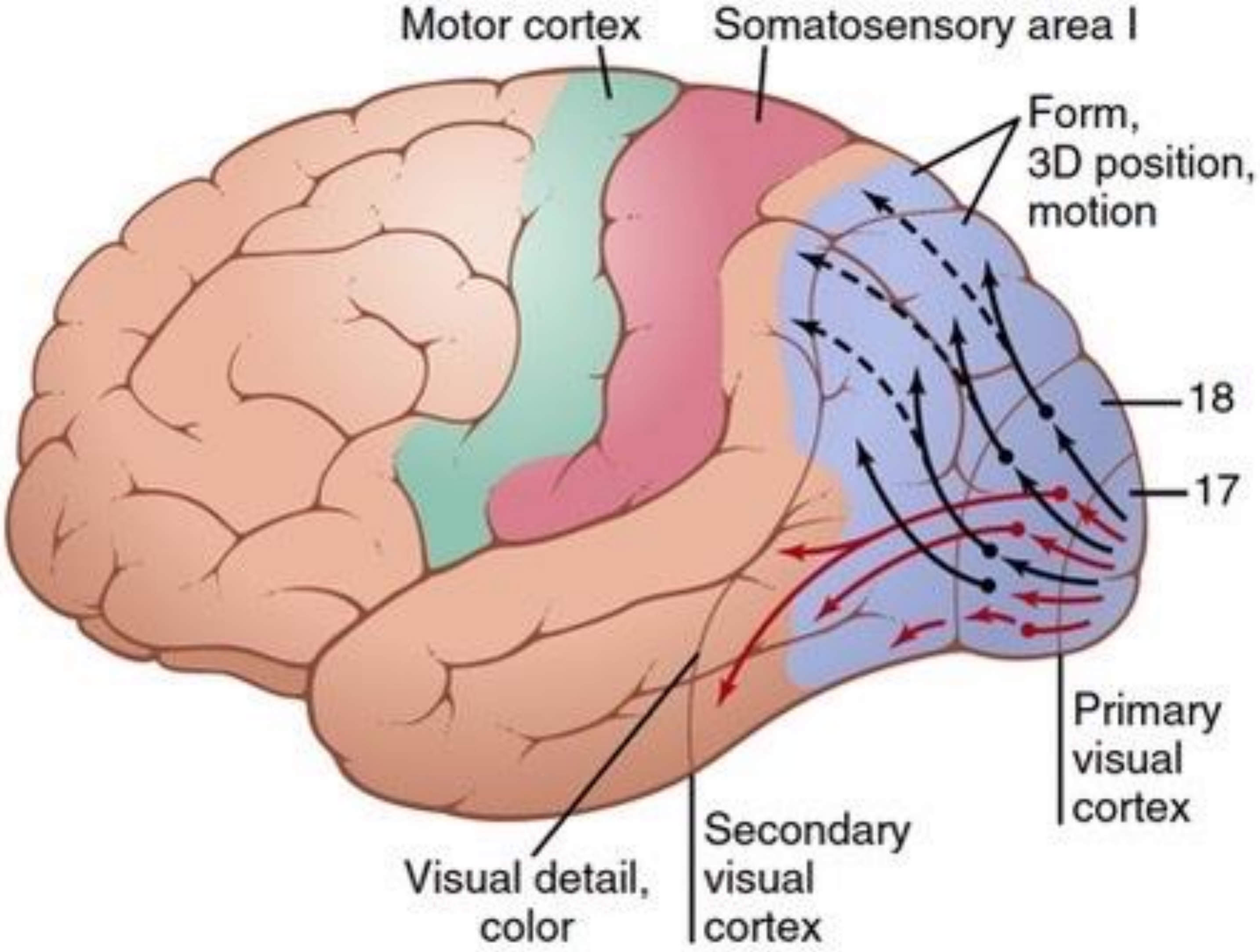
- The dorsal lateral geniculate nucleus serves two principal functions.
- First, it relays visual information from the optic tract to the visual cortex by way of the optic radiation.
- This relay function is so accurate that there is exact point to point transmission with a high degree of spatial fidelity all the way from the retina to the visual cortex.

Thalamus

- The second major function of the dorsal lateral geniculate nucleus is to "gate" the transmission of signals to the visual cortex—that is, to control how much of the signal is allowed to pass to the cortex.

- The nucleus receives gating control signals from two major sources:
- (1) corticofugal fibers returning in a backward direction from the primary visual cortex to the lateral geniculate nucleus.

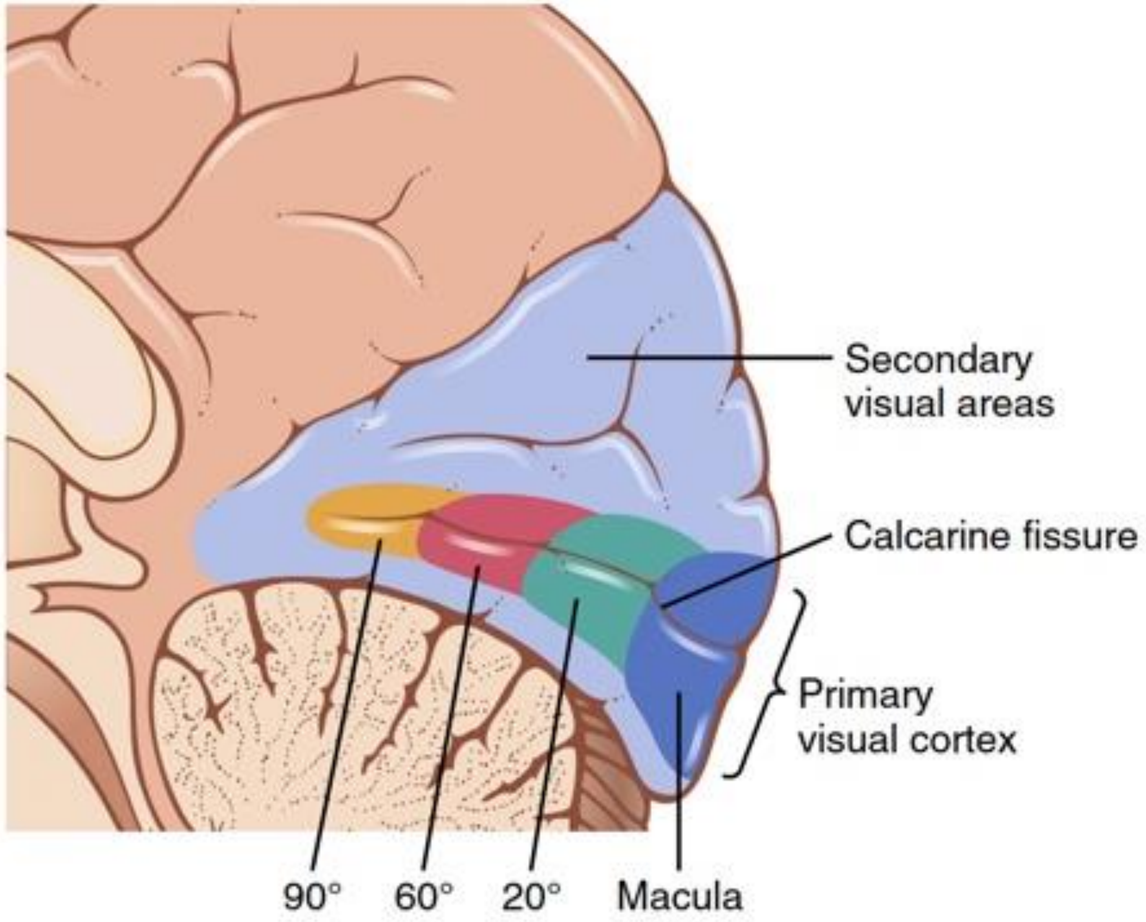
- (2) reticular areas of the mesencephalon. Both of these sources are inhibitory and, when stimulated, can turn off transmission through selected portions of the dorsal lateral geniculate nucleus.



Motor cortex
Somatosensory area I
Form,
3D position,
motion
18
17
Primary
visual
cortex
Secondary
visual
cortex
Visual detail,
color

Primary visual cortex

- Layers and columns
- Based on retinal area, the fovea has several hundred times as much representation in the primary visual cortex as do the most peripheral portions of the retina.

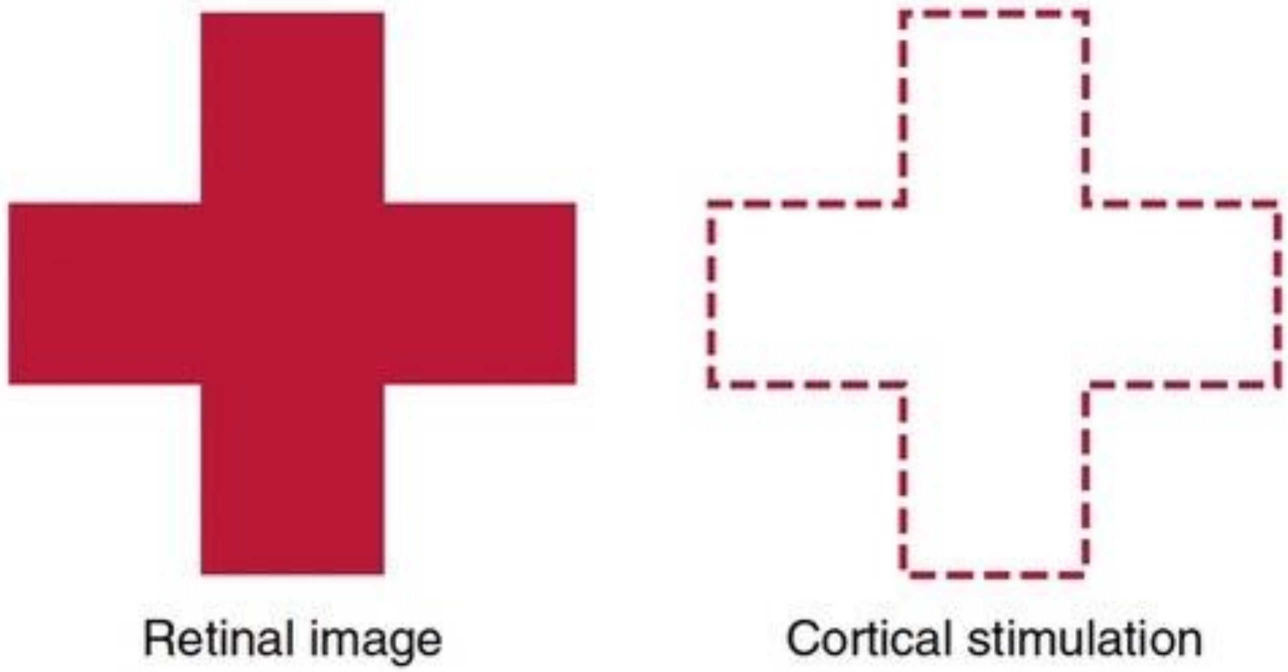

Secondary
visual areas
Calcarine fissure
Primary
visual cortex
90°
60°
20°
Macula

Primary visual cortex

- The areas of maximum excitation occur along the sharp borders of the visual pattern.

- Thus, the visual signal in the primary visual cortex is concerned mainly with contrasts in the visual scene, rather than with noncontrasting areas.

- Color is detected in much the same way that lines are detected—by means of color contrast.


Retinal image
Cortical stimulation

Primary visual cortex

- The visual cortex detects not only the existence of lines and borders in the different areas of the retinal image but also the direction of orientation of each line or border—that is, whether it is vertical or horizontal or lies at some degree of inclination.
- This capability is believed to result from linear organizations of mutually inhibiting cells that excite second-order Neurons when inhibition occurs all along a line of cells where there is a contrast edge.
- Thus, for each such orientation of a line, specific neuronal cells are stimulated.
- A line oriented in a different direction excites a different set of cells. These neuronal cells are called simple cells. They are found mainly in layer IV of the primary visual cortex.

Visual cortex

- “Complex” Cells Detect Line Orientation When a Line Is Displaced Laterally or Vertically in the Visual Field.

- Some neurons in the outer layers of the primary visual columns, as well as neurons in some secondary visual areas, are stimulated only by lines or borders of specific lengths, by specific angulated shapes, or by images that have other characteristics. That is, these neurons detect still higher orders of information from the visual scene.

Visual pathways

- after leaving the primary visual cortex, the visual information is analyzed in two major pathways in the secondary visual areas:

- 1. Analysis of Third-Dimensional Position, Gross Form, and Motion of Objects.
- The signals transmitted in this position-form-motion pathway are mainly from the large M optic nerve fibers of the retinal M ganglion cells, transmitting rapid signals but depicting only black and white with no color.

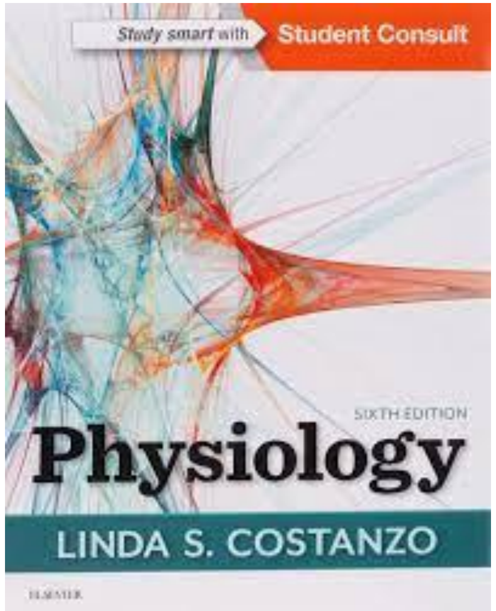
Visual pathways

- 2. Analysis of Visual Detail and Color:
- the principal pathway for analysis of visual detail.
- Separate portions of this pathway specifically dissect out color as well.
- Therefore, this pathway is concerned with recognizing letters, reading, determining the texture of surfaces, determining detailed colors of objects, and deciphering from all this information what the object is and what it means.

Stereopsis

- Because the two eyes are more than 2 inches apart, the images on the two retinas are not exactly the same.
- The closer the object, the greater the disparity.
- Therefore, it is still impossible for all corresponding points in the two visual images to be exactly in register at the same time.
- This degree of nonregister provides the neural mechanism for stereopsis, an important mechanism for judging the distances of visual objects.
- the distance is determined by which set or sets of pathways are excited by nonregister or register. This phenomenon is also called depth perception.

References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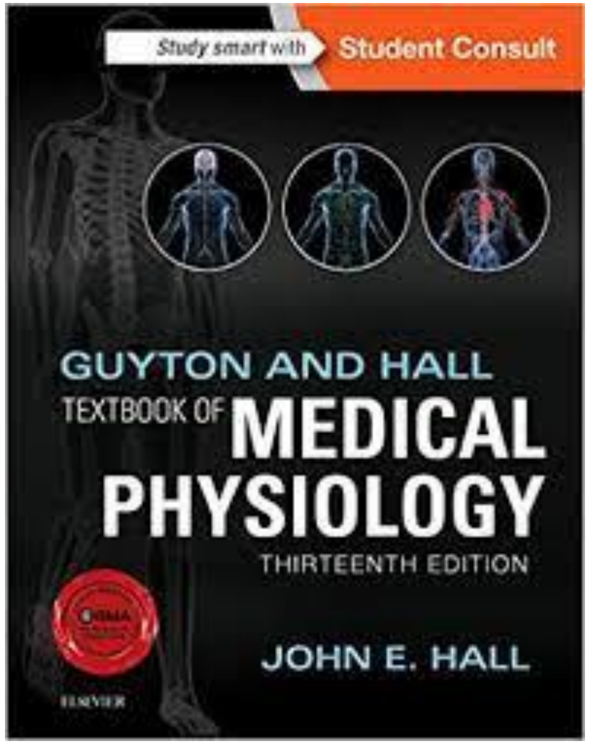
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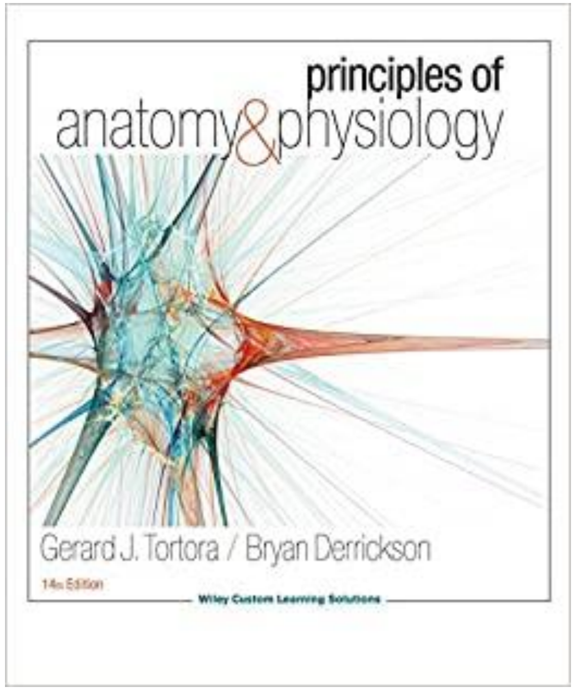
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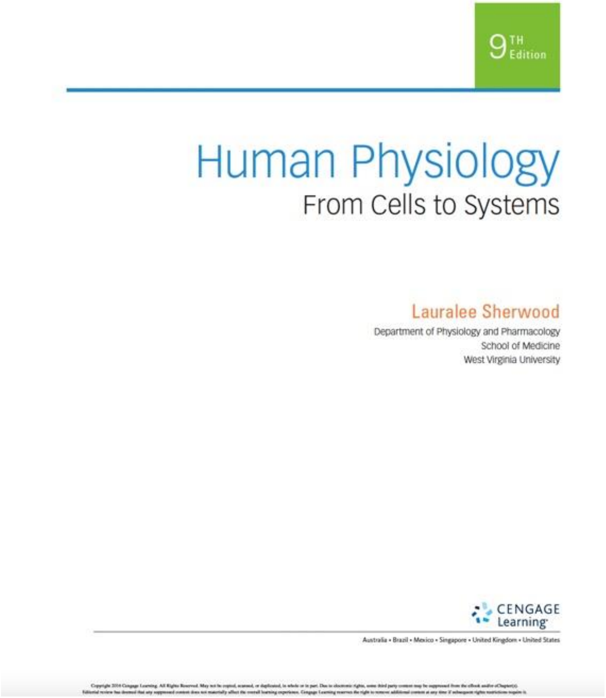
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