Physiology for medical students

Vision-III

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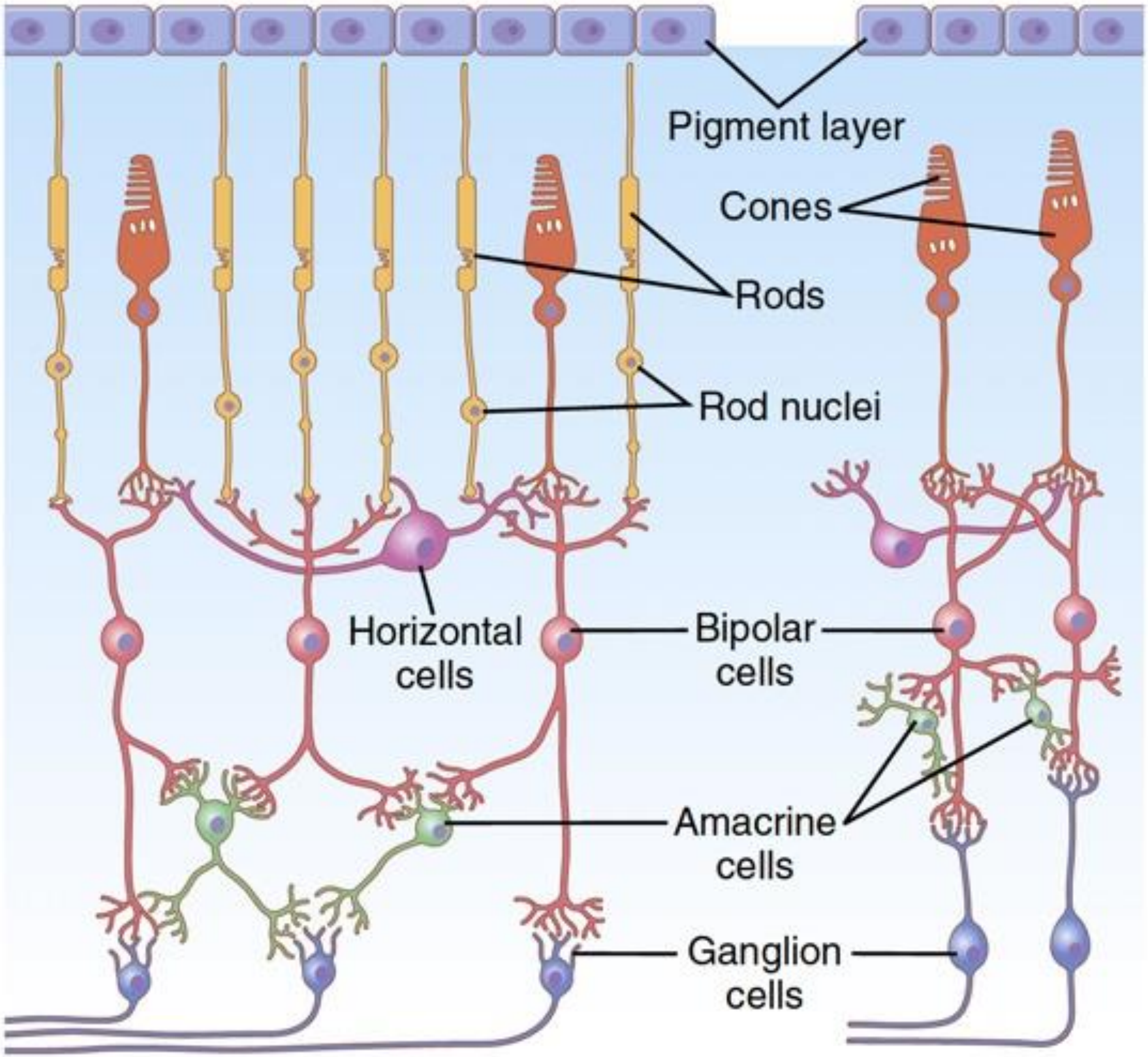
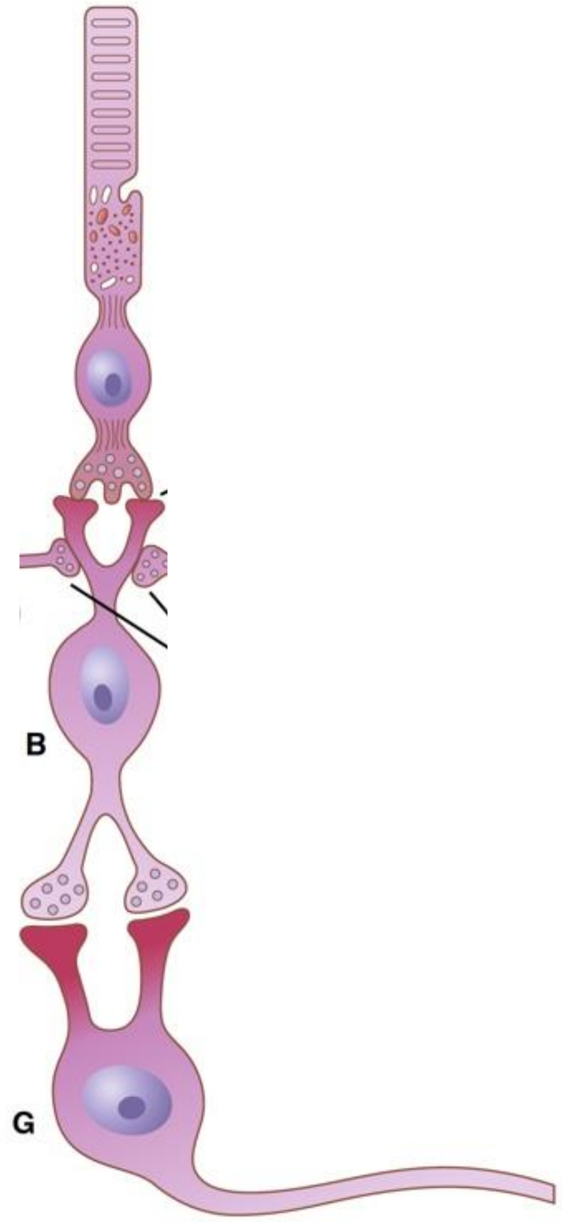
Central vs peripheral retina

- 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


B
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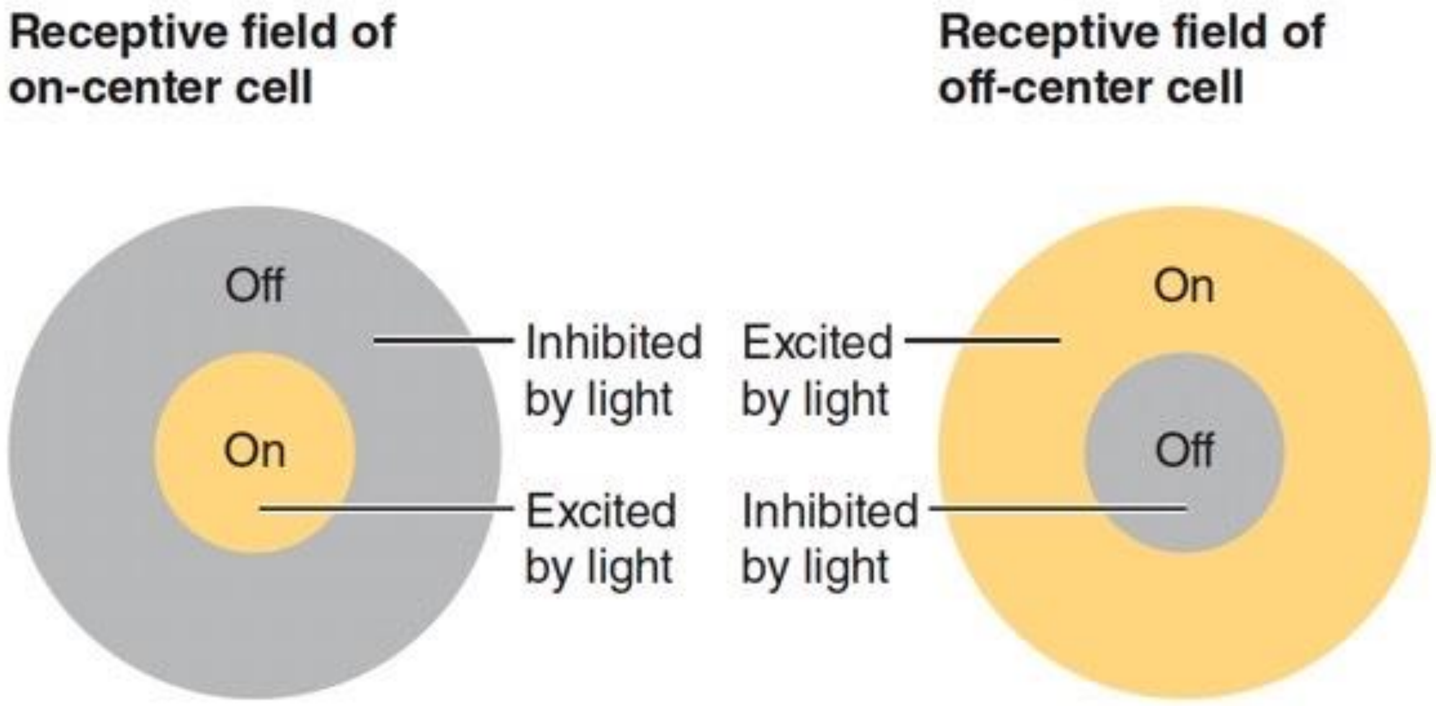
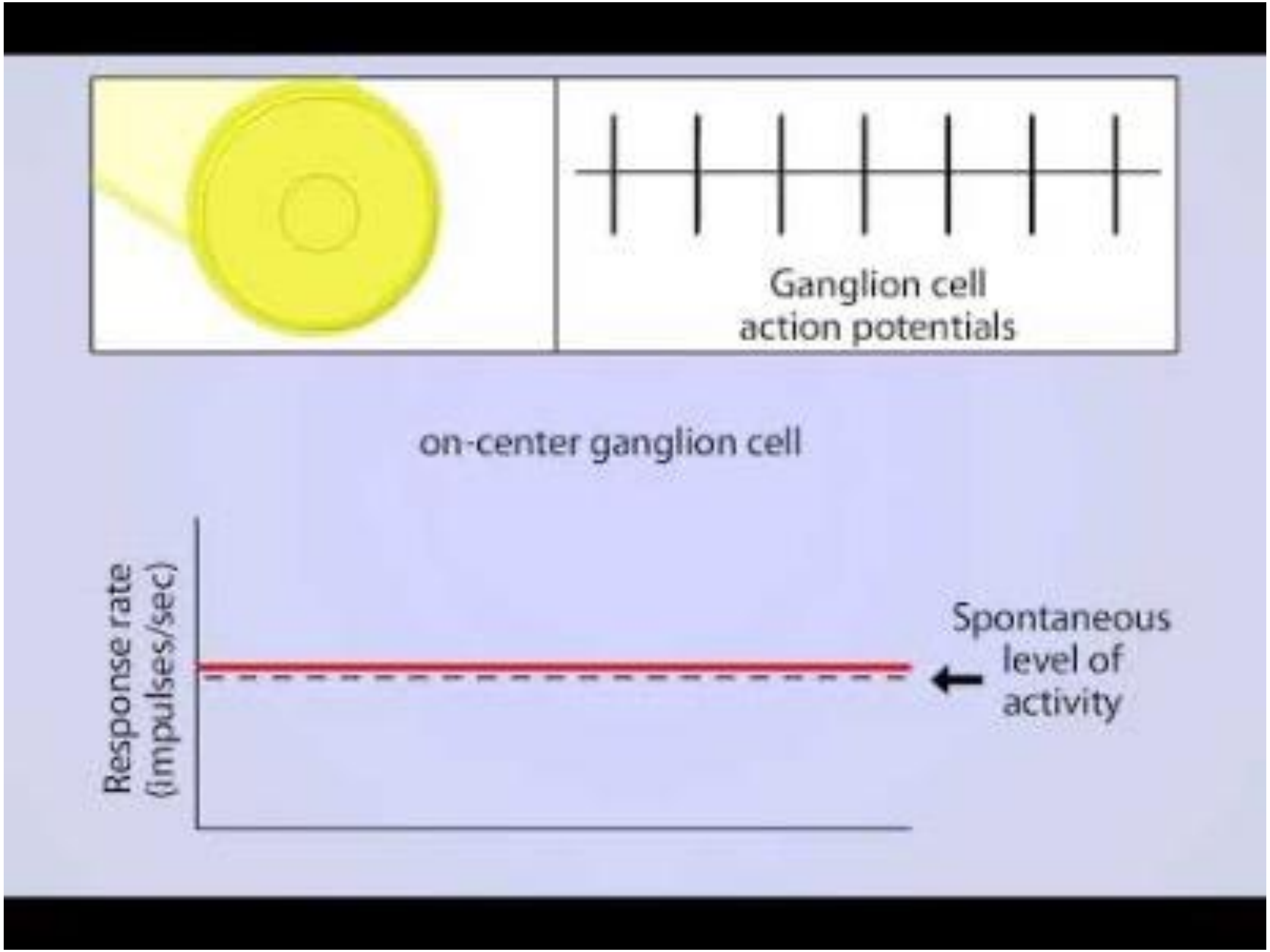
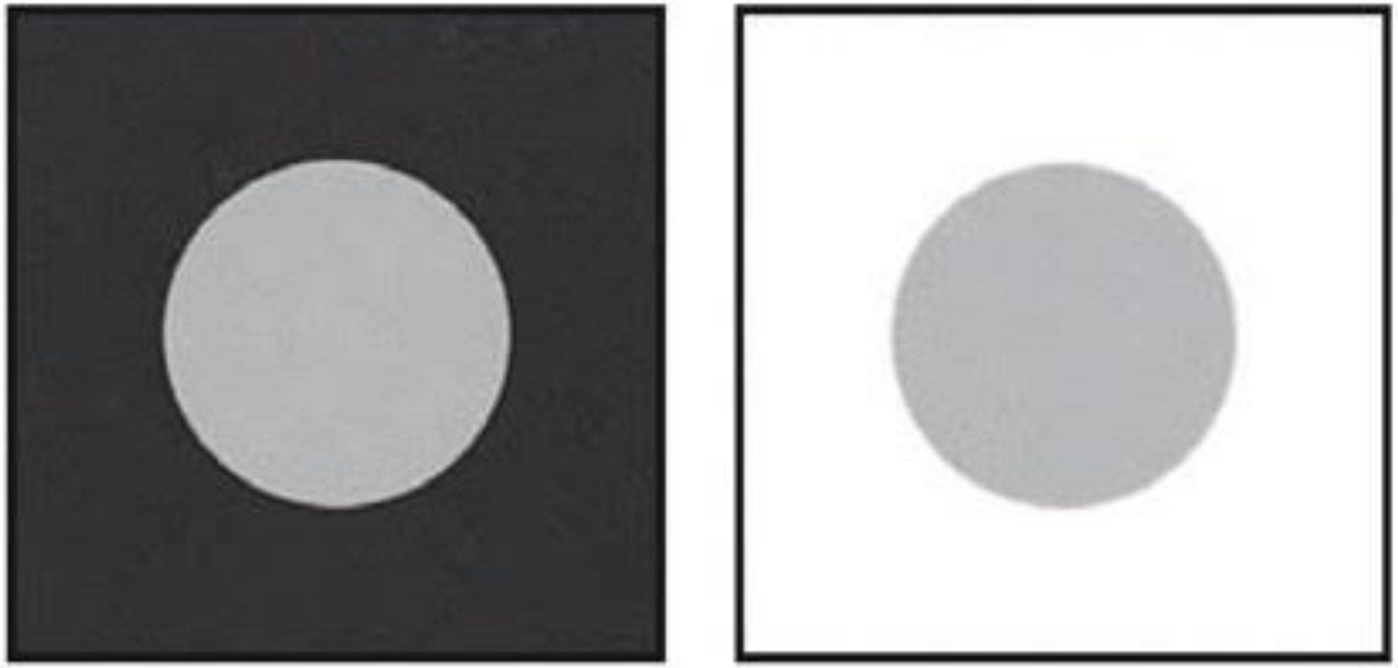

Receptive field of on-center cell
Receptive field of off-center cell
Off
On
Inhibited by light
Excited by light
On
Off
Excited by light
Inhibited by light


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



Retinal processing by on-center and off-center ganglion cells is largely responsible for enhancing differences in relative (rather than absolute) brightness, which helps define contours.

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.

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.

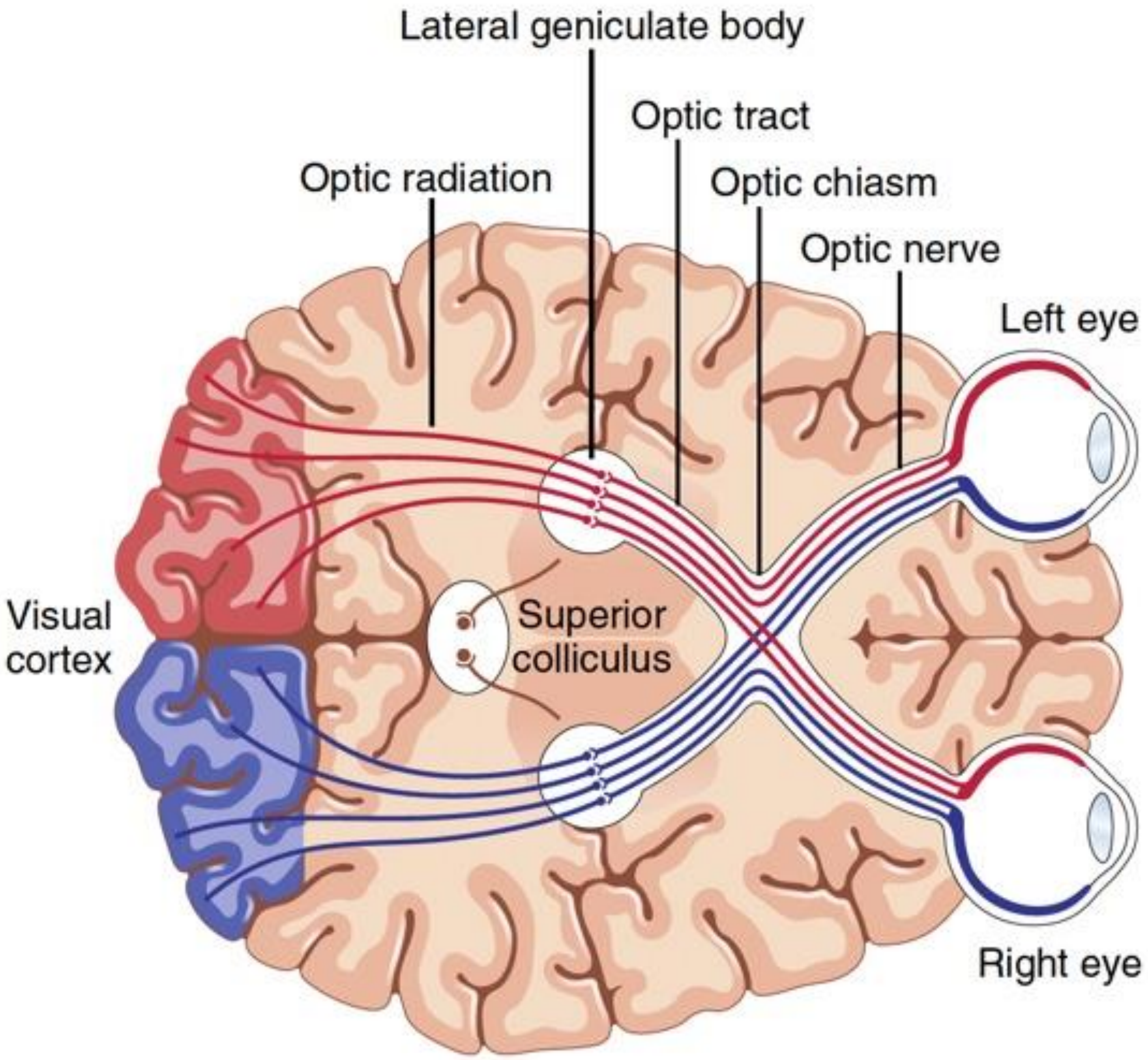
- the **M cells** are highly sensitive to low-contrast stimuli and to rapid movement visual signals.

Retinal Ganglion cells

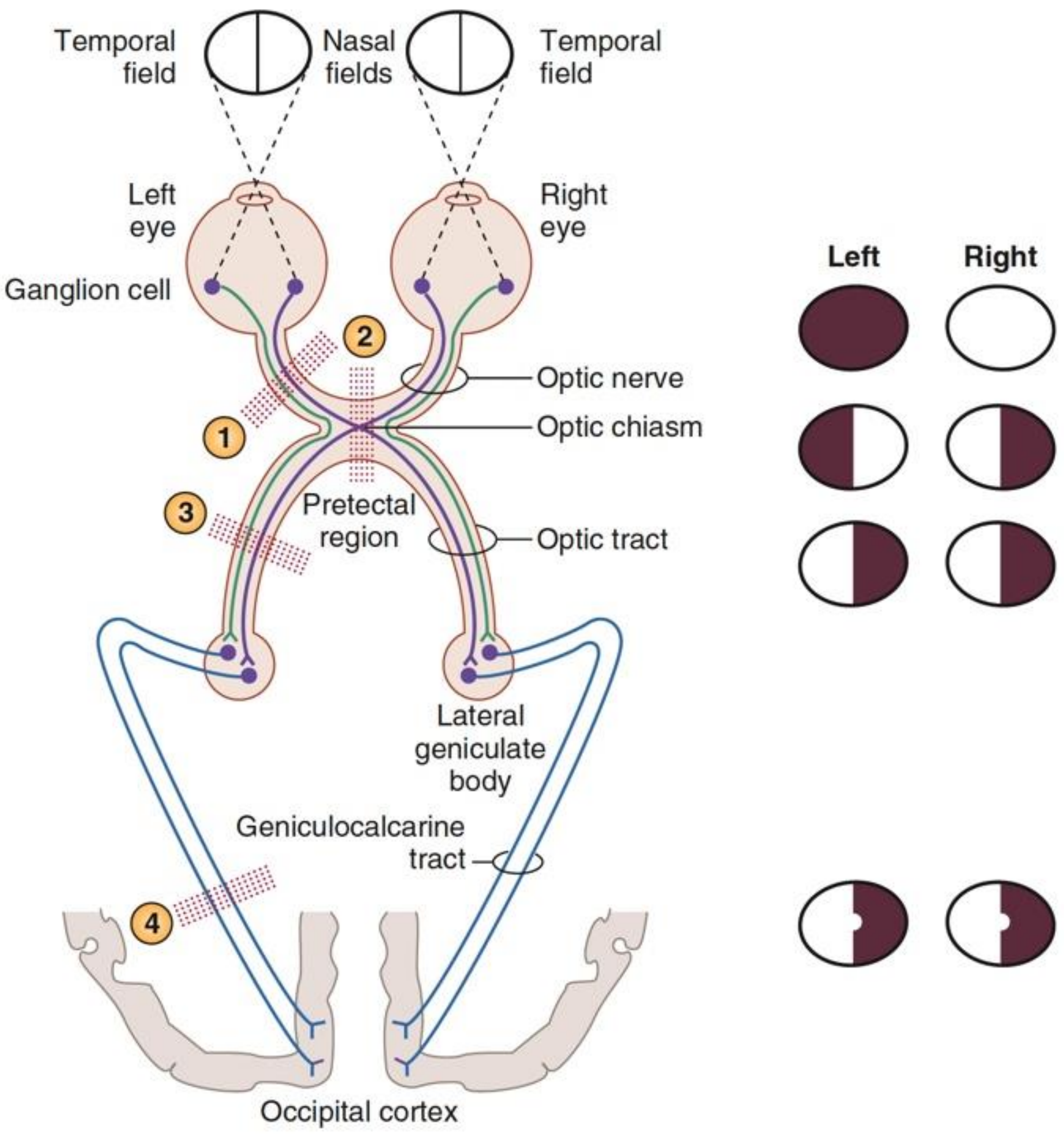
- A third type of photosensitive retinal ganglion cell has been described that contains its own photopigment, melanopsin.
- These cells appear to send signals mainly to nonvisual areas of the brain, particularly the suprachiasmatic nucleus of the hypothalamus, the master circadian pacemaker.
- not wired to rods and cones and are not involved in visual processing.

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.

Visual pathways

- (3) into the superior colliculus to control rapid directional movements of the two eyes.

- (4) into the ventral lateral geniculate nucleus of the thalamus.

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. Layers I and II are called 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.
- Also, its point to point transmission is poor because there are not many M ganglion cells, and their dendrites spread widely in the retina.

Dorsal lateral geniculate nucleus

- 2. Layers III through VI are called 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.

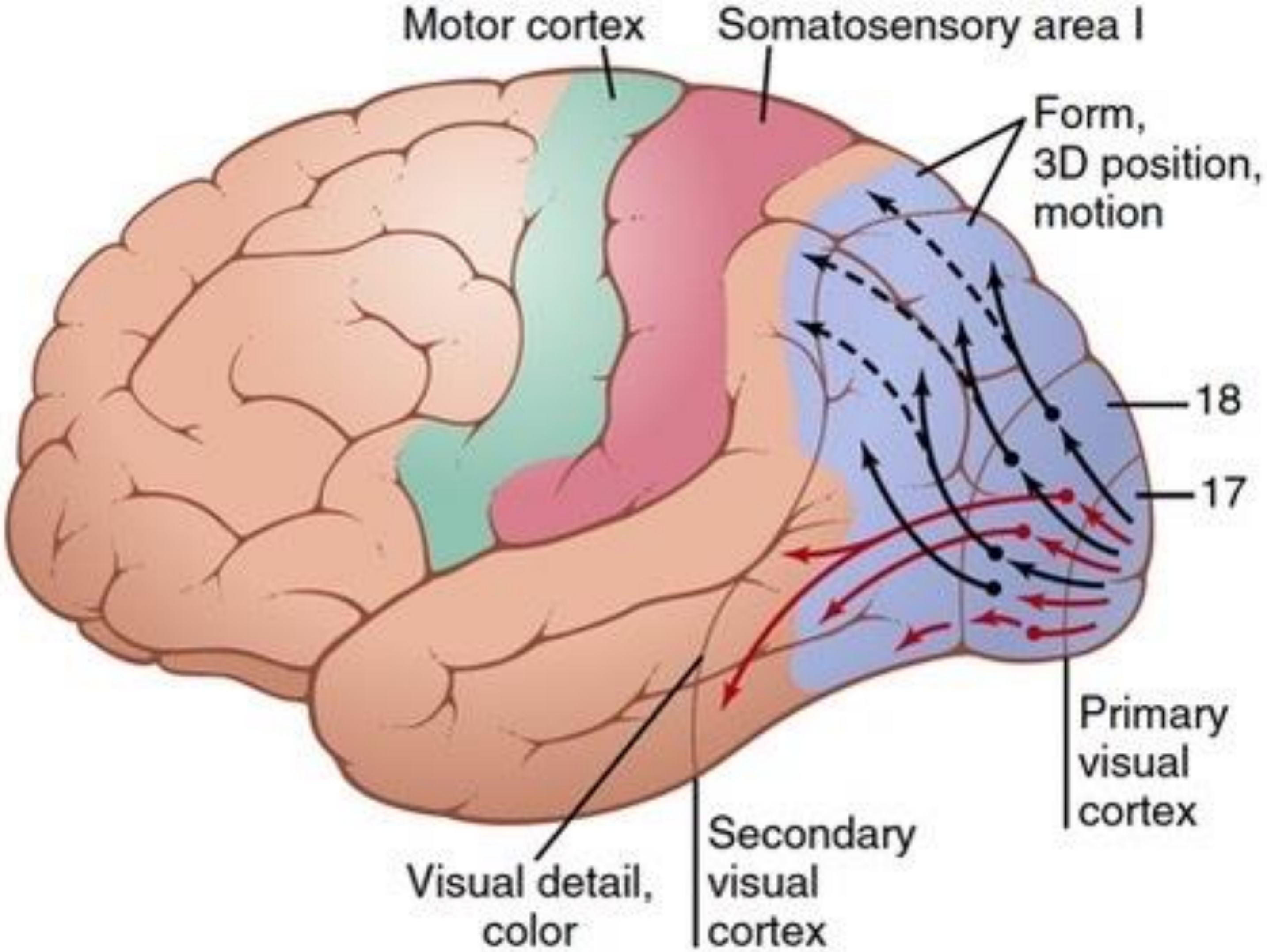
- First, it relays visual information from the optic tract to the visual cortex by way of the optic radiation.
- This relay function is so accurate that there is exact point to point transmission with a high degree of spatial fidelity all the way from the retina to the visual cortex.

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.

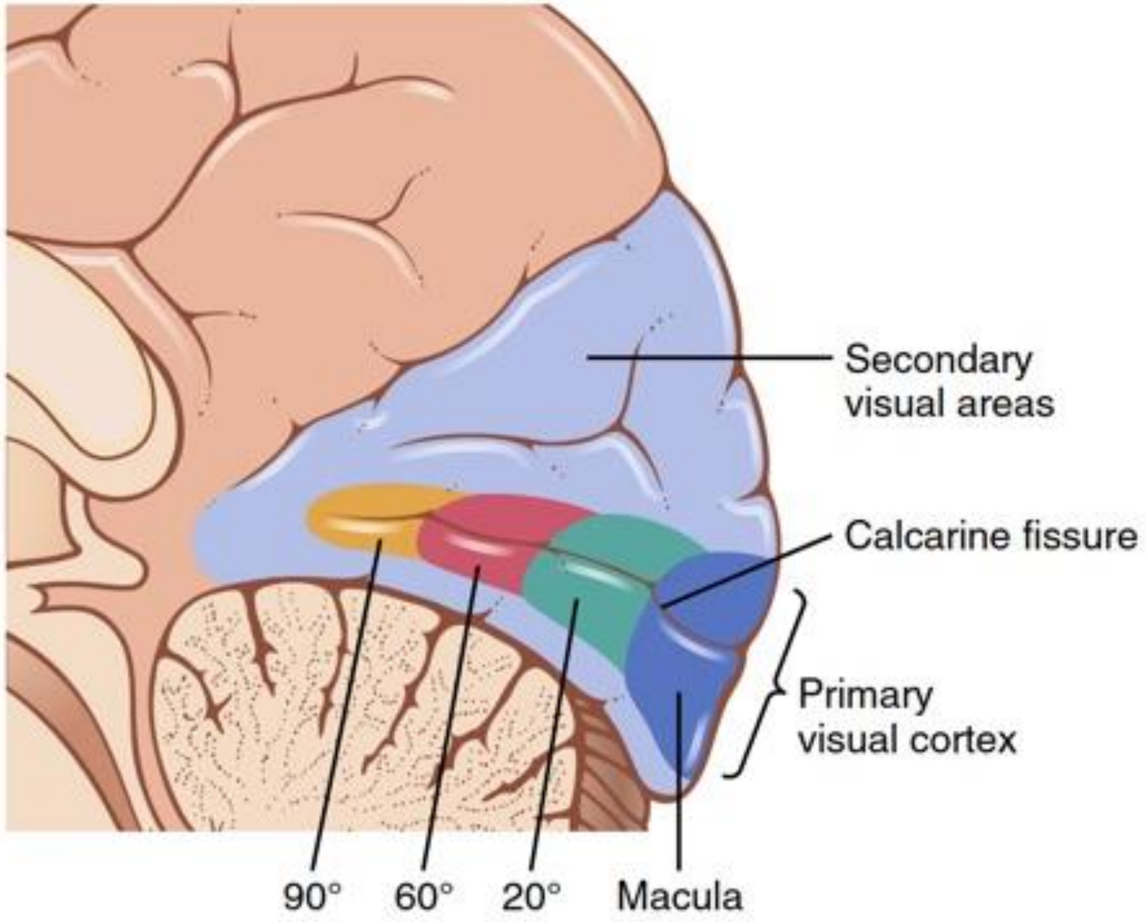
- The nucleus receives gating control signals from two major sources:
- (1) corticofugal fibers returning in a backward direction from the primary visual cortex to the lateral geniculate nucleus.

- (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

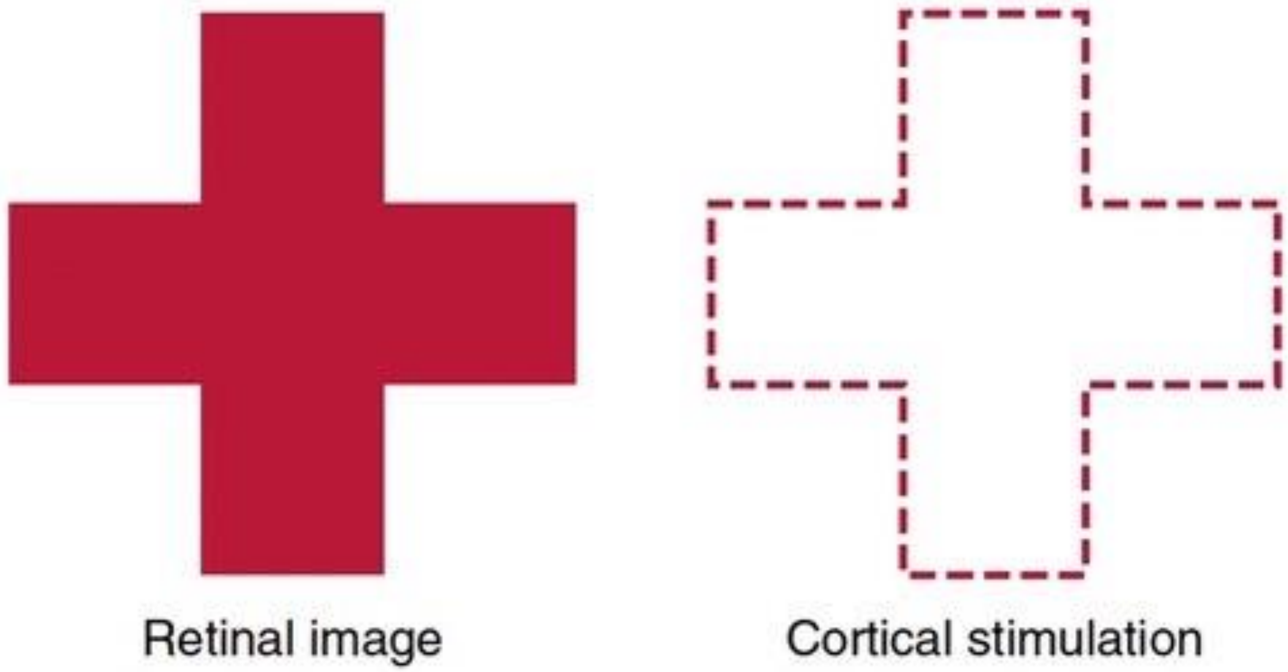
Primary visual cortex

- 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.

Eye movement

- To summarize, posterior “involuntary” occipital cortical eye fields automatically “lock” the eyes on a given spot of the visual field and thereby prevent movement of the image across the retinas.

- To unlock this visual fixation, voluntary signals must be transmitted from cortical “voluntary” eye fields located in the frontal cortices.

Saccadic movement

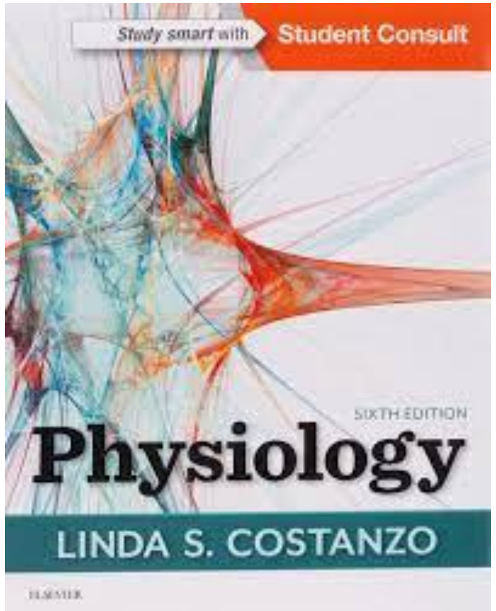
- When a visual scene is moving continually before the eyes, such as when a person is riding in a car, the eyes fix on one highlight after another in the visual field, jumping from one to the next at a rate of two to three jumps per second. The jumps are called saccades.
- The saccades occur so rapidly that no more than 10% of the total time is spent moving the eyes, with 90% of the time being allocated to the fixation sites. Also, the brain suppresses the visual image during saccades, so the person is not conscious of the movements from point to point.

Eye movement

- During the process of reading, a person usually makes several saccadic movements of the eyes for each line.
- In this case, the visual scene is not moving past the eyes, but the eyes are trained to move by means of several successive saccades across the visual scene to extract the important information.

- The eyes can also remain fixed on a moving object, which is called pursuit movement.
- A highly developed cortical mechanism automatically detects the course of movement of an object and then rapidly develops a similar course of movement for the eyes.

References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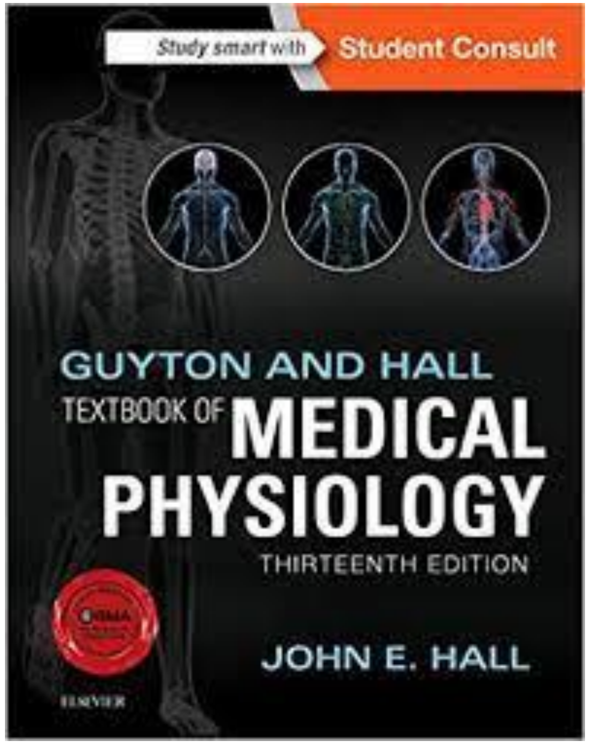
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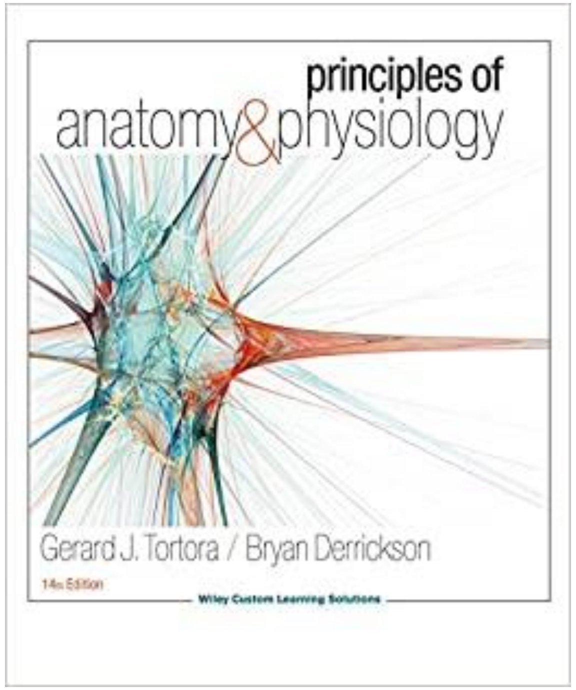
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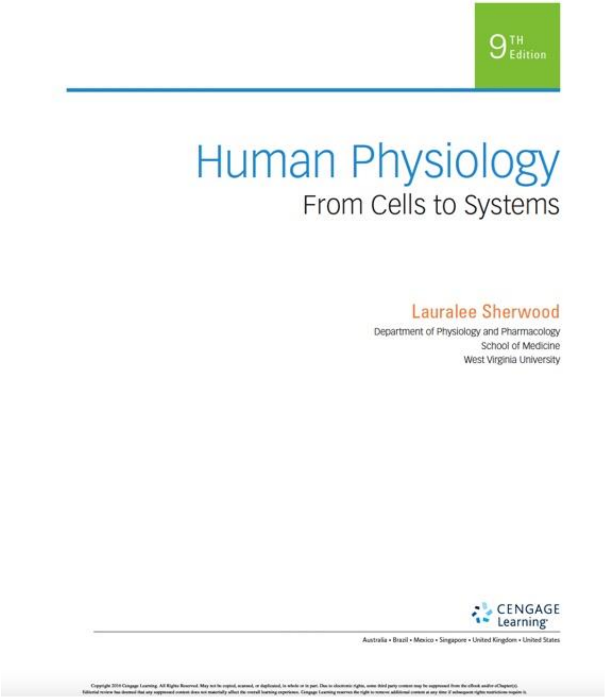
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