

Human Physiology PCB4701

Sensory Physiology
Fox Chapter 10 part 3
Vision

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Vision

Frequency of Light coming from Objects

Position of Objects in Visual Field

Shape of Objects

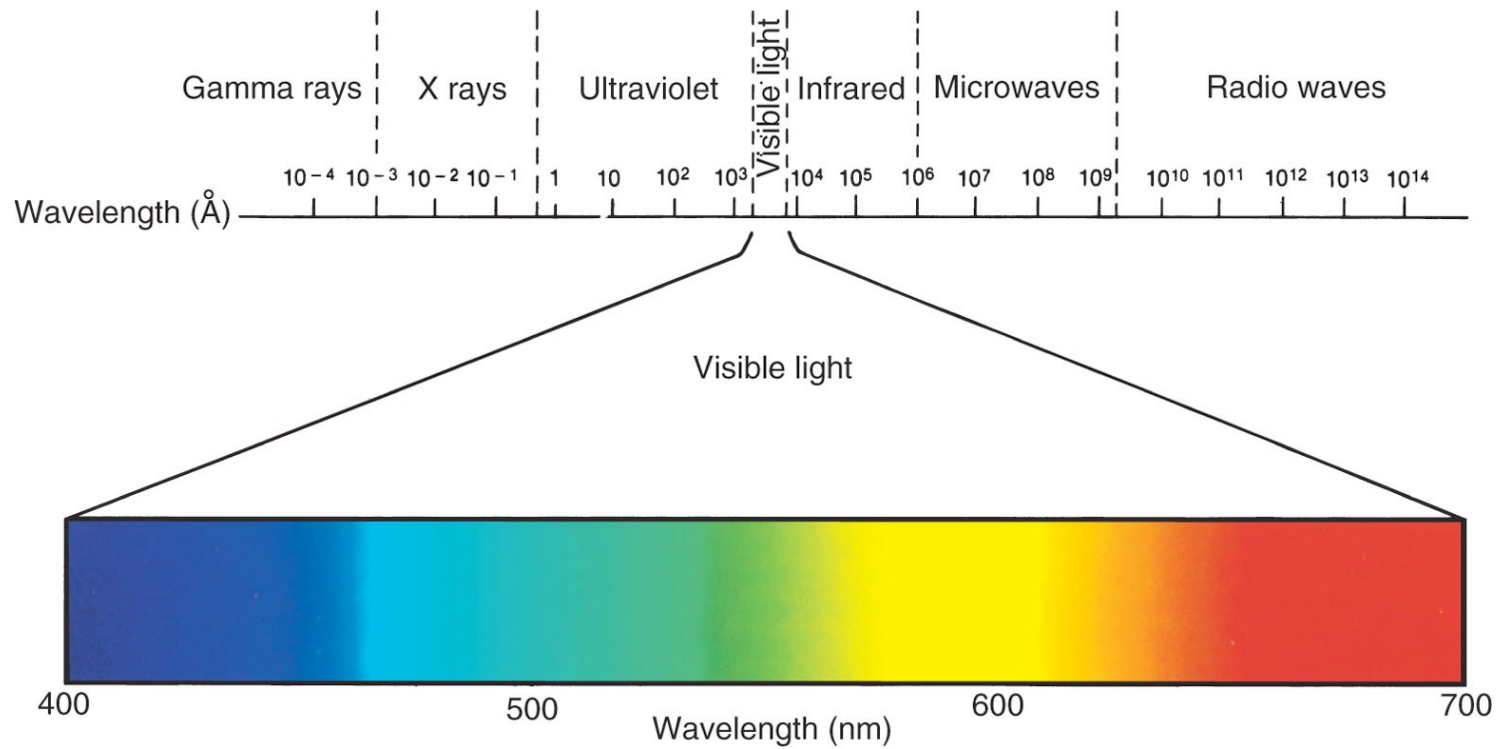


Figure 10.26

Anatomy of eye

Pupil & Lens

Recall constriction & dilation of pupil. Ciliary muscle contraction focuses lens on nearby objects.

Note: Lens inverts (flips) visual field projected onto retina.

Optic Disk (blind spot)

Point where Optic Nerve (cranial nerve 2) leaves eye and central artery & vein enter eye. Interrupts retina, so no photoreceptor cells

Retina

Layer of photoreceptor cells, neurons, and ganglion cells at back of eye.

Note: Photoreceptor cells are at back of retina, so light passes through neural layers to reach photoreceptors.

Fovea

Highest density of photoreceptors; center of visual field with highest acuity. In fovea, one photoreceptor transmits to one ganglion cell. In periphery, multiple photoreceptors transmit to one ganglion cell, so lower acuity.

Figure 10.27

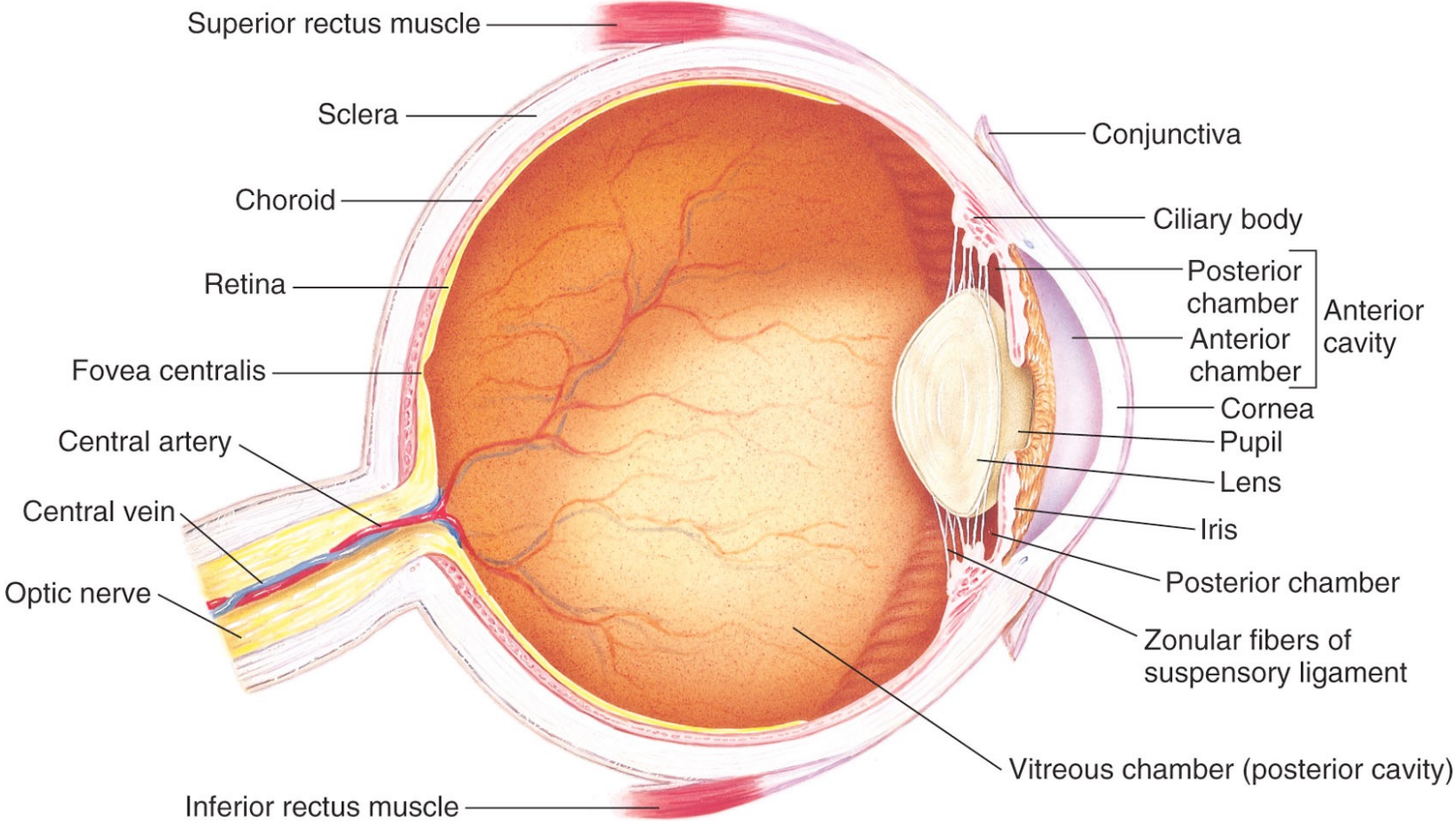
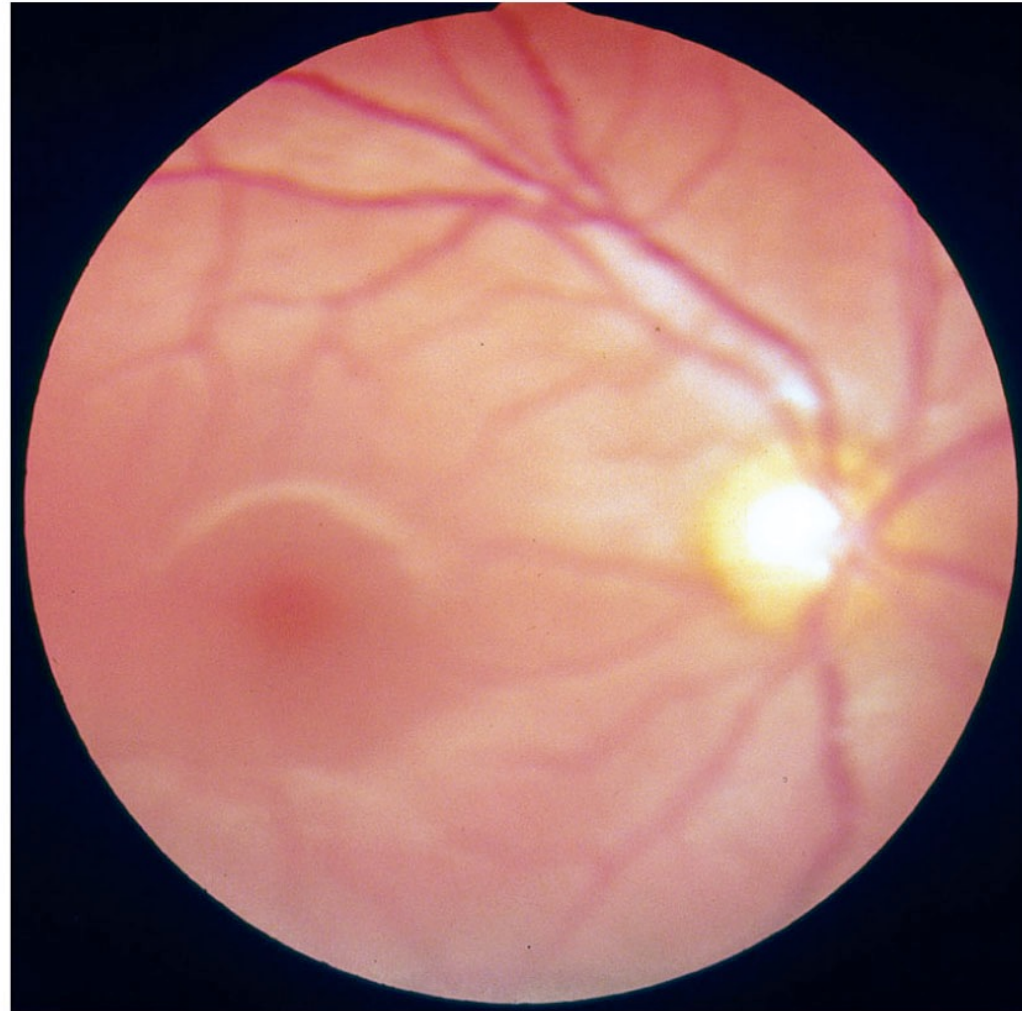


Figure 10.30a



(a)

Figure 10.30b

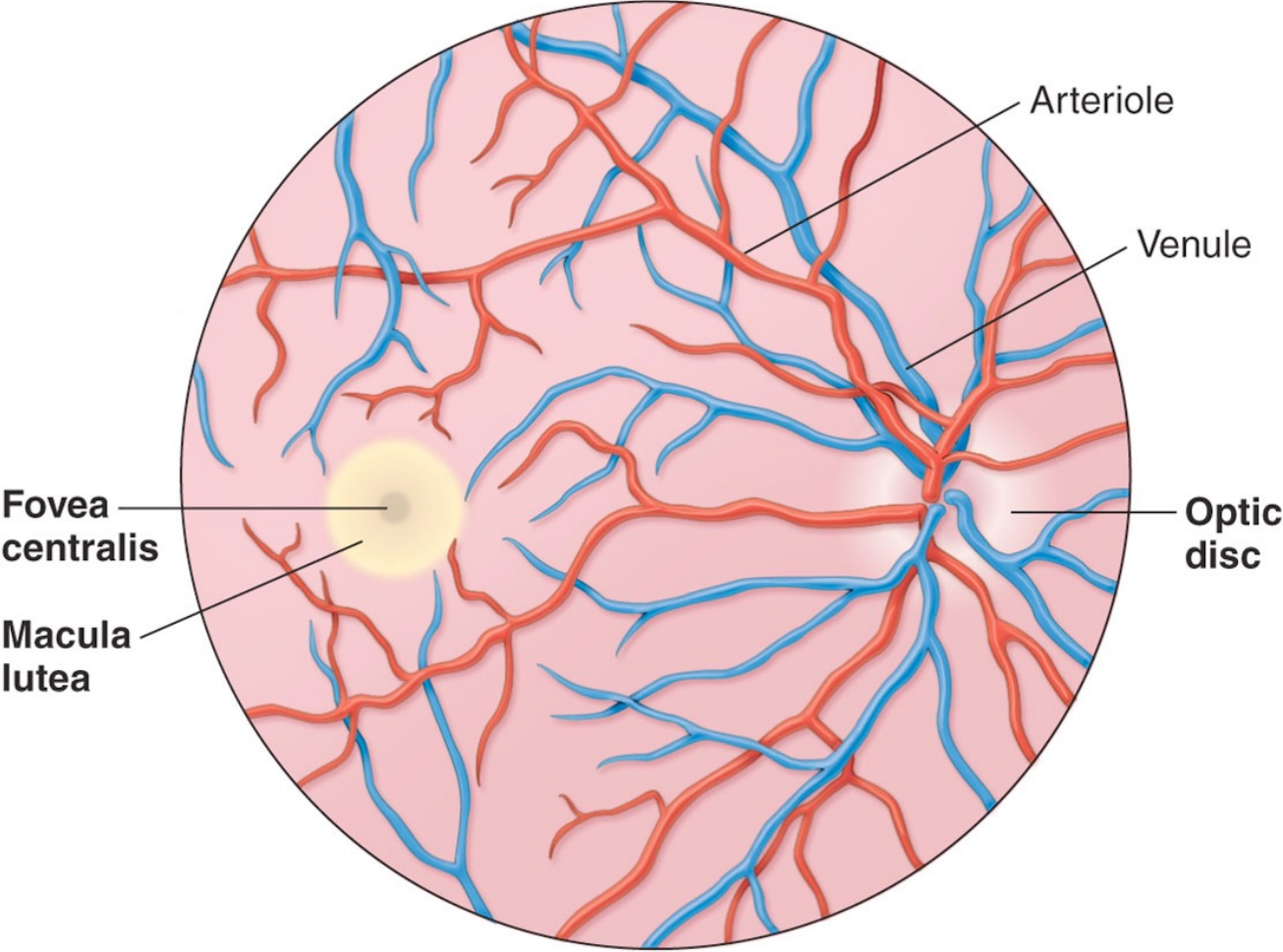
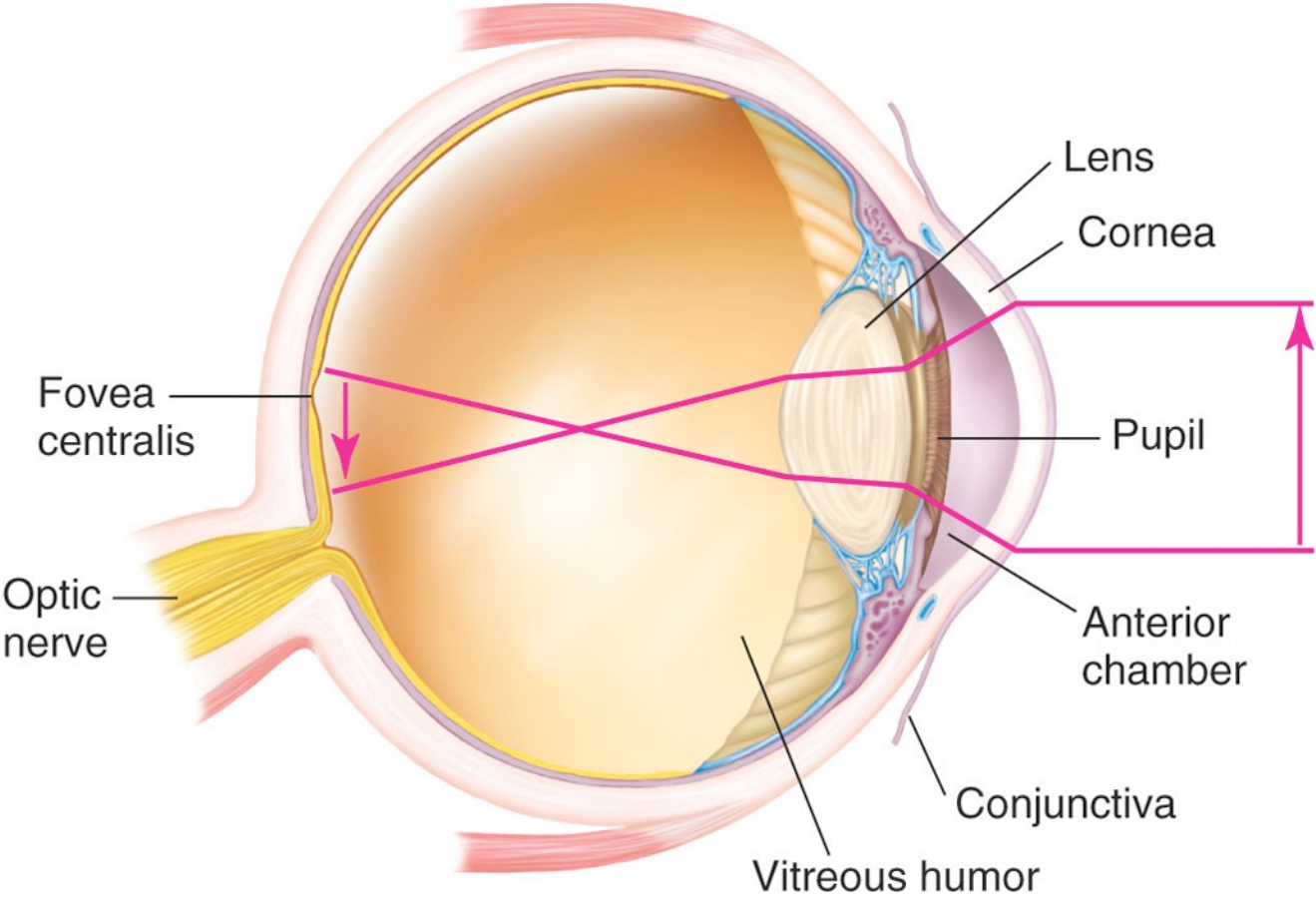
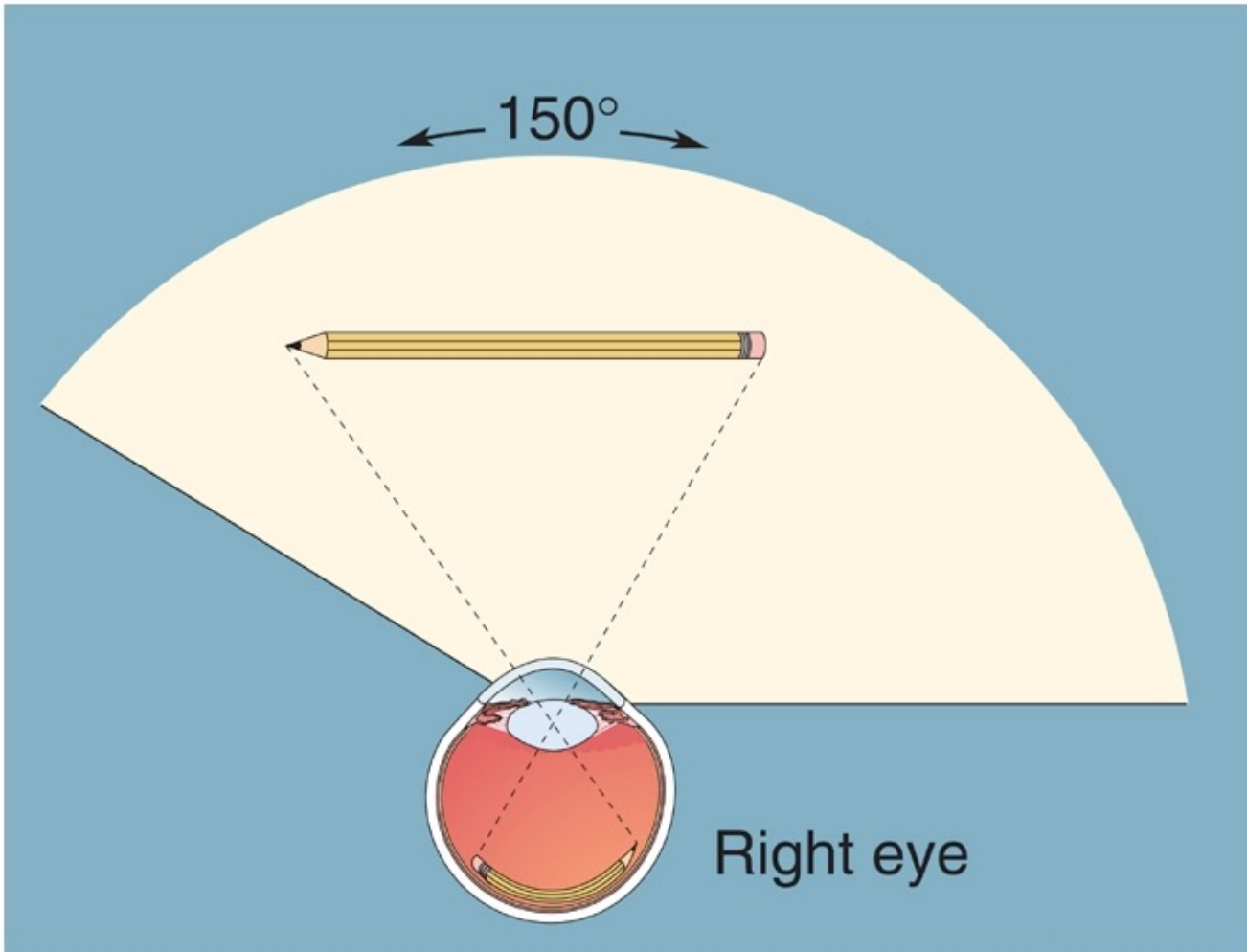


Figure 10.31





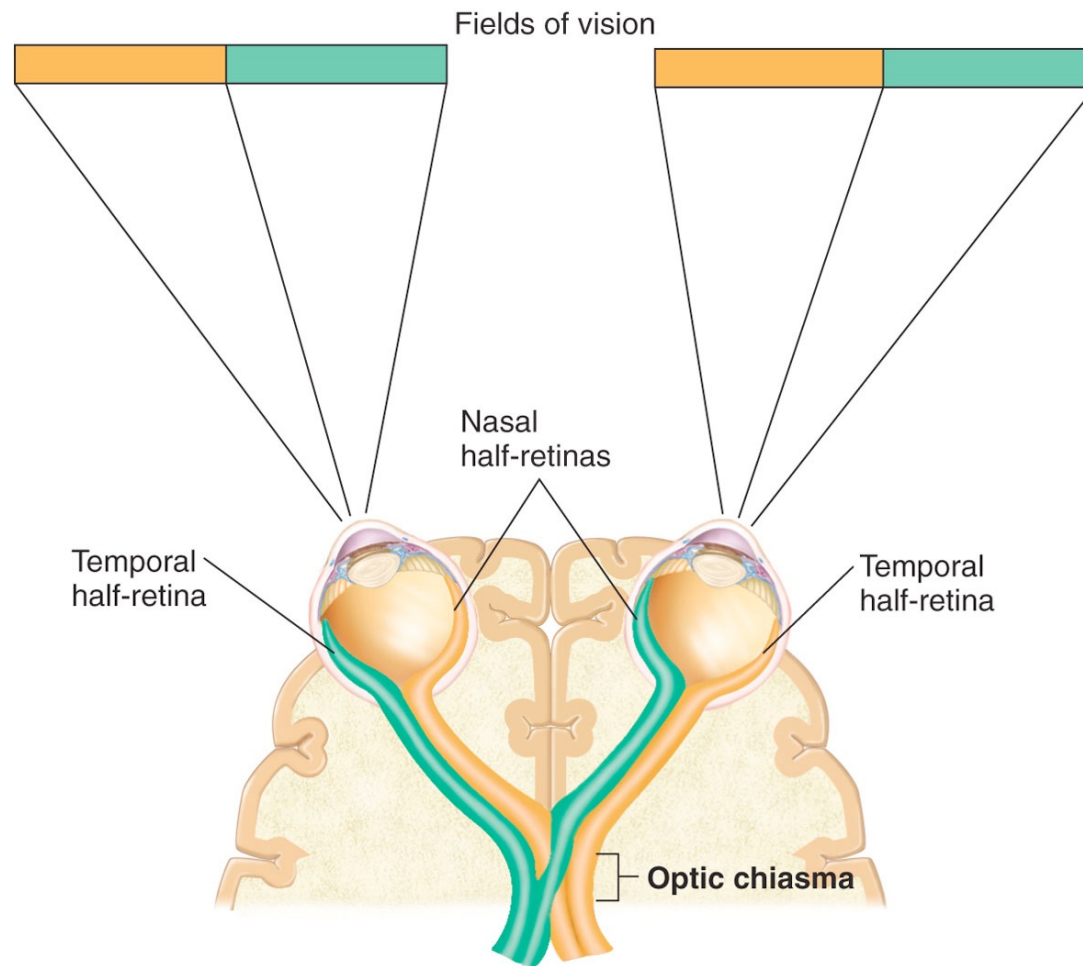


Figure 10.32

Anatomy of Retina

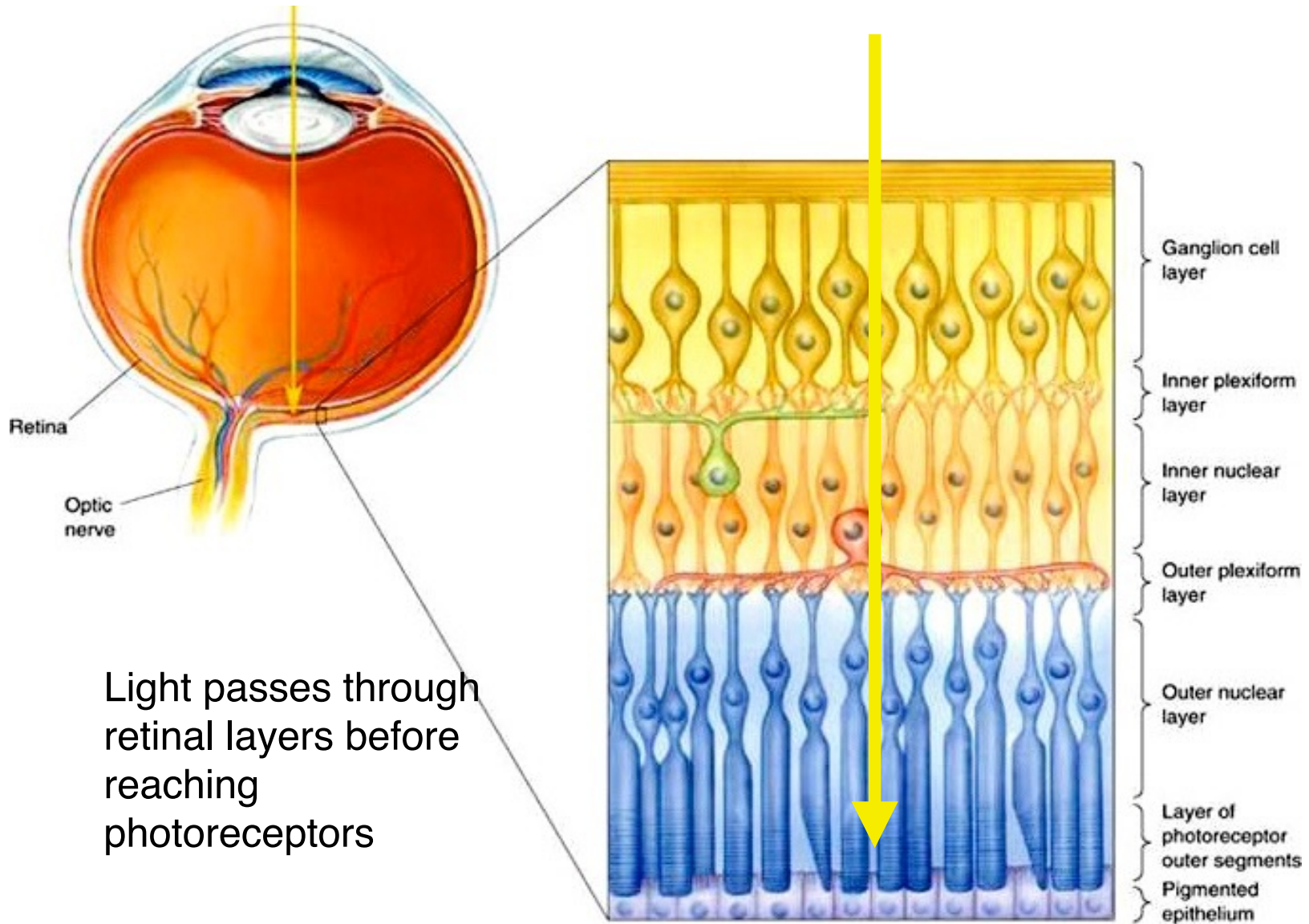
Layer of photoreceptor cells (rods and cones) at back of eye. Photoreceptor cells synapse onto bipolar cells (neurons).

Bipolar cells synapse onto ganglion cells (neurons).

Ganglion cells project to brain via optic nerve (cranial nerve 2).

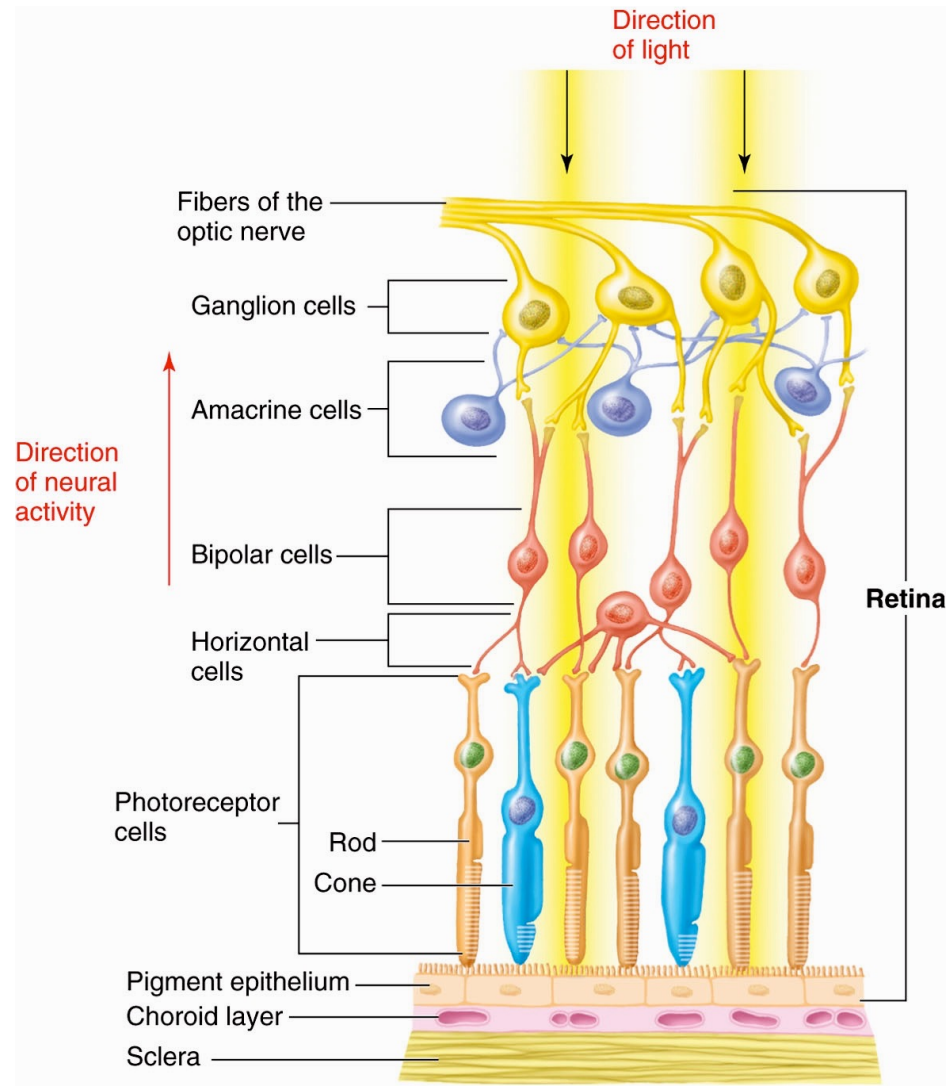
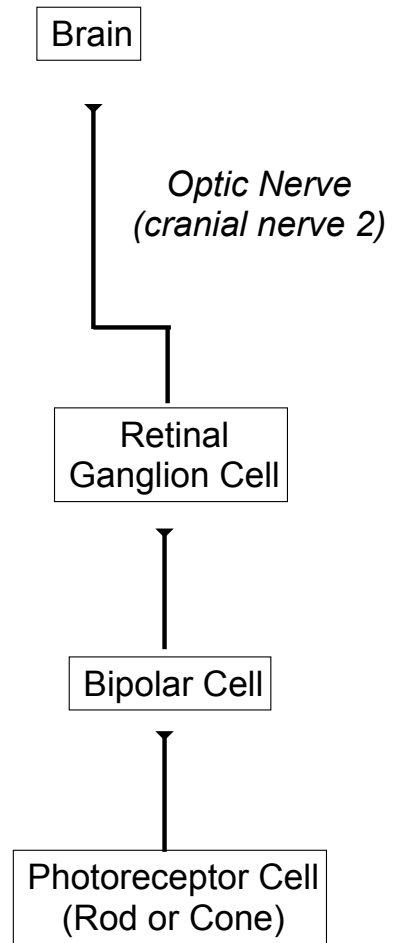
Fovea

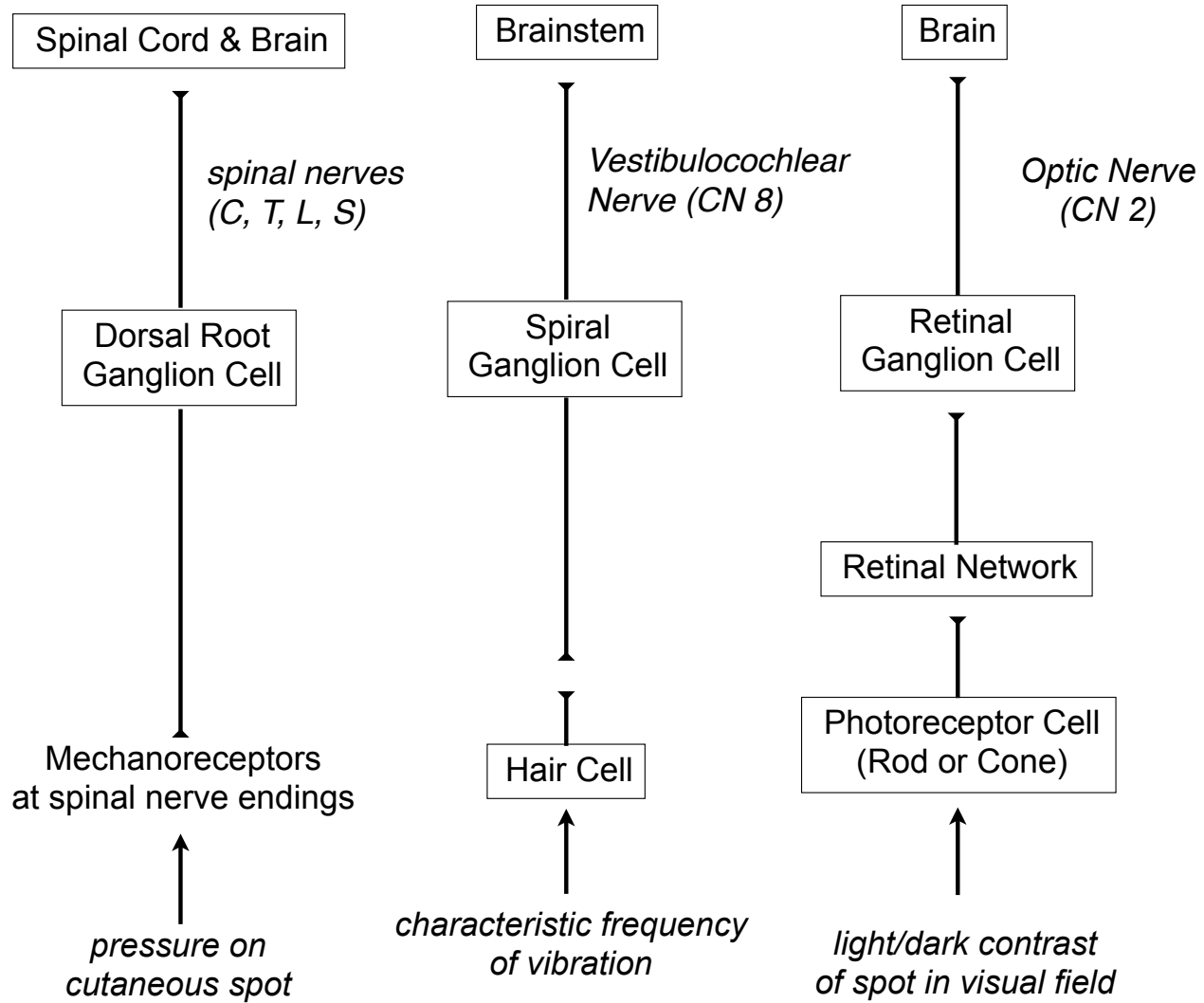
Highest density of photoreceptors; center of visual field with highest acuity. In fovea, one photoreceptor transmits to one ganglion cell. In periphery, multiple photoreceptors transmit to one ganglion cell, so lower acuity.



Light passes through retinal layers before reaching photoreceptors

Figure 10.36





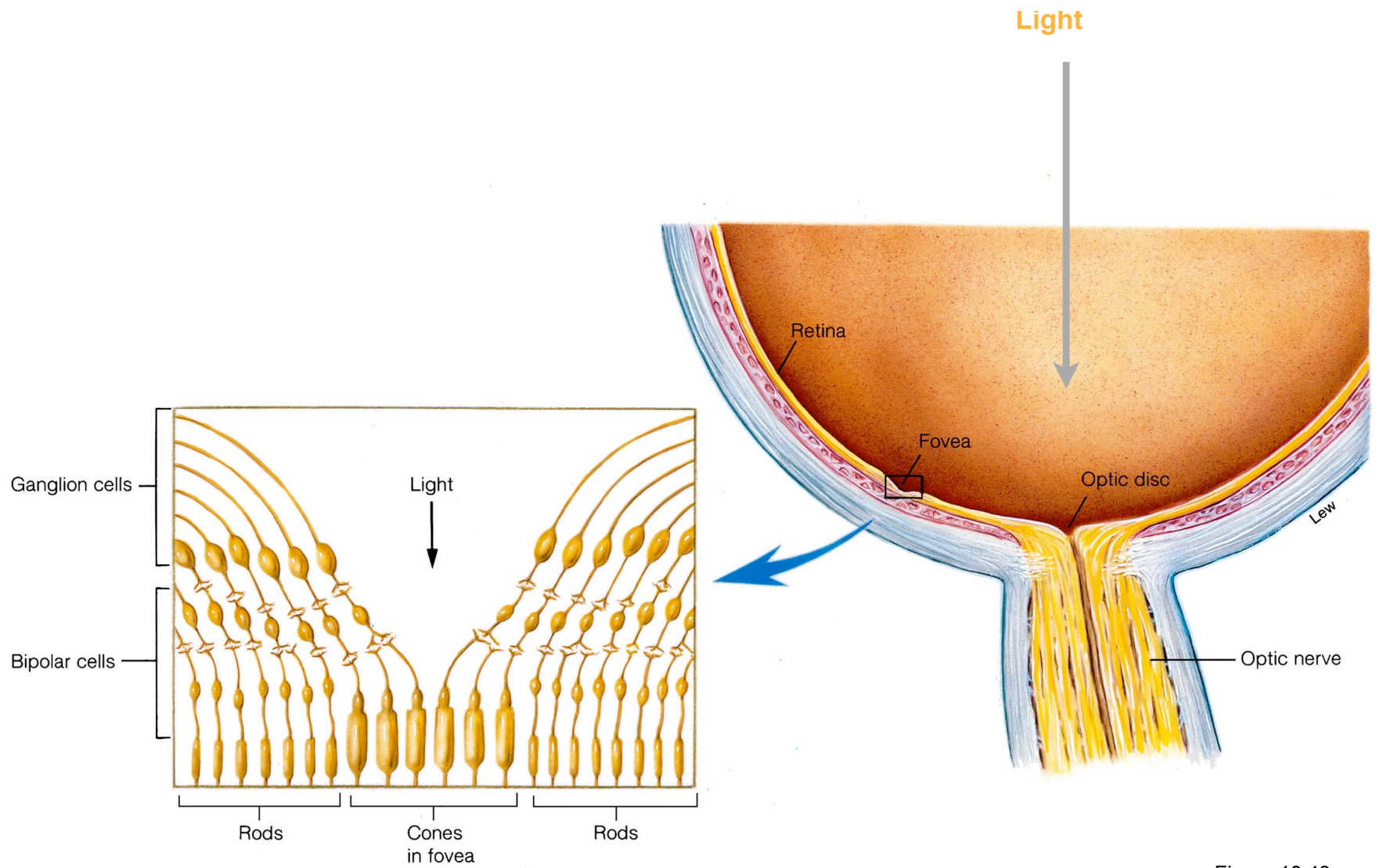
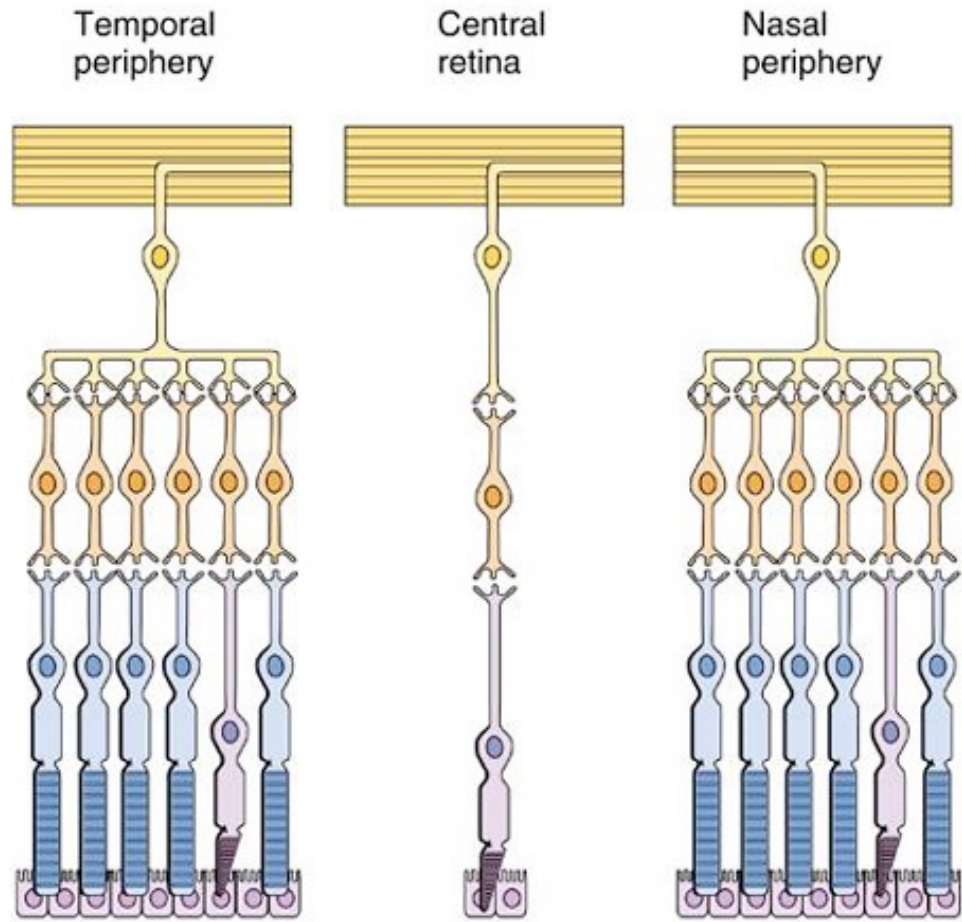
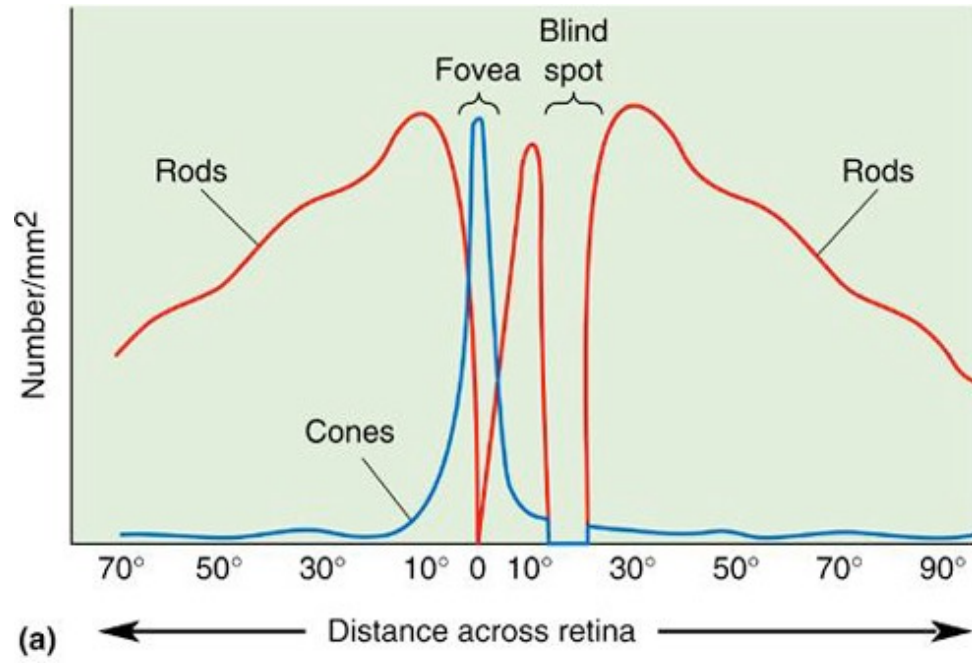


Figure 10.43



(b) Peripheral retina Central retina Peripheral retina

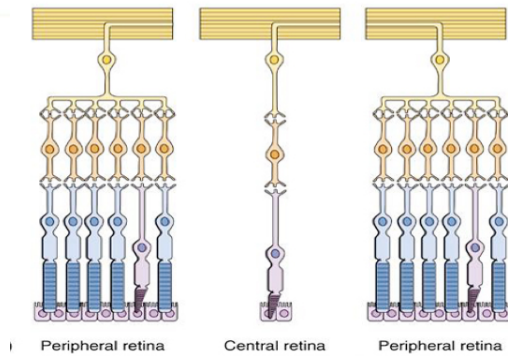
note different receptive field sizes



Temporal periphery

Central retina

Nasal periphery



Photoreceptor Cells

Rods

contain light-sensitive photopigment protein **rhodopsin**; grayscale, low-light level, night vision, peripheral vision

Cones

contain photopigment **photopsins**:

either **S (short blue)**, **M (medium green)** or **L (long red)**

High-light level, high density in fovea, so detail vision.

L & M pigment genes are next to each other on X chromosome; loss of M or L gene leads to X-linked red-green color blindness

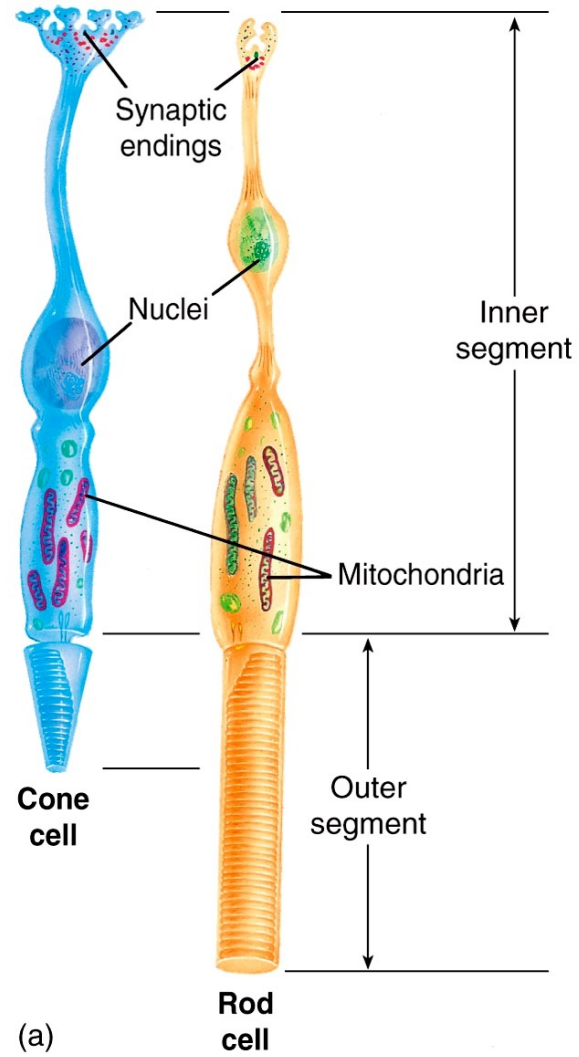
Outer Segment & Discs

Extension of cell body that contains phospholipid bilayer discs. Photopigments float in membrane of discs. (discs increase surface area that can intercept photons of light).

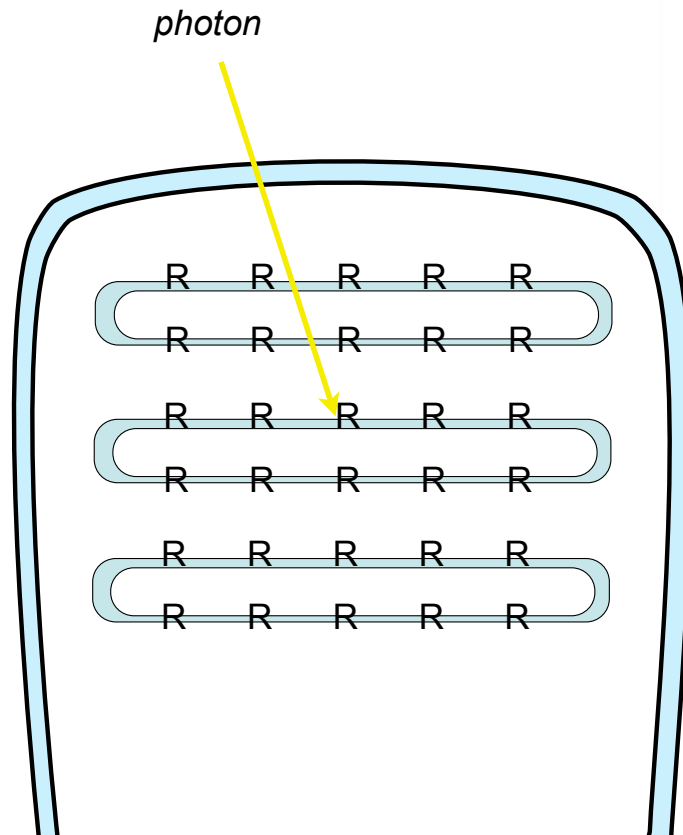
Synaptic endings on opposite end of cell body.

*Small number of ganglion cells are also photosensitive; contain **melanopsin** to detect general luminance for pupillary reflex & entrain circadian rhythms*

Figure 10.37a



Membranous Discs in
Rod Outer Segment



R = rhodopsin



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Figure 10.38

Rhodopsin is G-protein coupled receptor

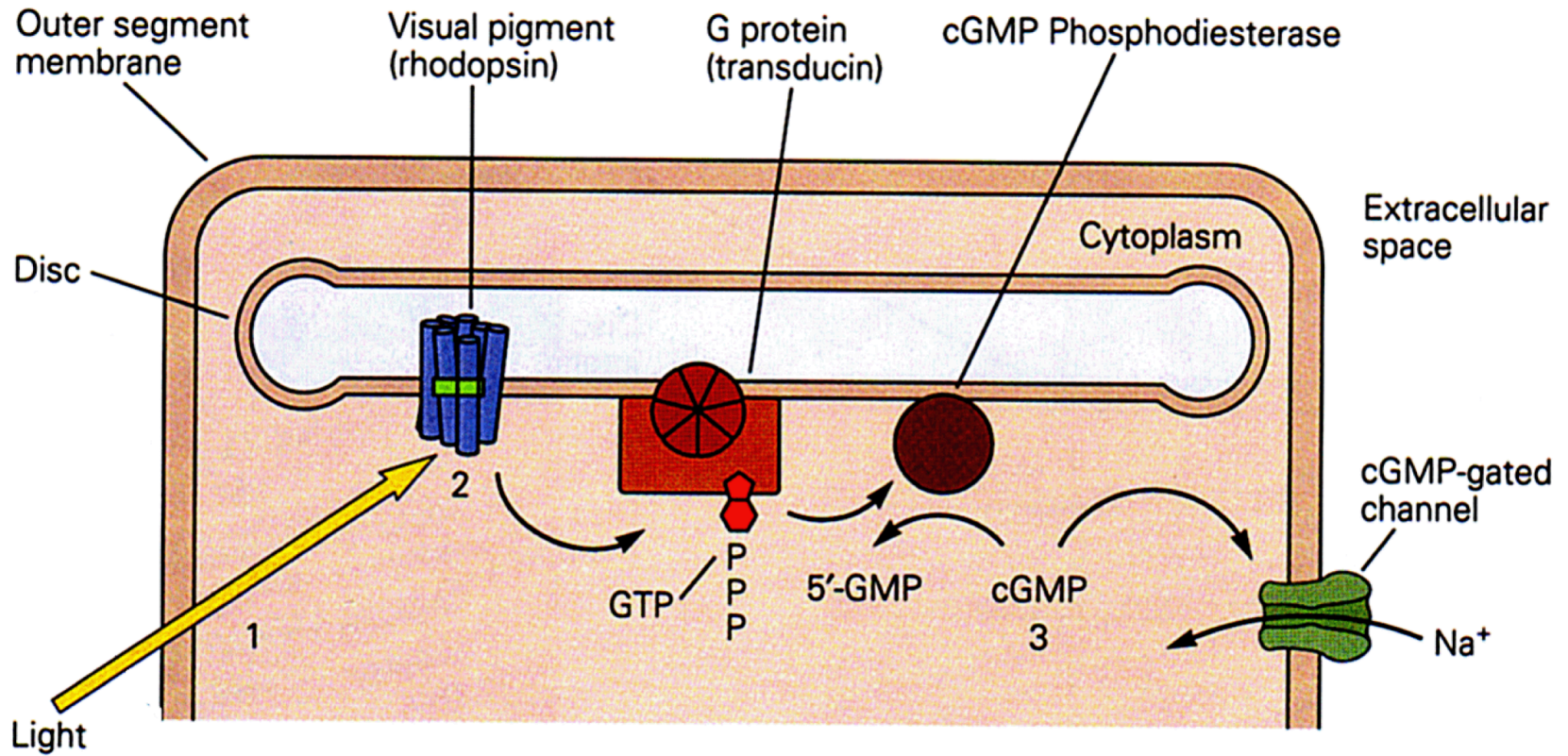
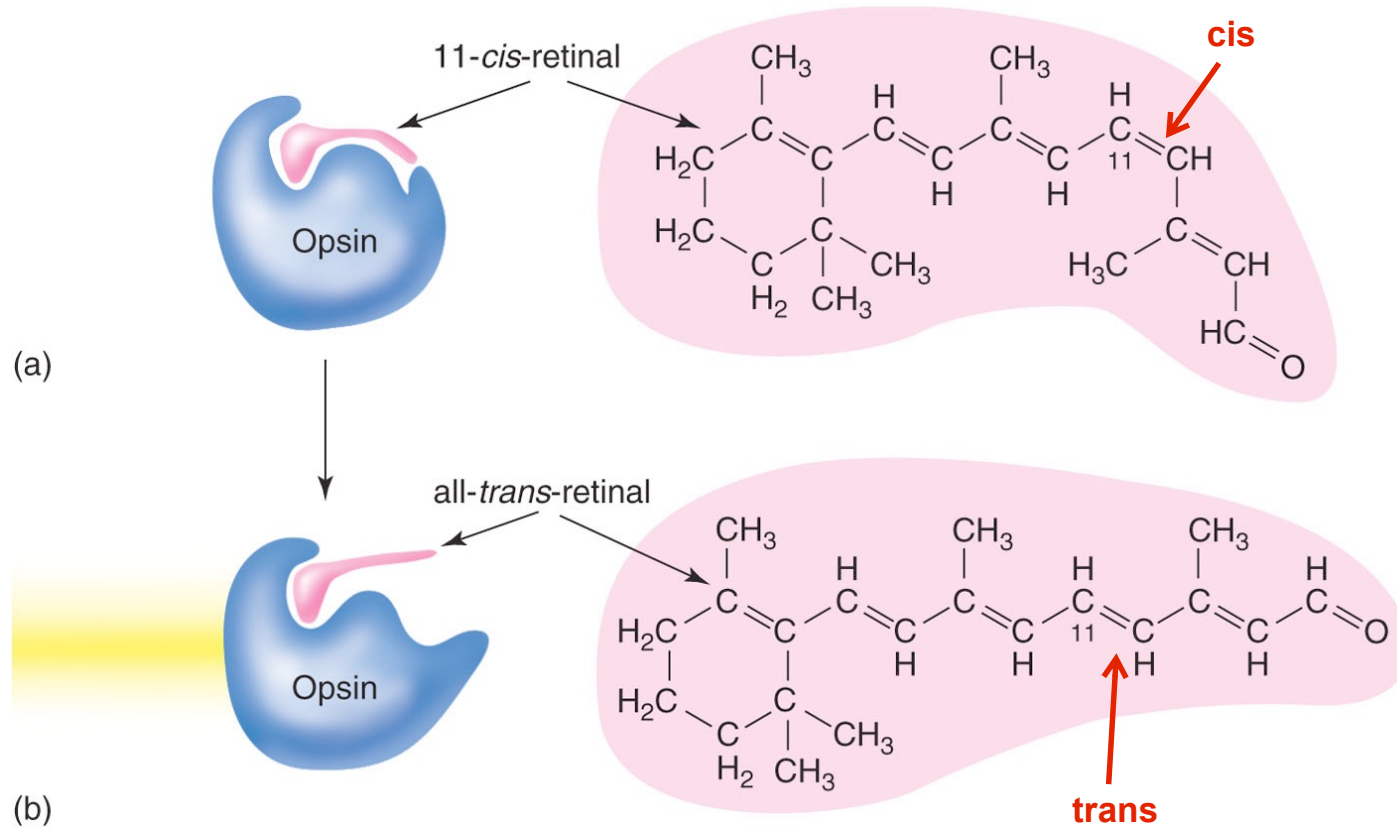


Figure 10.39



In the dark, cGMP-gated Na^+ channels are OPEN, so rod is depolarized (V_m more positive).

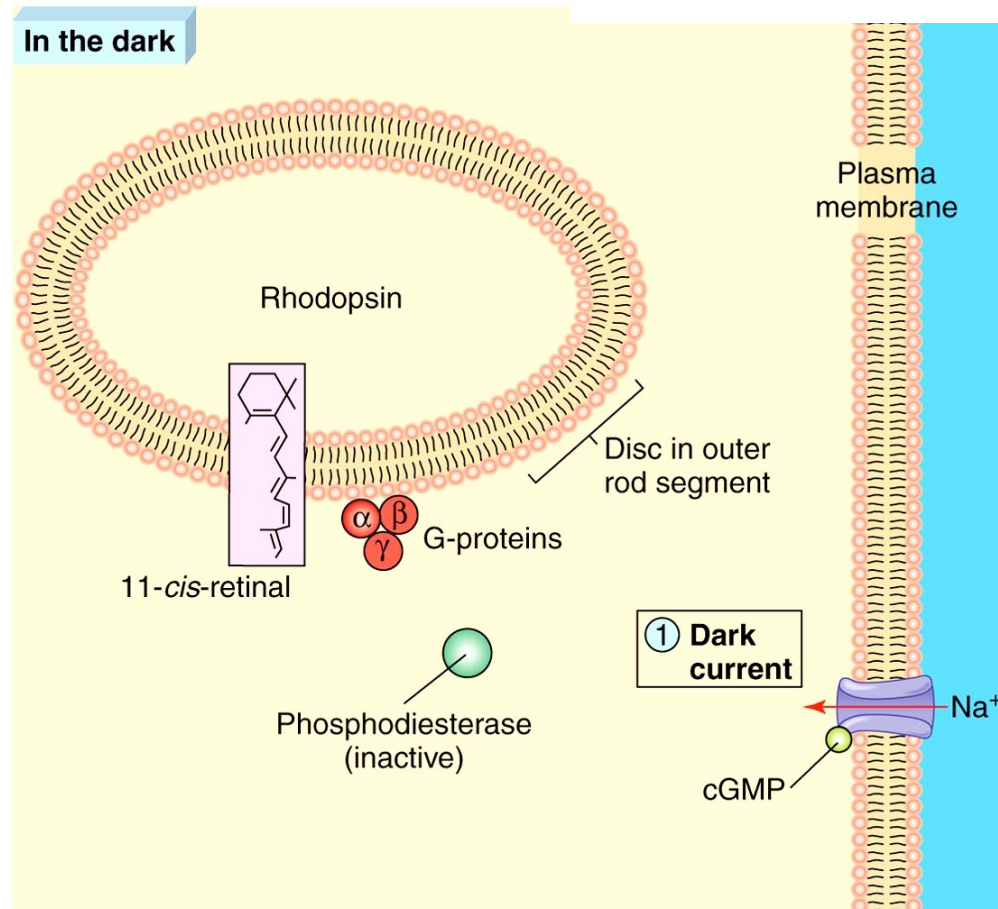


Figure 10.40

In the light, activated rhodopsin causes drop in cGMP, so cGMP-gated Na^+ channels CLOSE, so rod is hyperpolarized (V_m more negative).

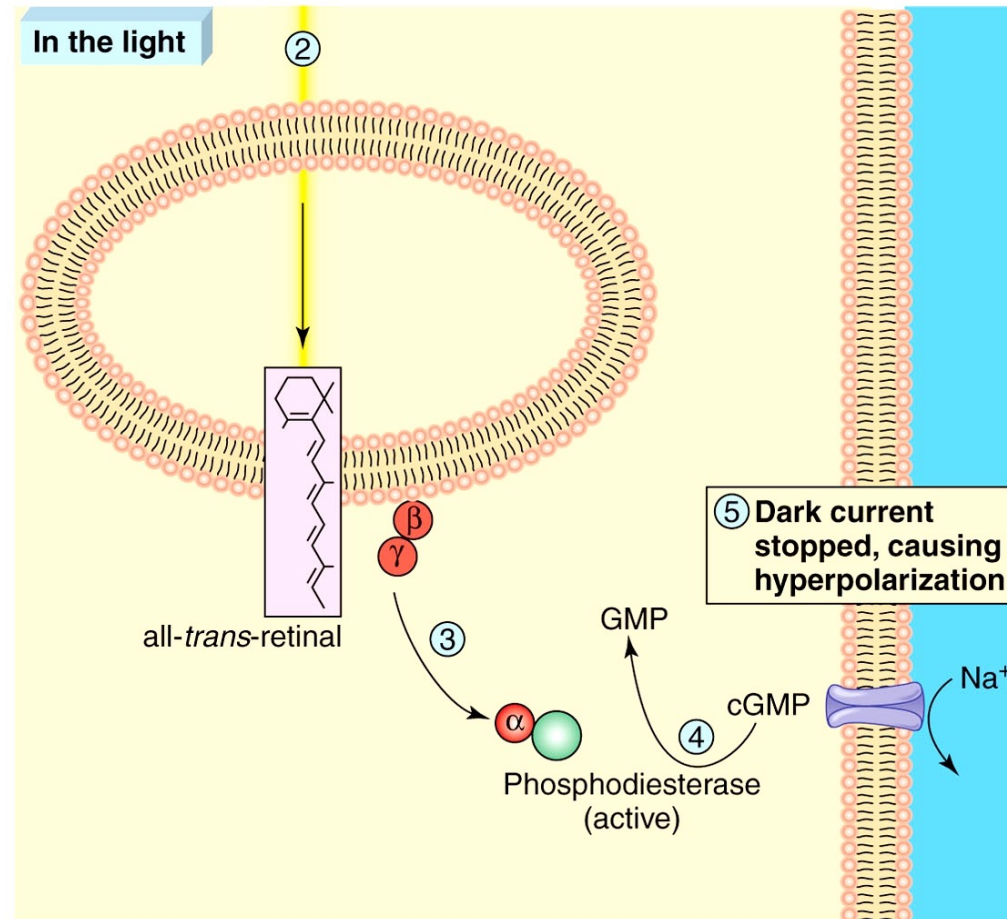
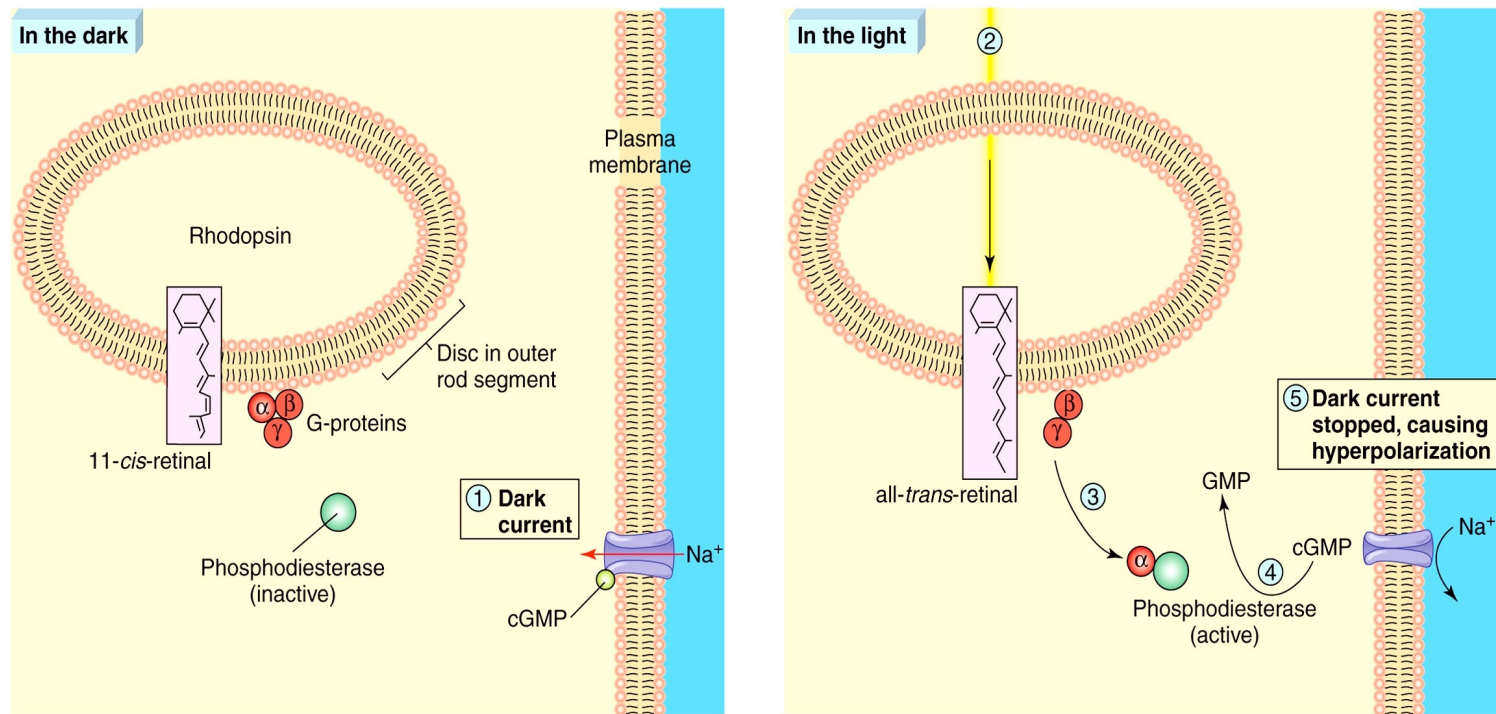


Figure 10.40

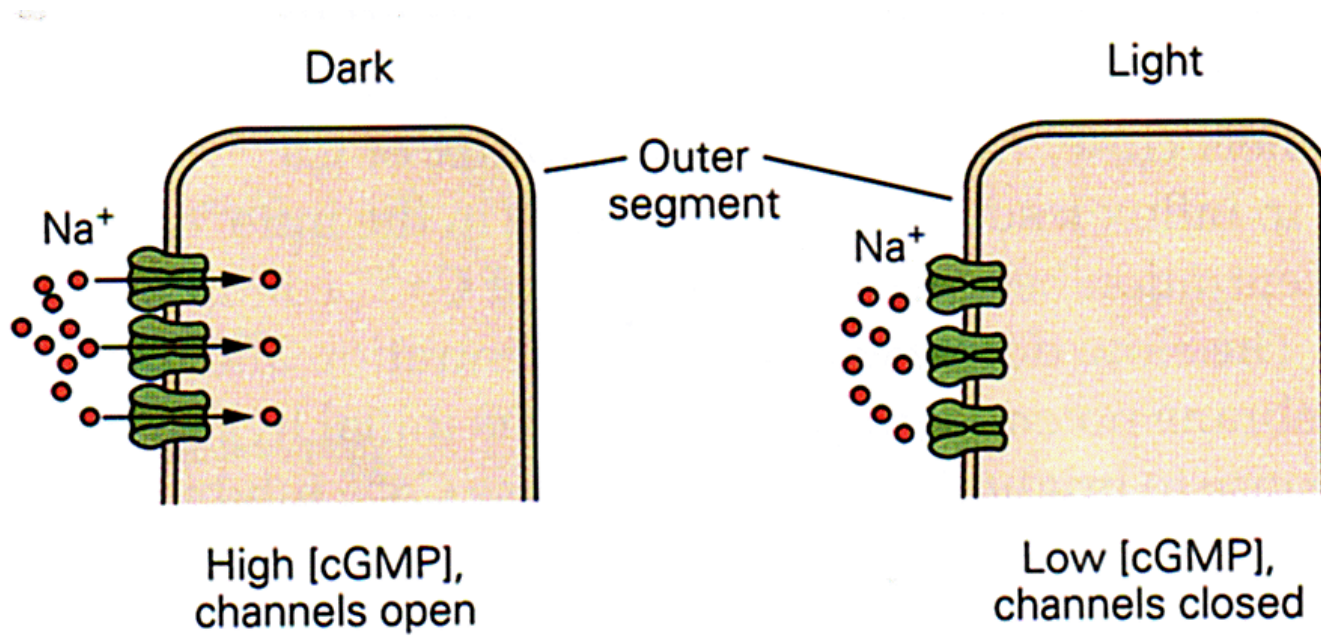
Figure 10.40

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In the light, activated rhodopsin causes drop in cGMP, so cGMP-gated Na^+ channels CLOSE, so rod is hyperpolarized (V_m more negative).

Dark -> high cGMP -> Na⁺ channels close

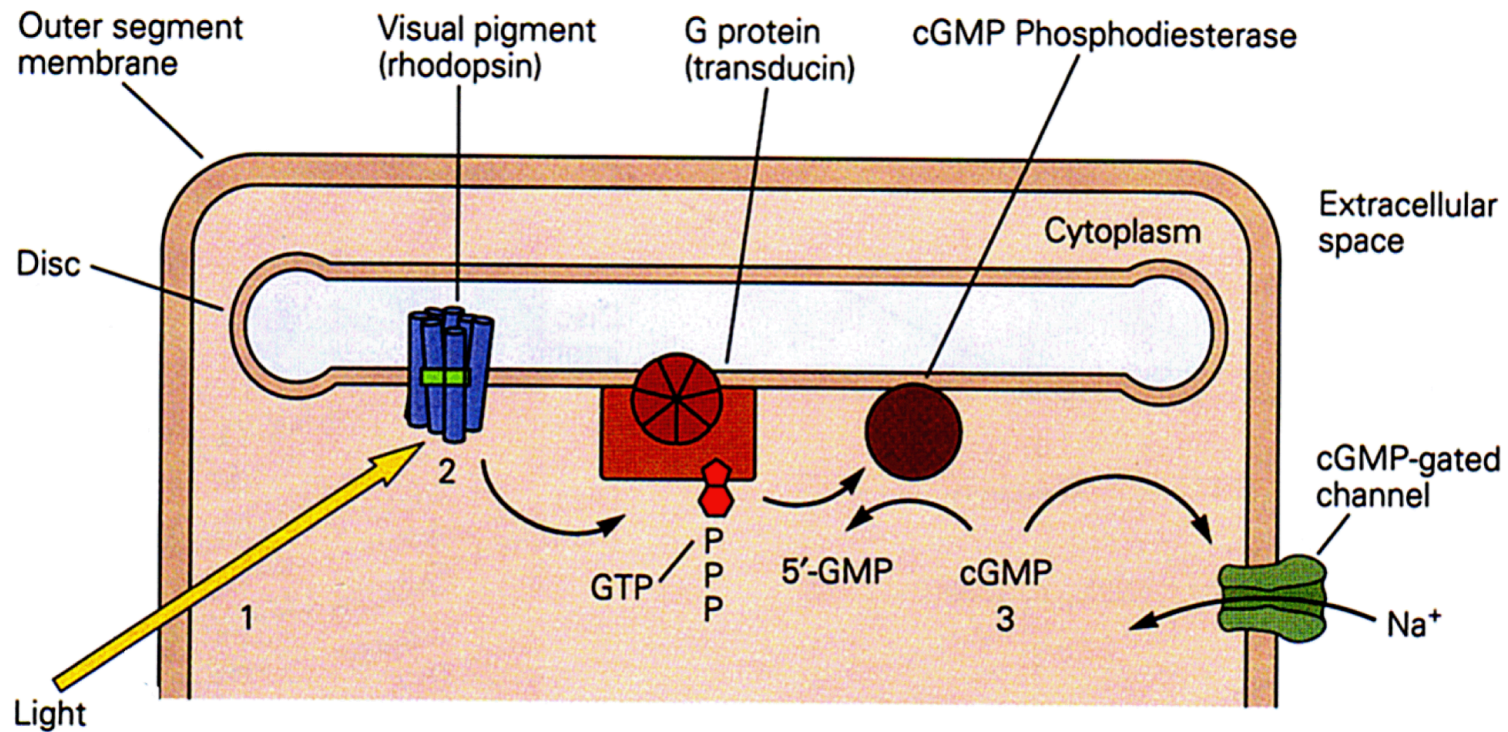


Light -> low cGMP -> Na⁺ channels close

Summary of Dark Current & Activation of Rhodopsin

1. Rod Photoreceptors have **cGMP-gated Na⁺ channels** on their plasma membrane.
2. In the dark, cGMP levels are high, so Na⁺ channels are open.
3. In-rush of Na⁺ depolarizes photoreceptor cell, so it releases **more** neurotransmitter in the dark.
4. Light activates **rhodopsin** in the disk membranes by altering configuration of **retinal** (vitamin A).
5. Rhodopsin is a **G-protein coupled receptor** (activated by light, not a ligand). Activated G-proteins activate a **phosphodiesterase** that breaks down cGMP.
6. So in light, cGMP levels fall. cGMP-gated Na⁺ channels close.
7. Photoreceptor cell becomes hyperpolarized, so it releases **less** neurotransmitter in the light.

Rhodopsin is G-protein coupled receptor

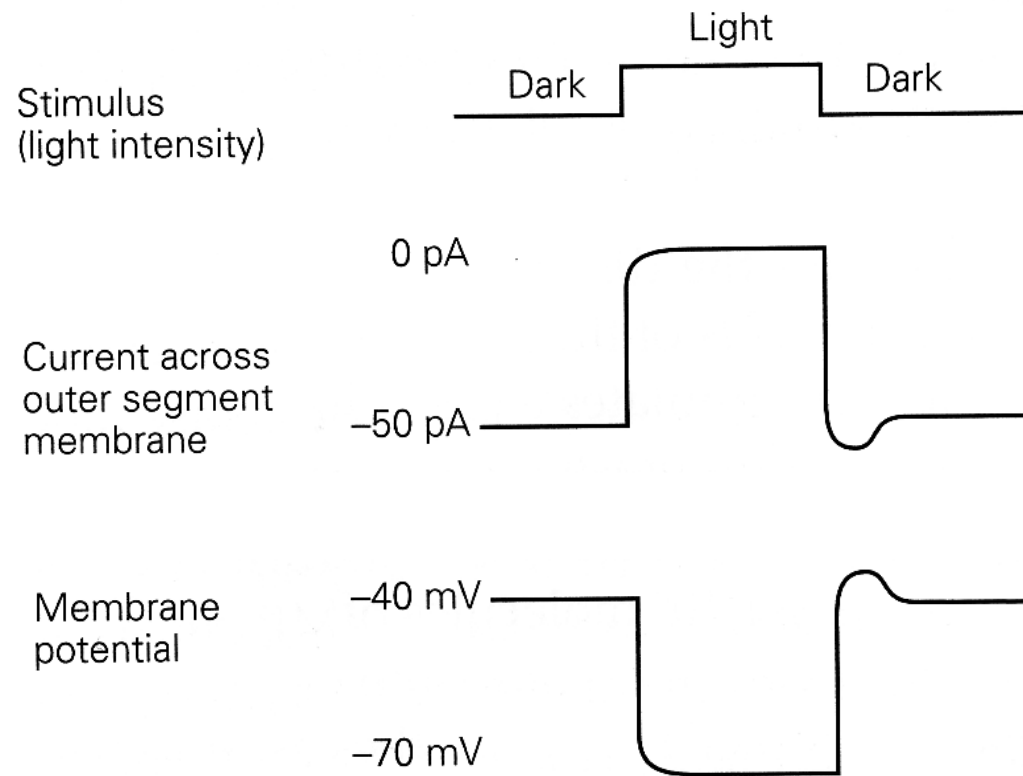


1 rhodopsin -> 100s of G-proteins -> 100s of phosphodiesterase
-> closing of 1,000 Na⁺ channels/second.

so 1 photon -> blocks 1,000,000 Na⁺ ions from entering cell

Light -> Hyperpolarization

-> less transmitter release by rod photoreceptor



Photoreceptor Cells

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contain light-sensitive photopigment protein **rhodopsin**; grayscale, low-light level, night vision, peripheral vision

Cones

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High-light level, high density in fovea, so detail vision.

L & M pigment genes are next to each other on X chromosome; loss of M or L gene leads to X-linked red-green color blindness

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Extension of cell body that contains phospholipid bilayer discs. Photopigments float in membrane of discs. (discs increase surface area that can intercept photons of light).

Synaptic endings on opposite end of cell body.

*Small number of ganglion cells are also photosensitive; contain **melanopsin** to detect general luminance for pupillary reflex & entrain circadian rhythms*

Figure 10.37a

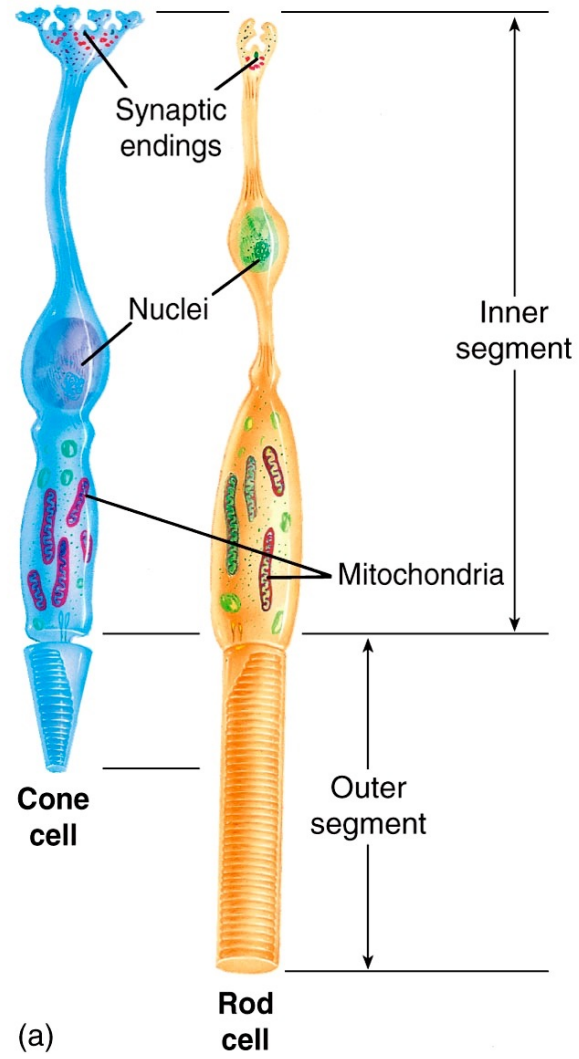
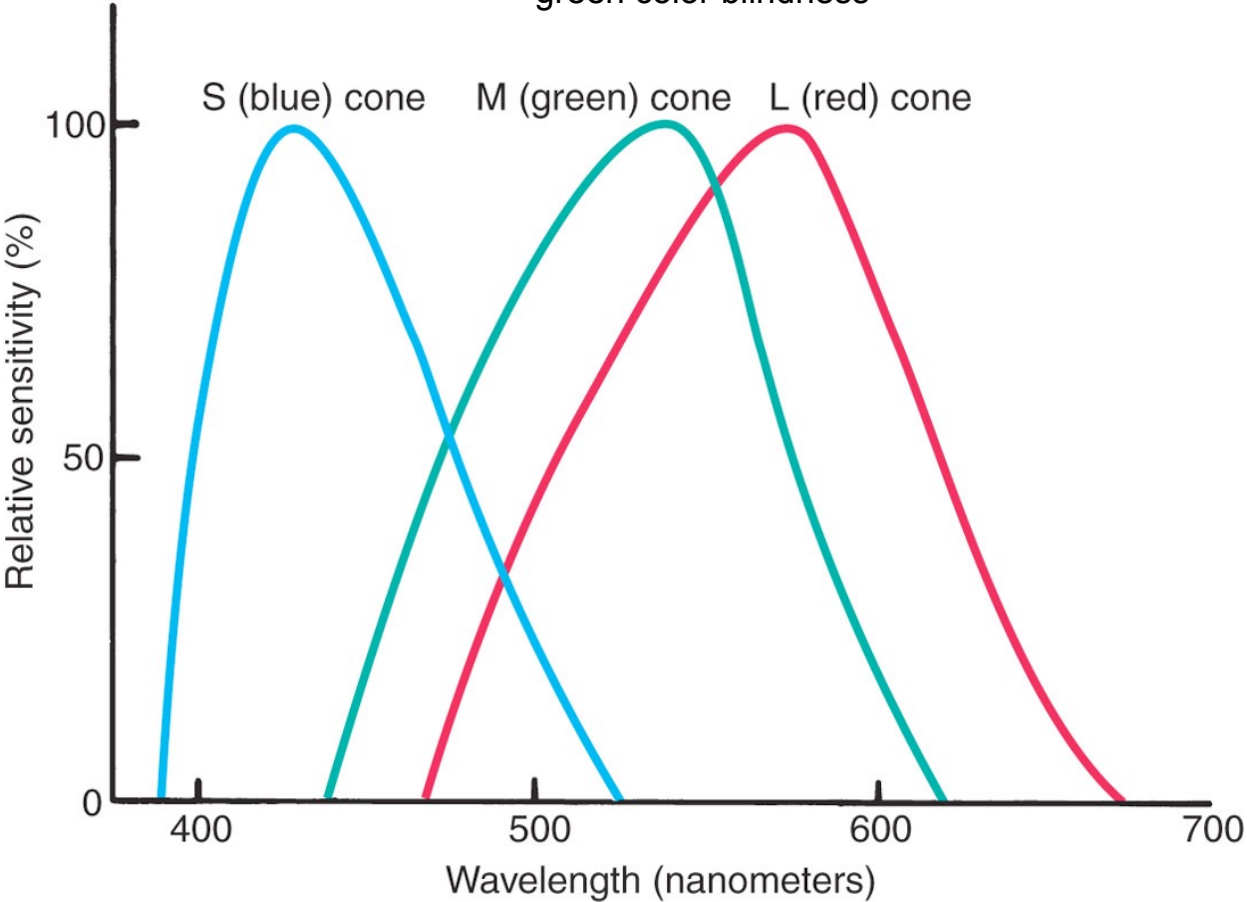


Figure 10.42

L & M pigment genes are next to each other on X chromosome; loss of M or L leads to X-linked red-green color blindness



tophat

Receptive Fields of Retinal Ganglion Cells

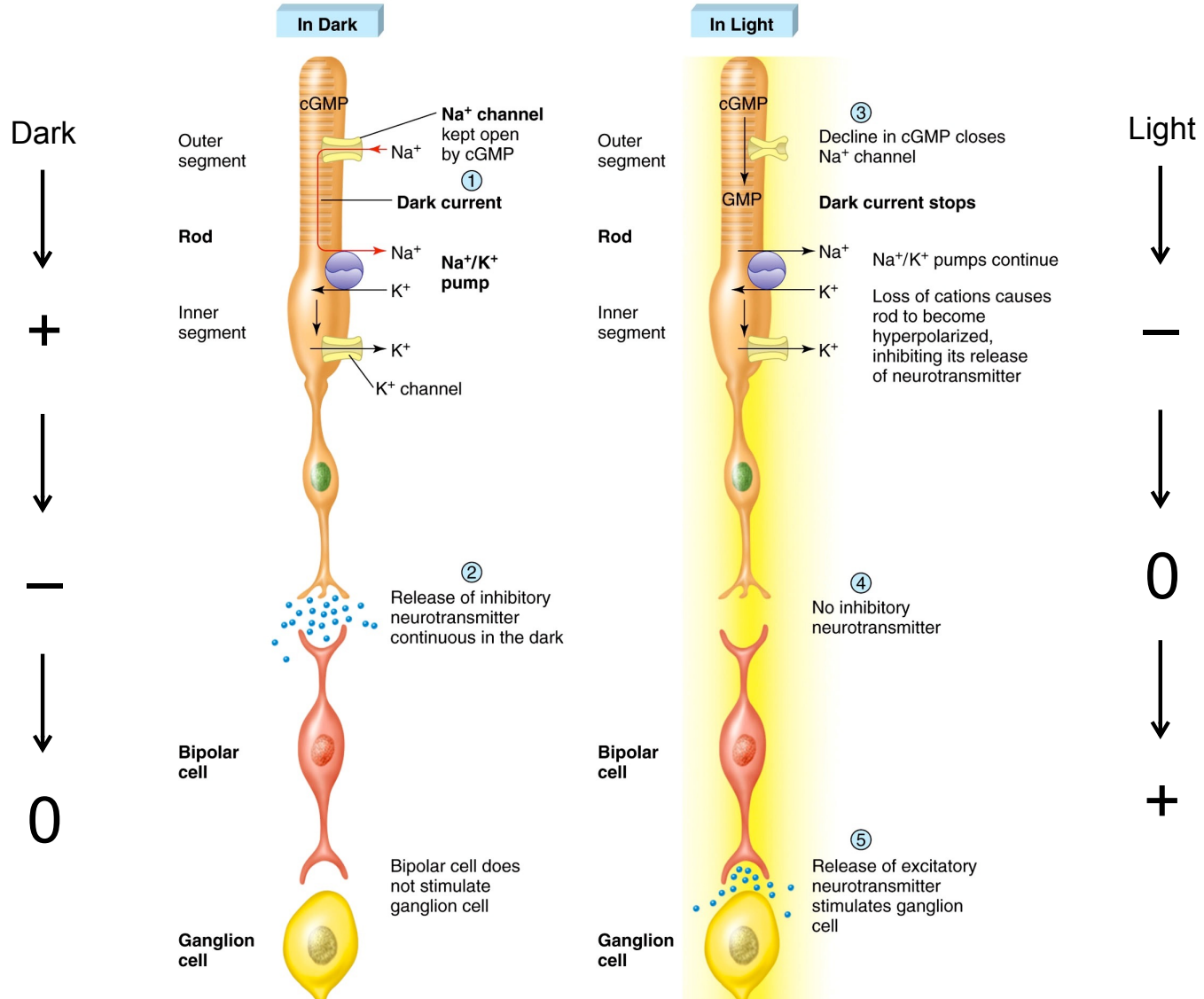
Photoreceptor cells are coupled to ganglion cells via **bipolar cells**. Input from bipolar cells is modulated by **horizontal cells**.

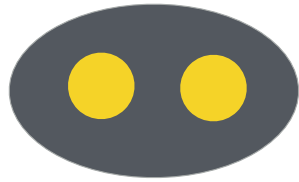
Receptive field of ganglion cell is based on:

1. **Spatial Location**: A specific spot in the visual field as it is projected onto the retina at the back of the eye.
2. **Contrast**: ganglion cells are either **on-center** or **off-center** cells: they respond to either light surrounded by dark, or dark surrounded by light. This allows ganglion cells to respond well to **high contrast edges** in the visual field.

Ganglion cells activity is influenced by multiple photoreceptors and bipolar cells, which contribute to ganglion receptive field.

Figure 10.41

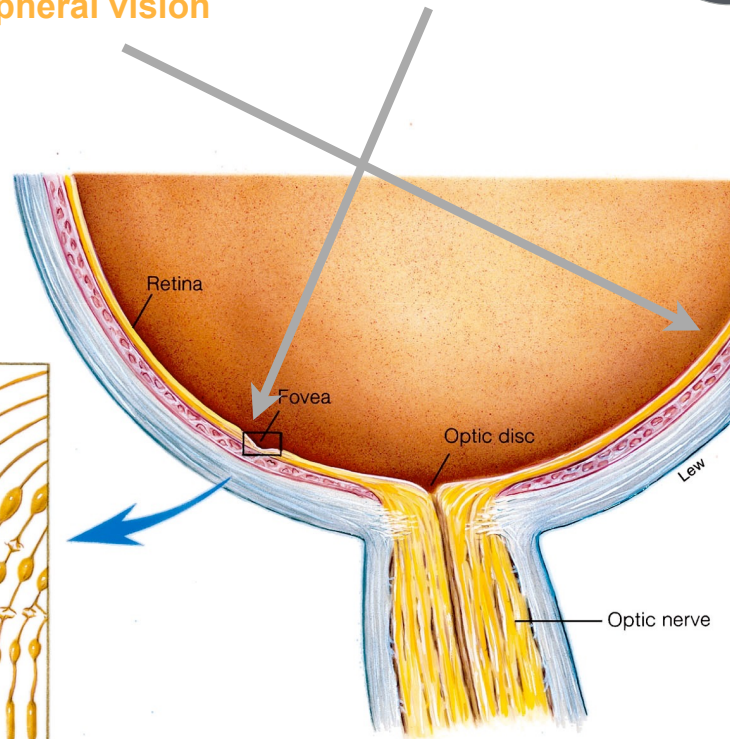
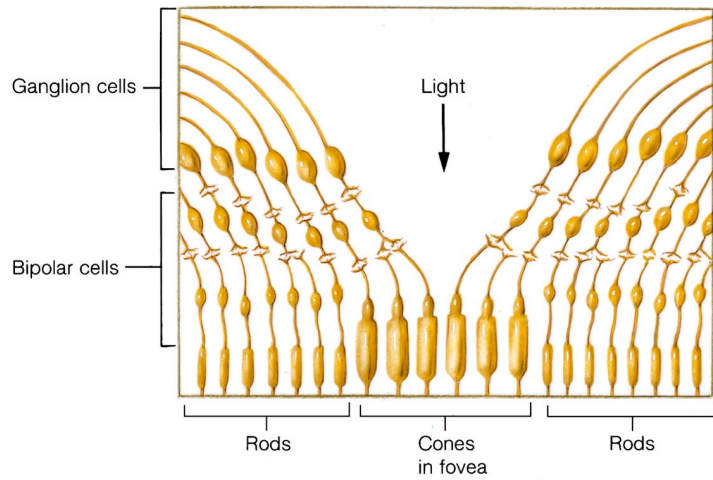




Light from peripheral vision



Light from center



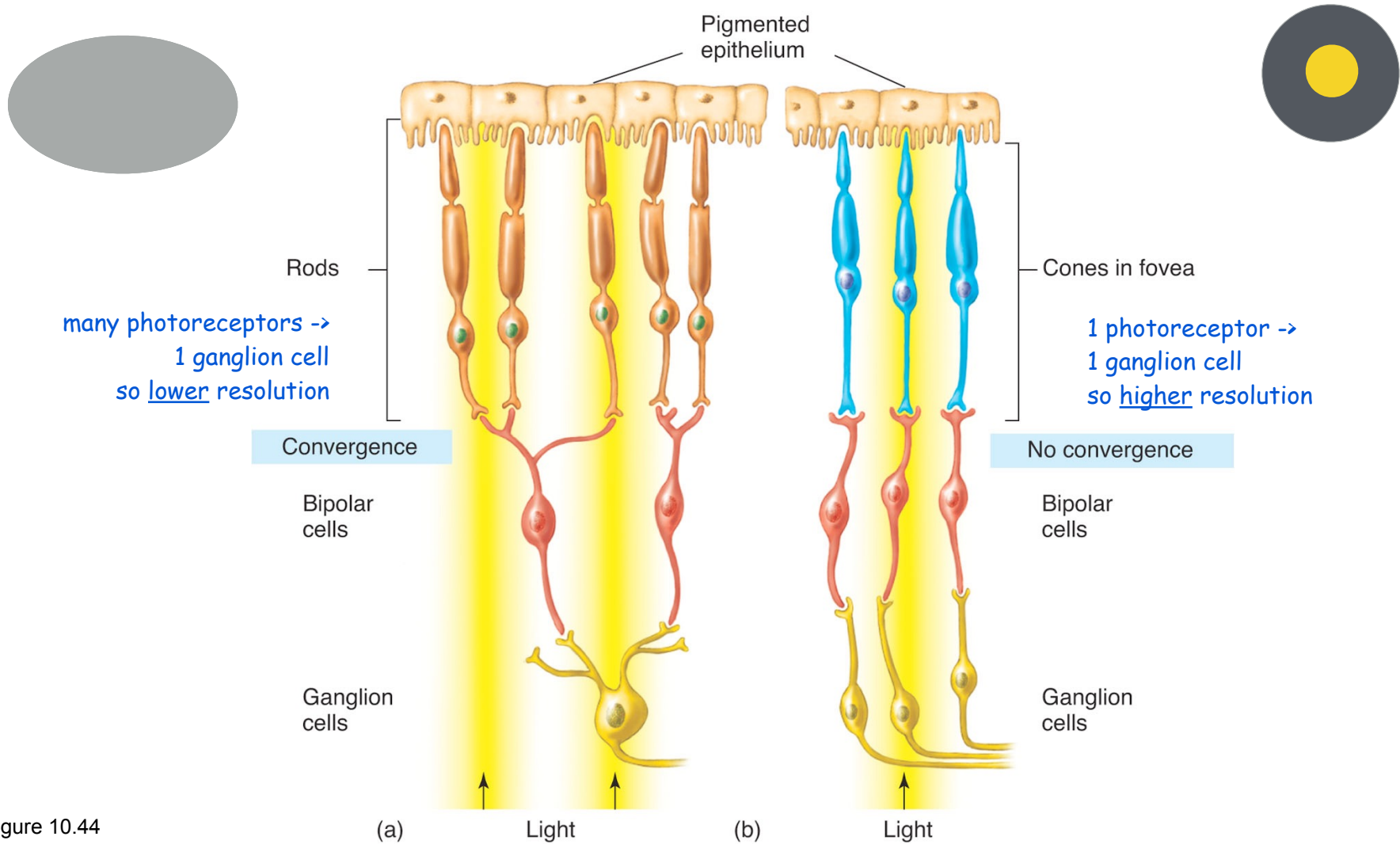
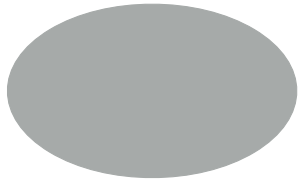
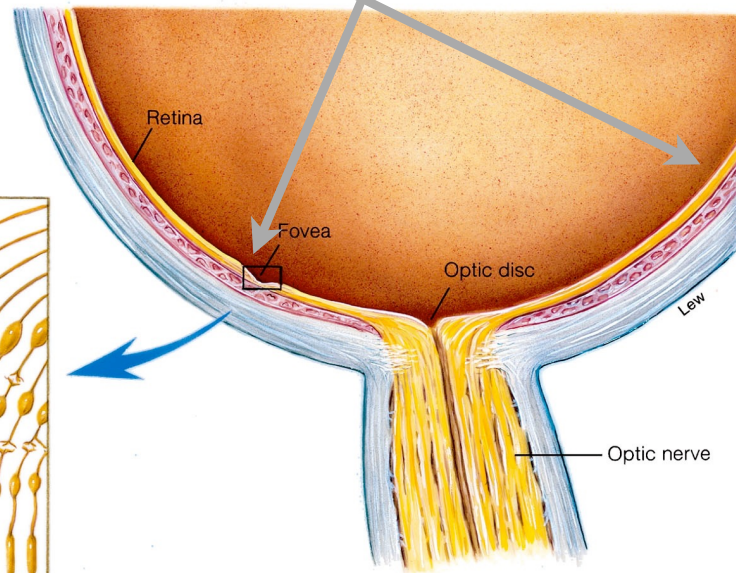
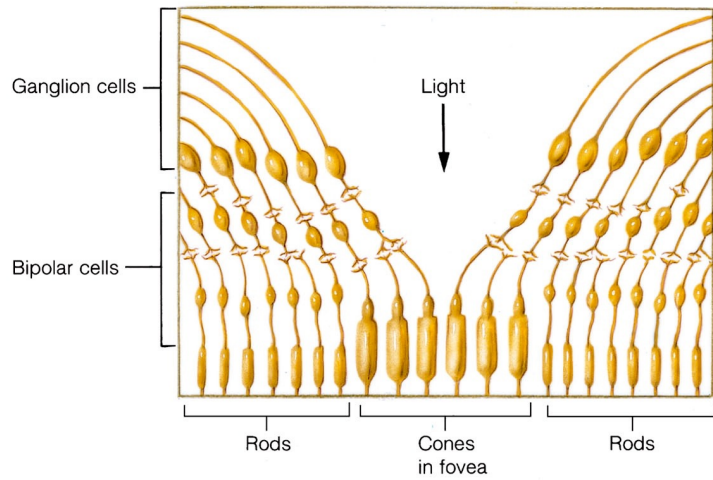


Figure 10.44

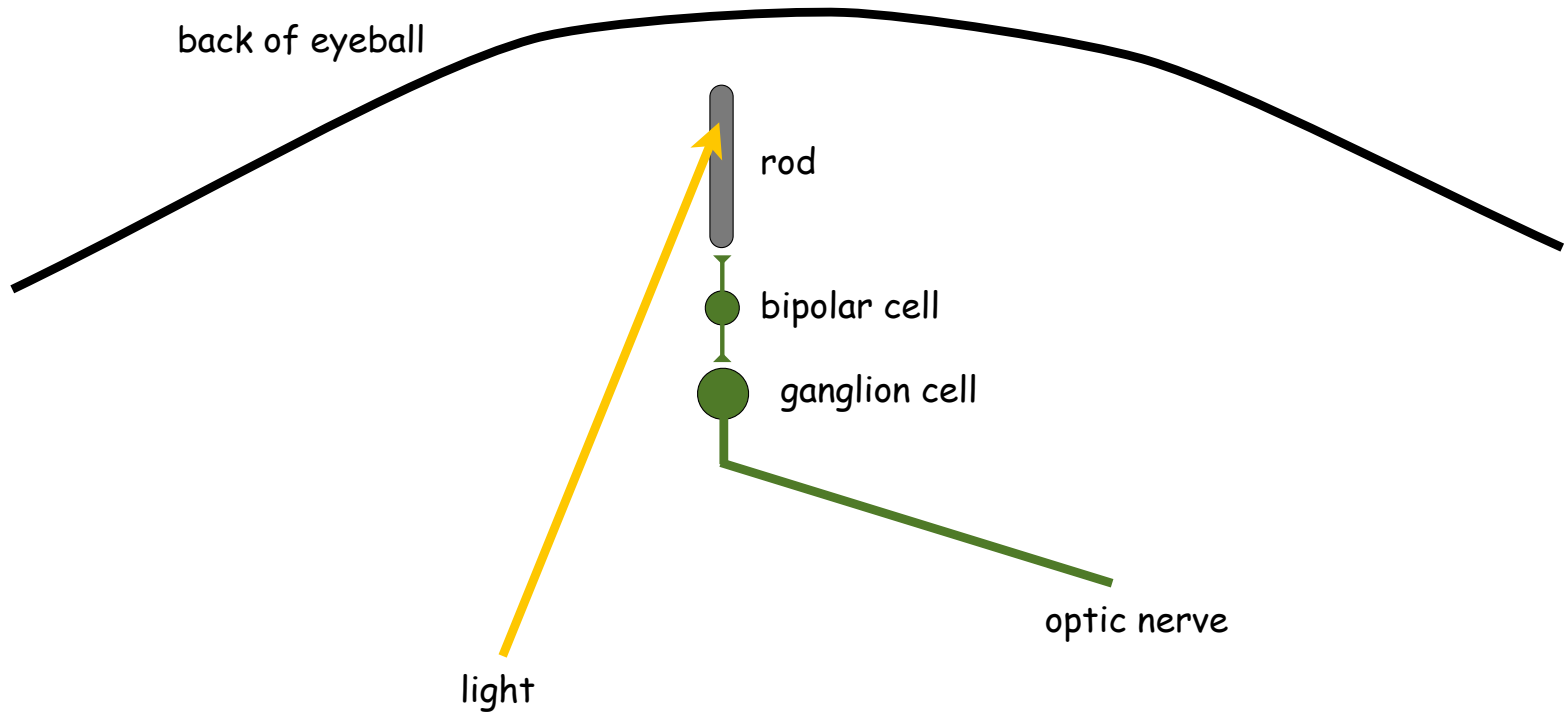


Light from peripheral vision

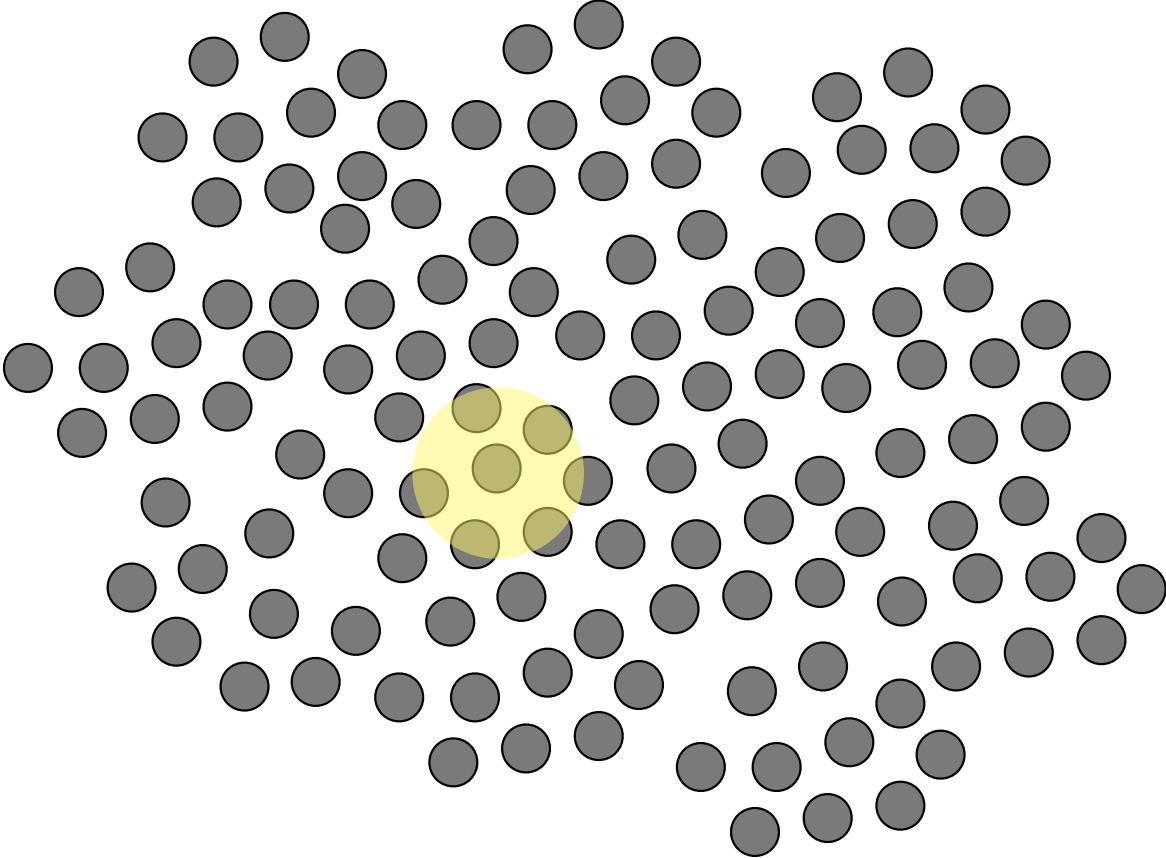
Light from center



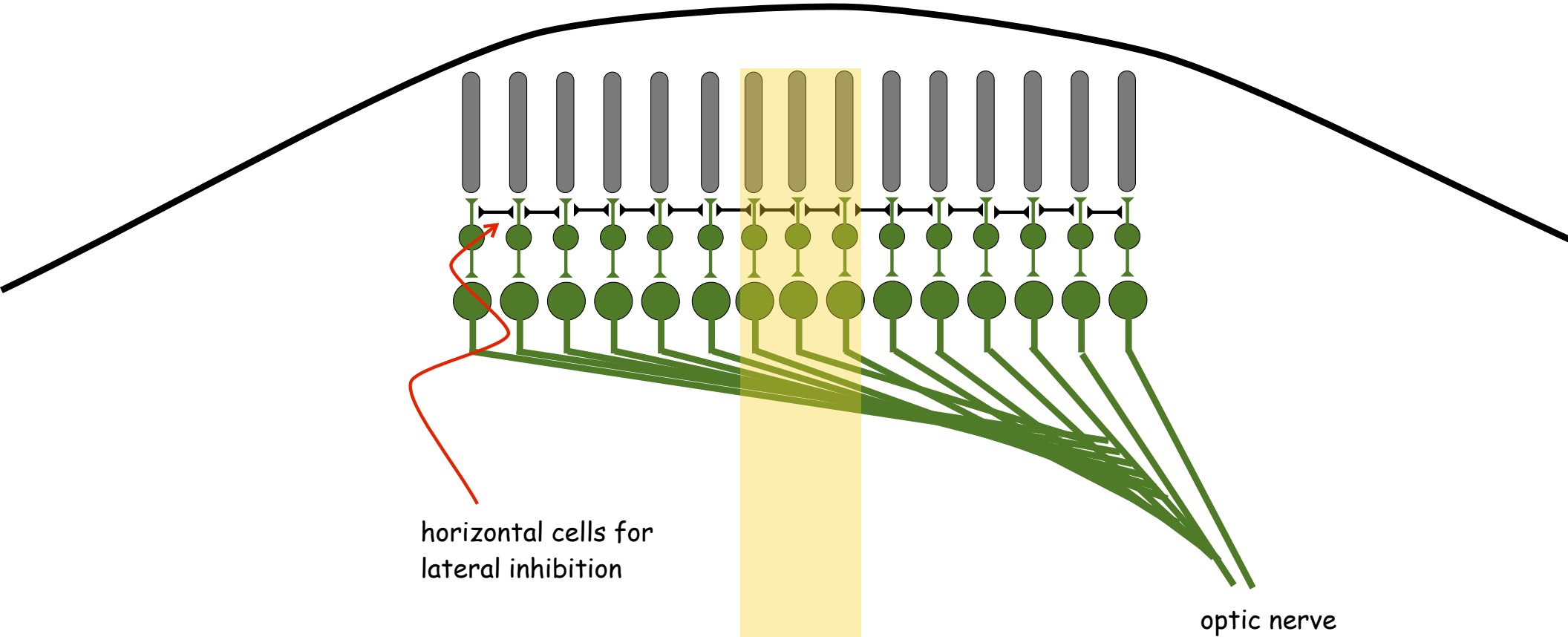
Cross-Section of Retina from side



Looking Down on Retina



Cross-Section of Retina from side



horizontal cells for lateral inhibition

optic nerve

On-Center Bipolar/Ganglion Cell

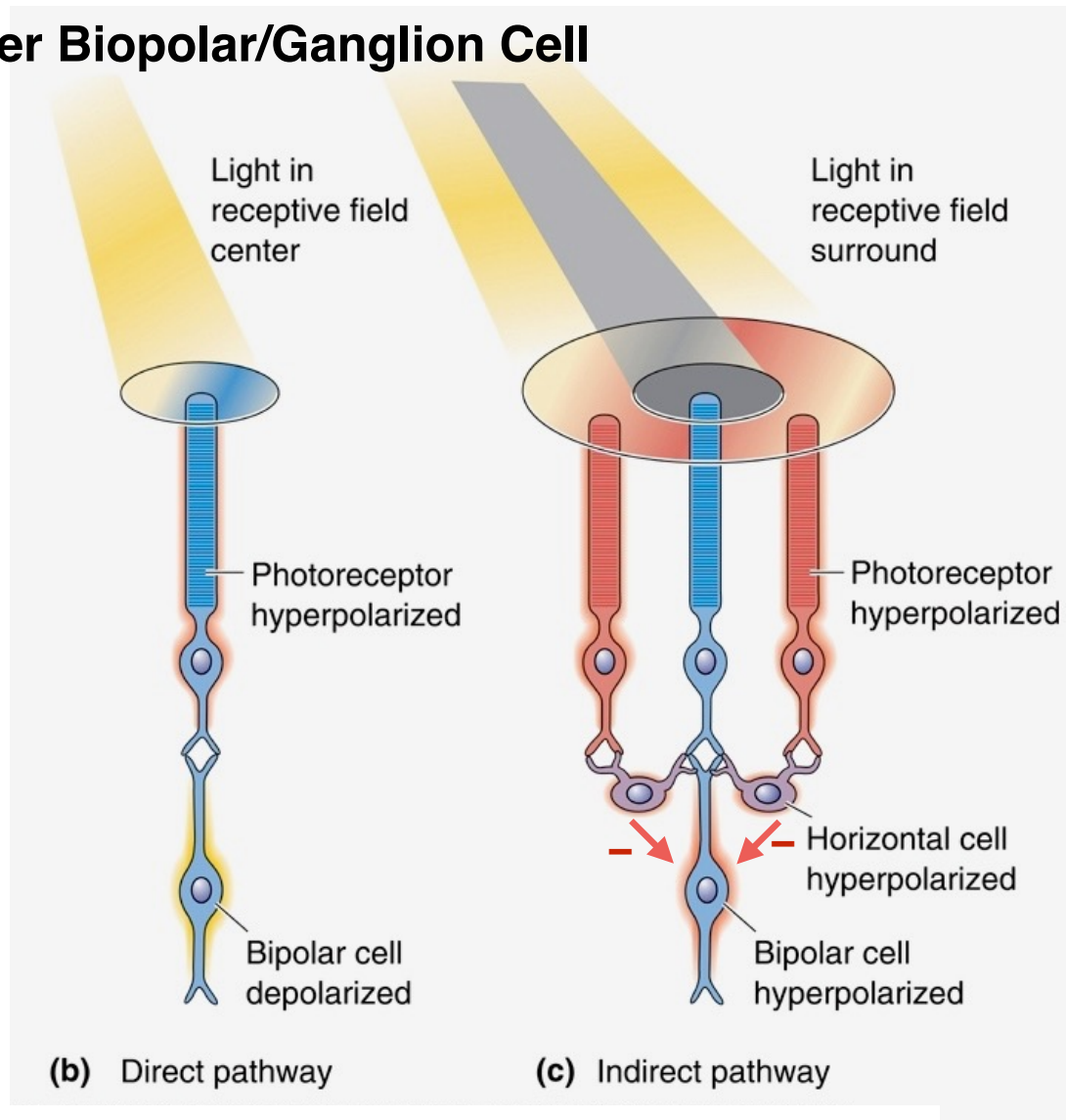
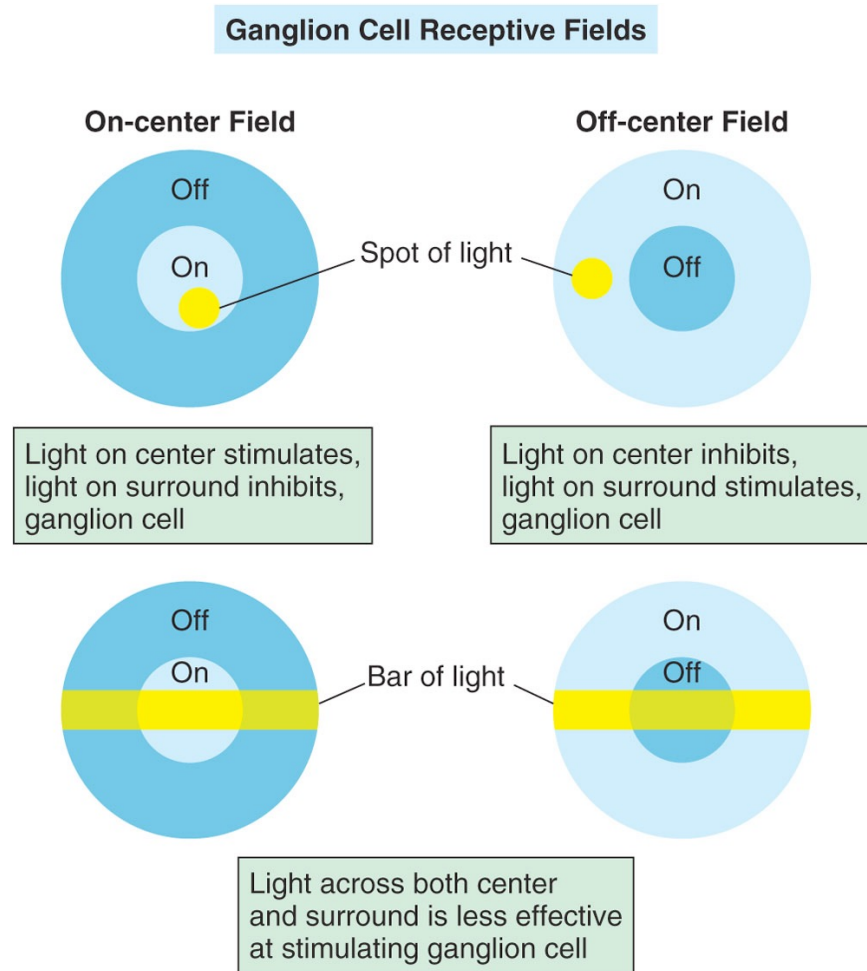
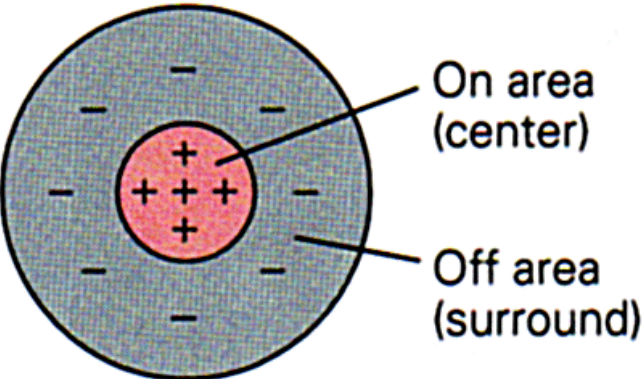


Figure 10.47

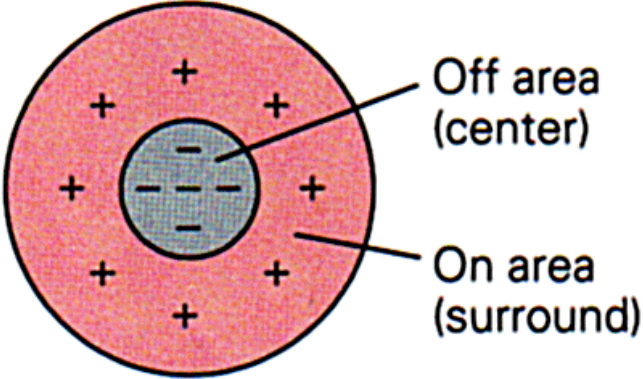


Center/Surround Cells

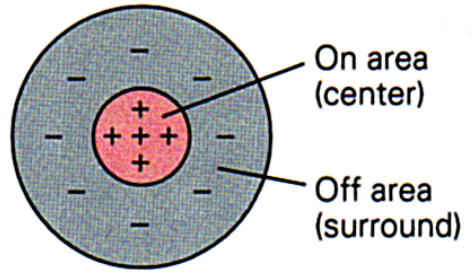
On-center ganglion cells



Off-center ganglion cells

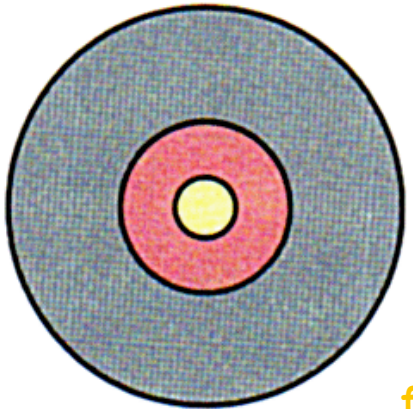


On-center ganglion cells

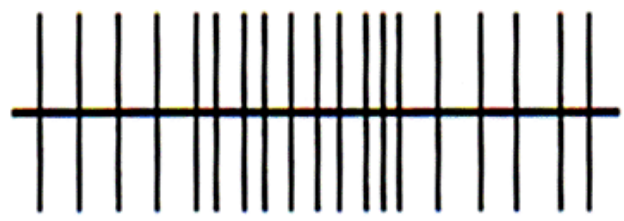


Note: slow steady firing in the dark

1
Central
spot

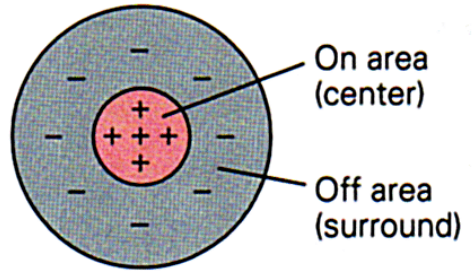


Light on

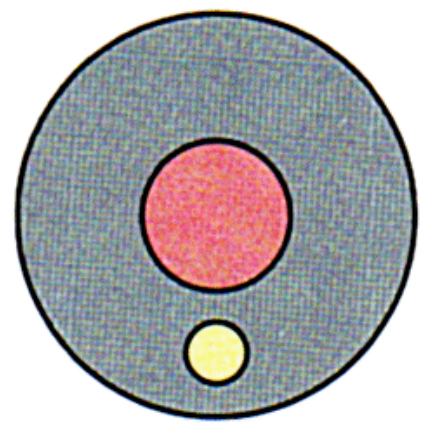


firing increases with light on center

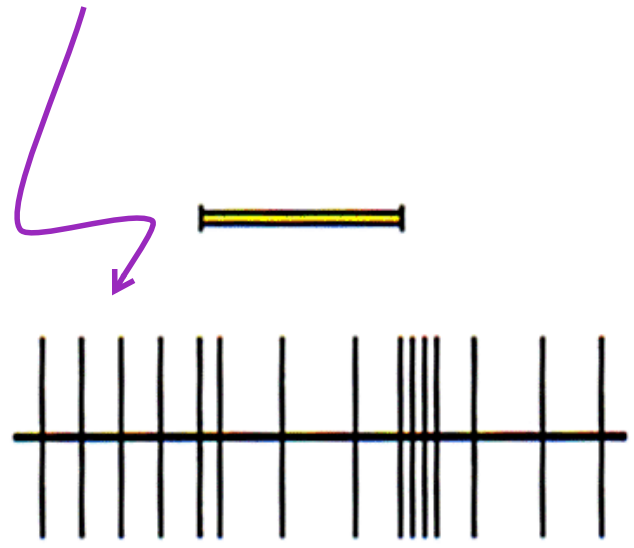
On-center ganglion cells



2
Peripheral
spot

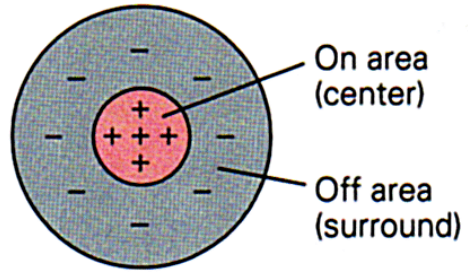


Note: slow steady firing in the dark

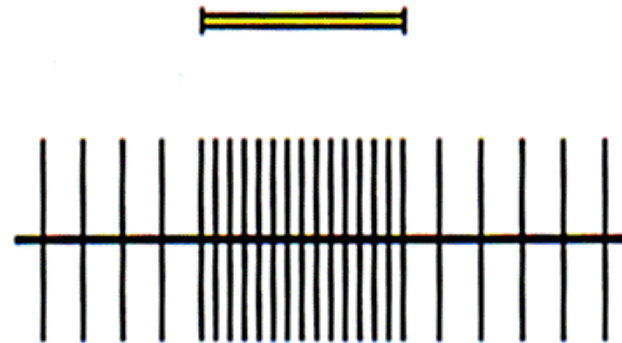
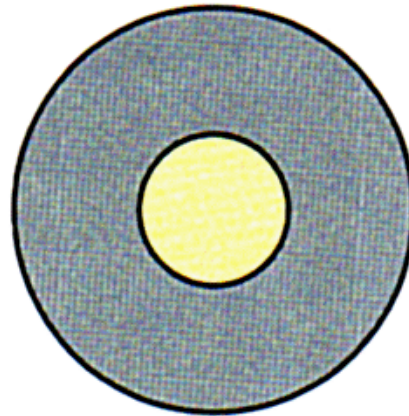


firing decreases with light on center

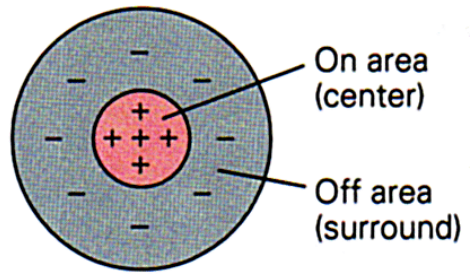
On-center ganglion cells



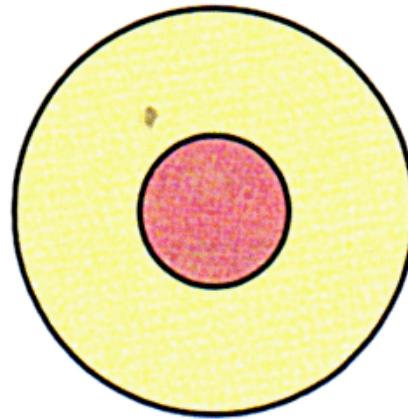
3
Central
illumination



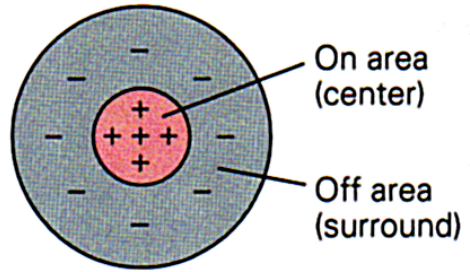
On-center ganglion cells



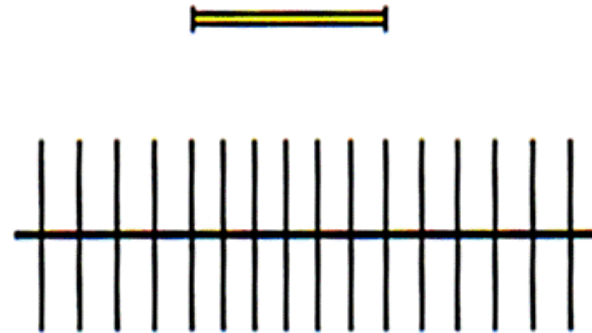
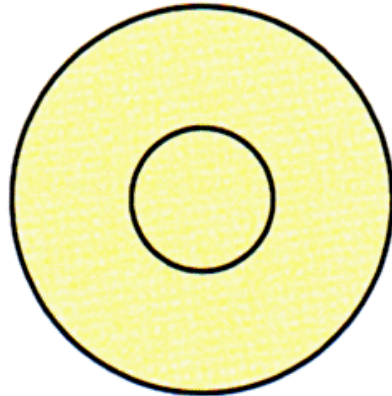
4
Surround
illumination



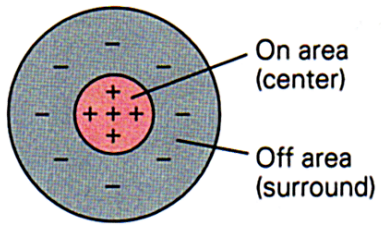
On-center ganglion cells



5
Diffuse
illumination



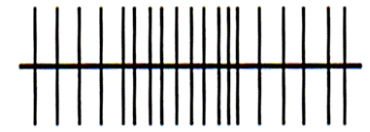
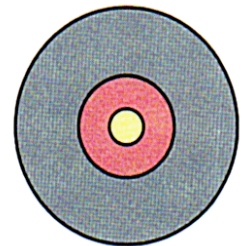
On-center ganglion cells



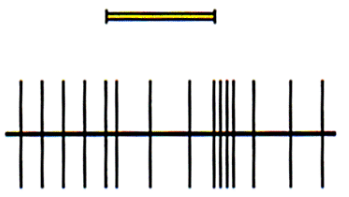
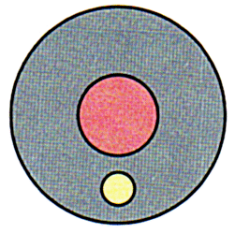
ON-CENTER

Light on

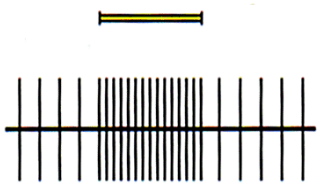
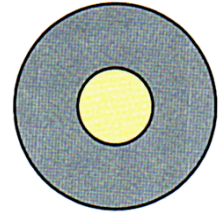
1
Central spot



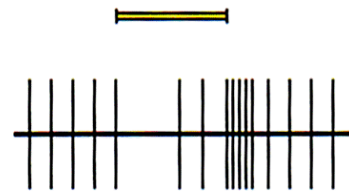
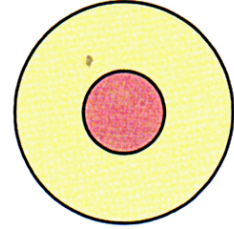
2
Peripheral spot



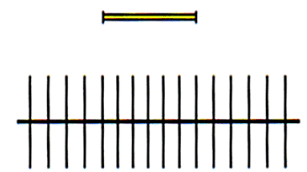
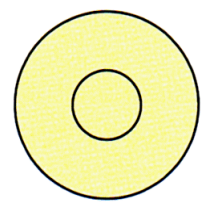
3
Central illumination



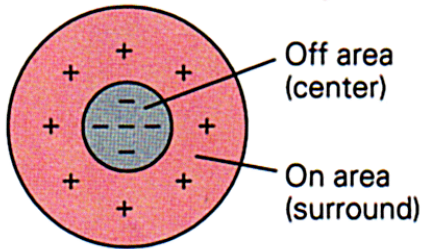
4
Surround illumination



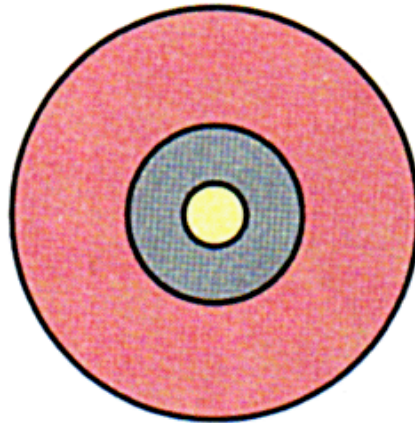
5
Diffuse illumination



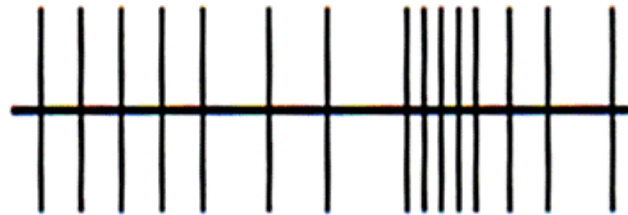
Off-center ganglion cells



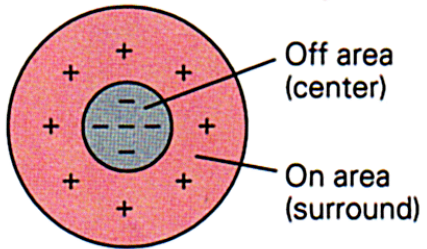
1
Central
spot



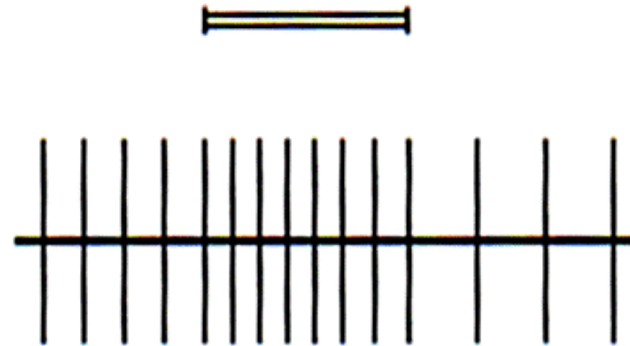
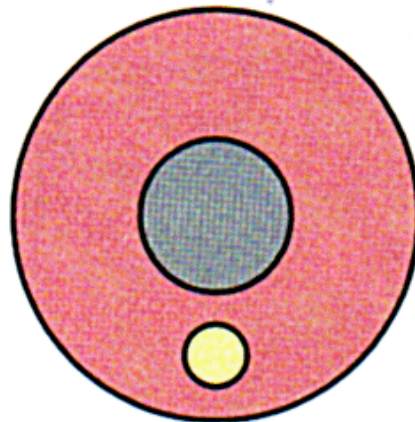
Light on



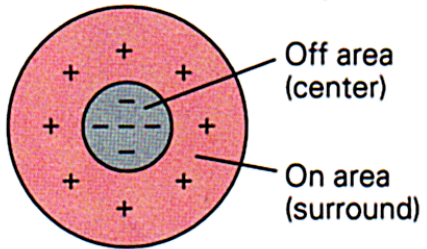
Off-center ganglion cells



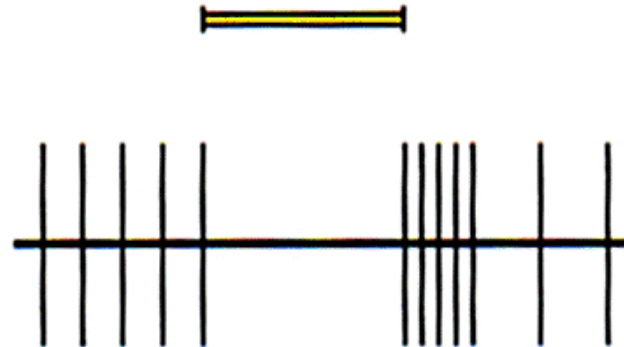
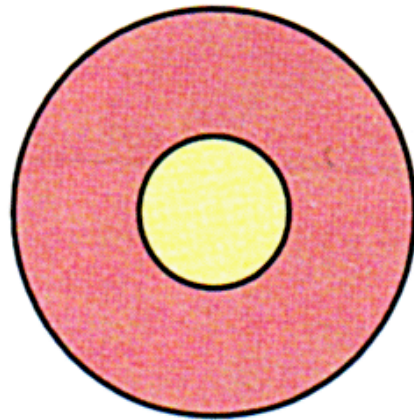
2
Peripheral
spot



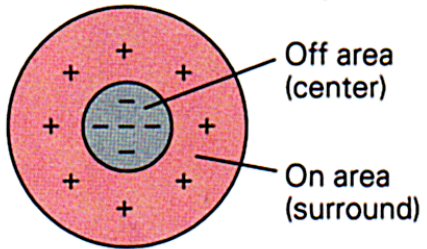
Off-center ganglion cells



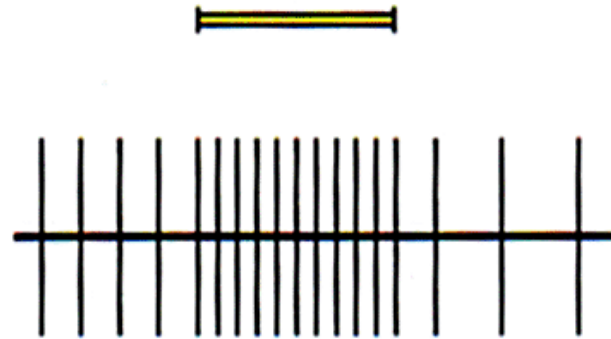
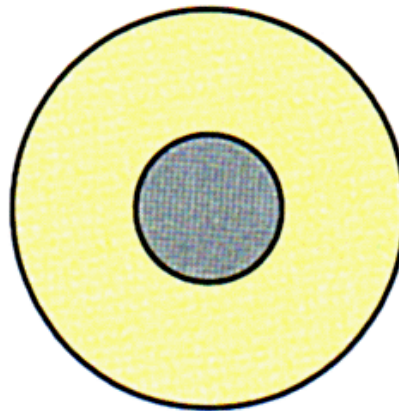
3
Central
illumination



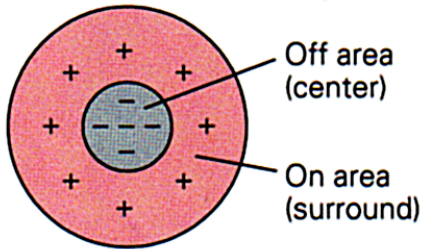
Off-center ganglion cells



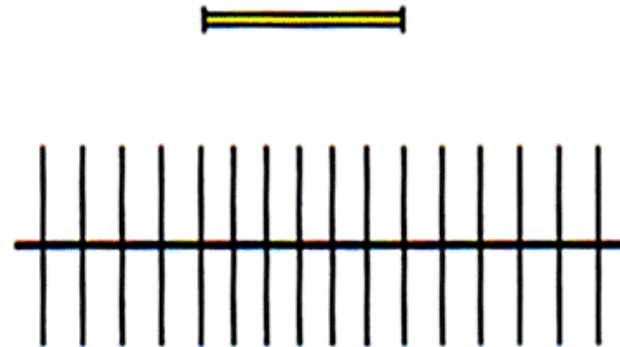
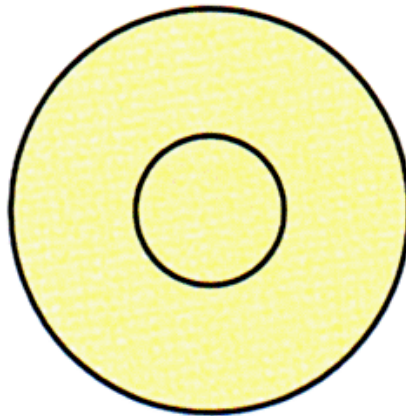
4
Surround
illumination



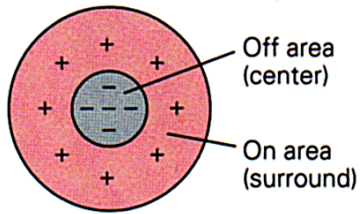
Off-center ganglion cells



5
Diffuse
illumination

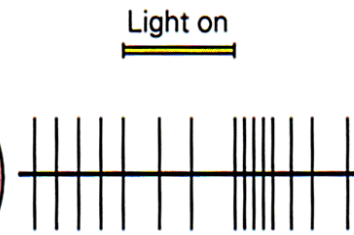
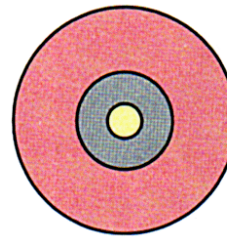


Off-center ganglion cells

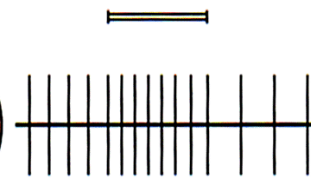
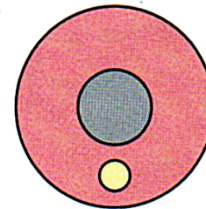


OFF-CENTER

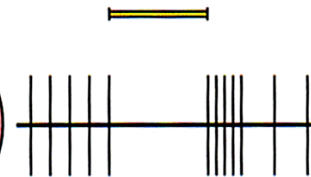
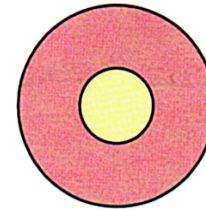
1
Central spot



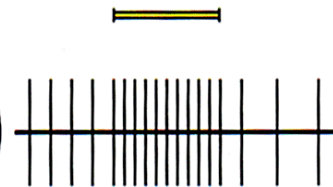
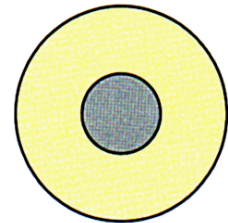
2
Peripheral spot



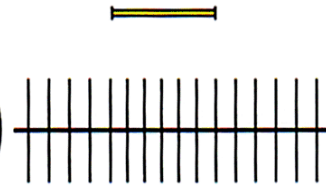
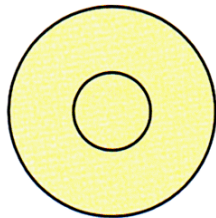
3
Central illumination



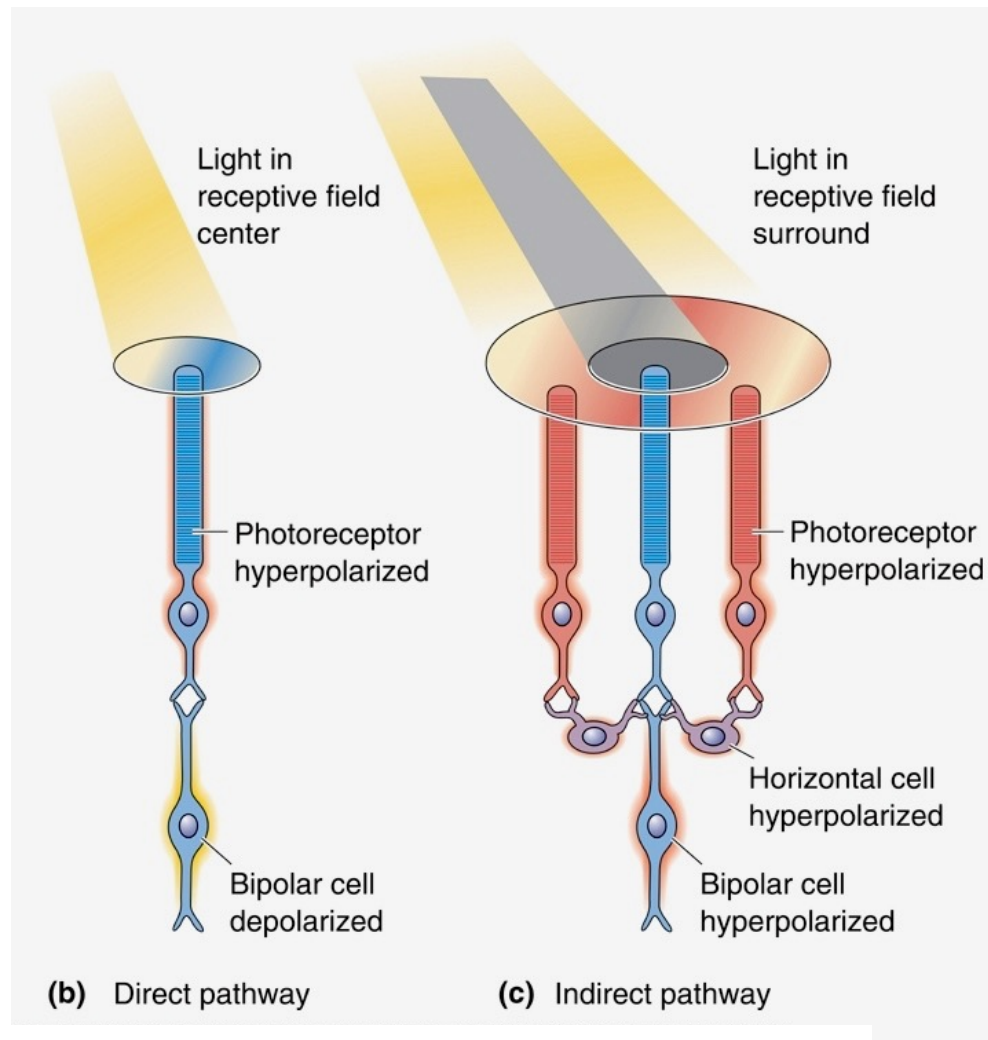
4
Surround illumination



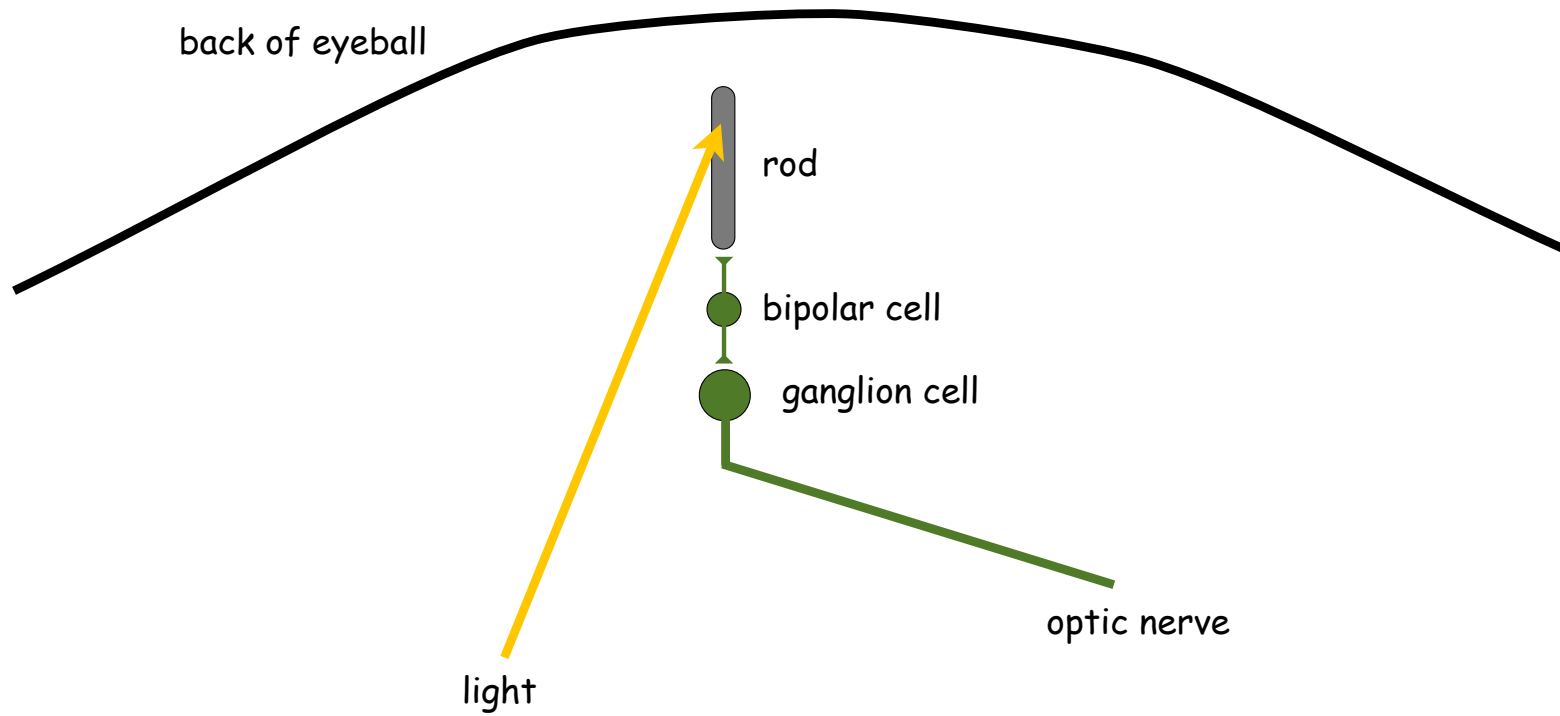
5
Diffuse illumination



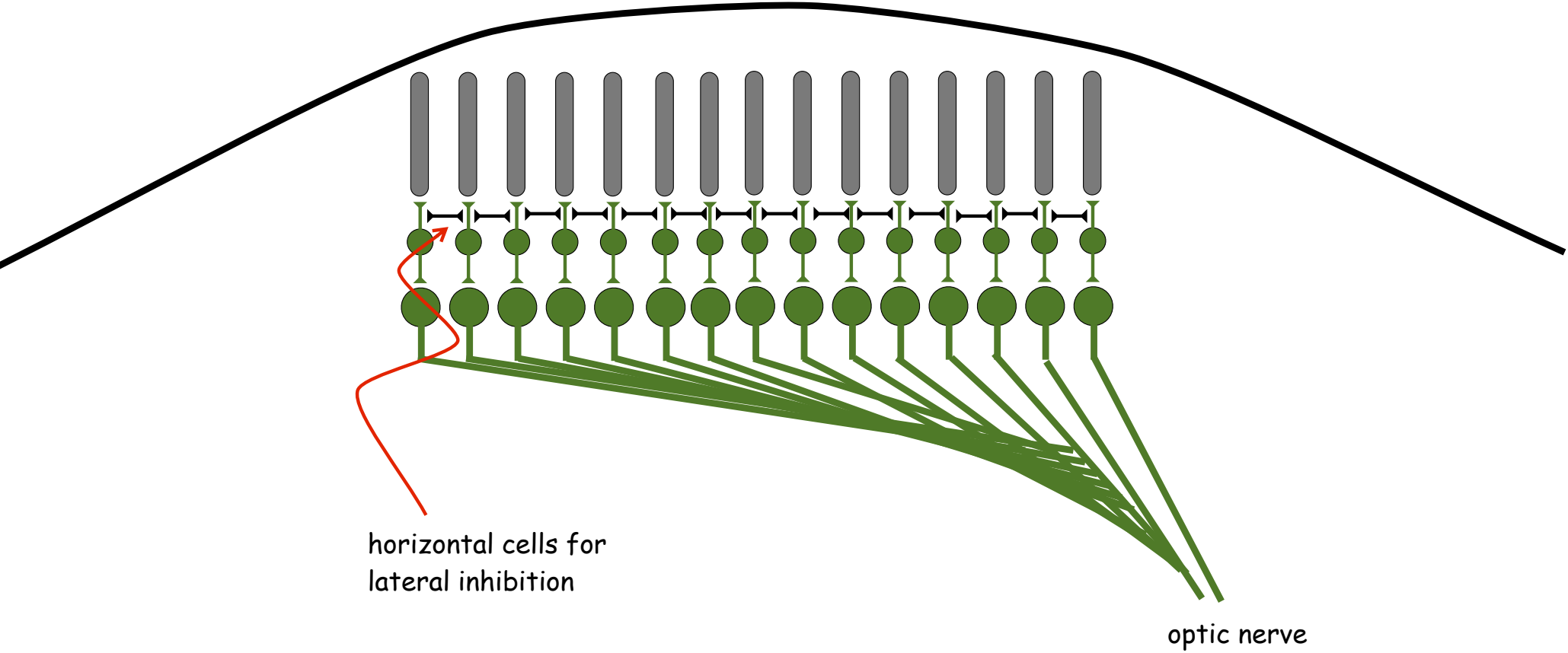
On-Center Bipolar/Ganglion Cell



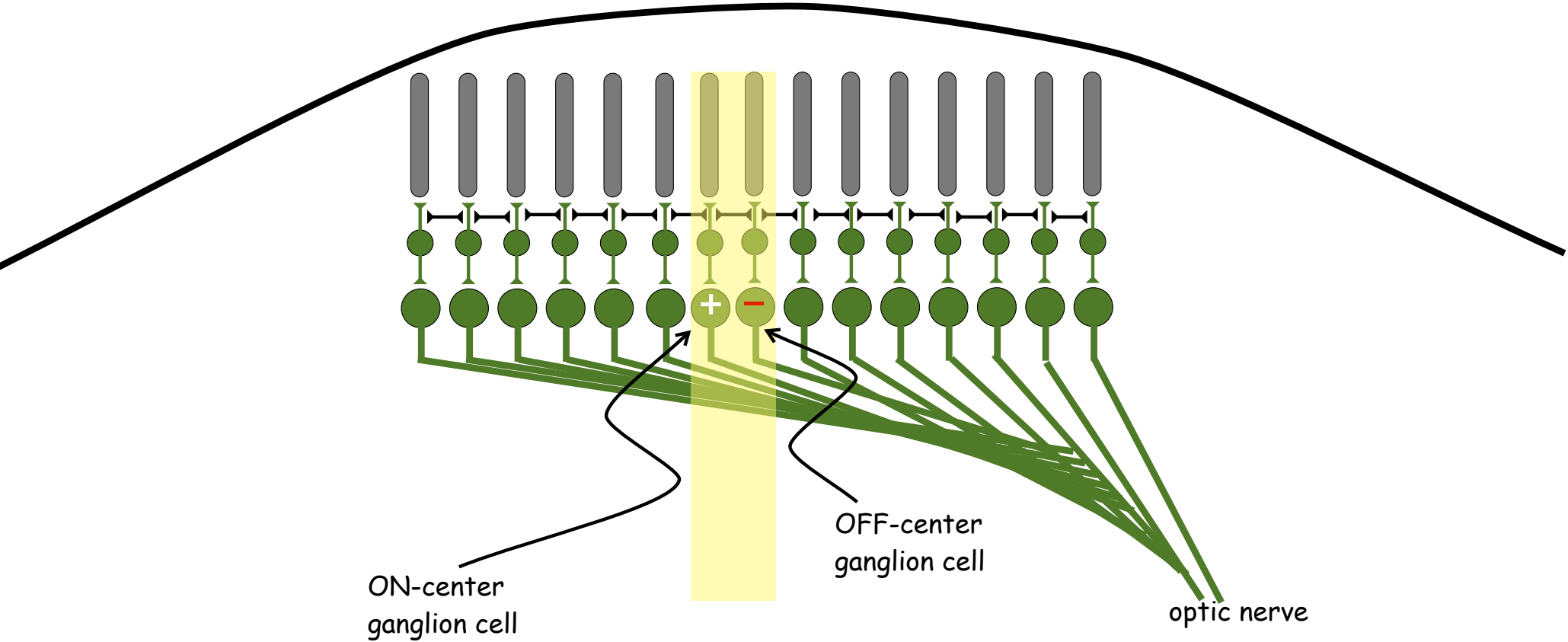
Cross-Section of Retina from side



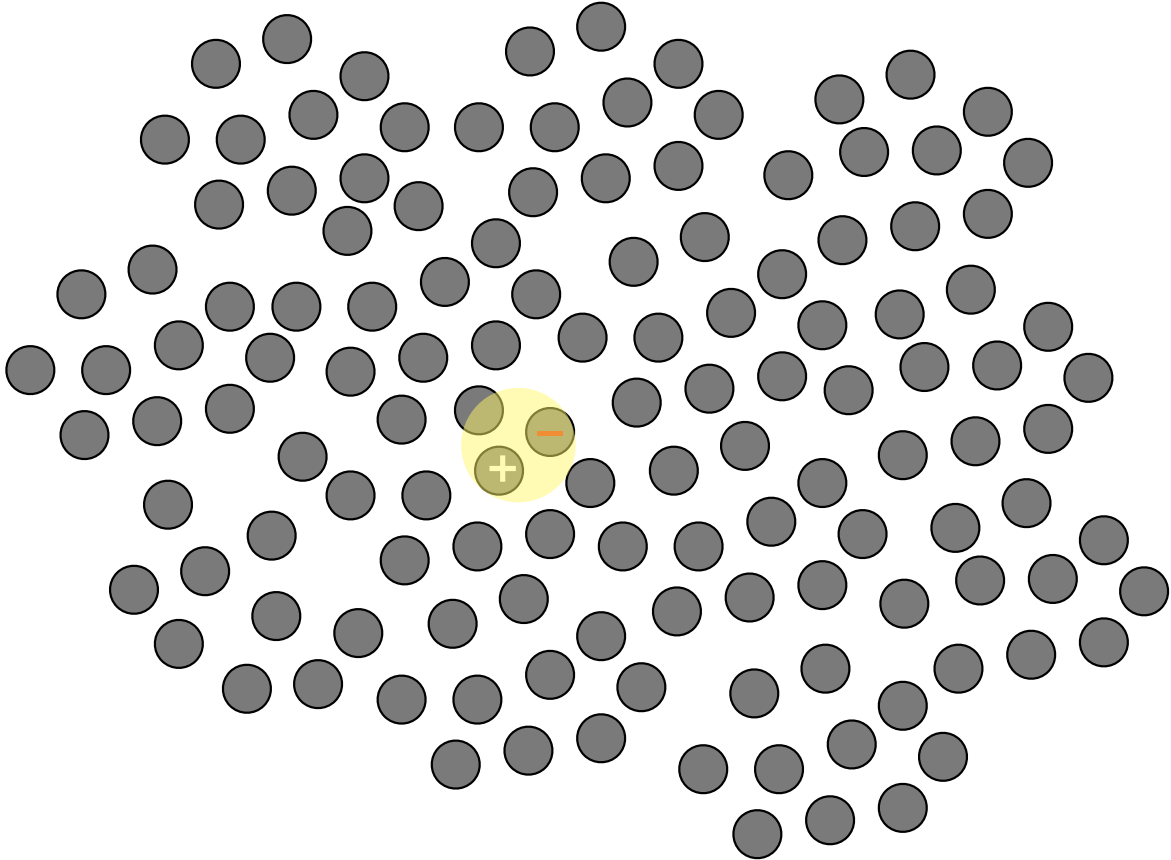
Cross-Section of Retina from side



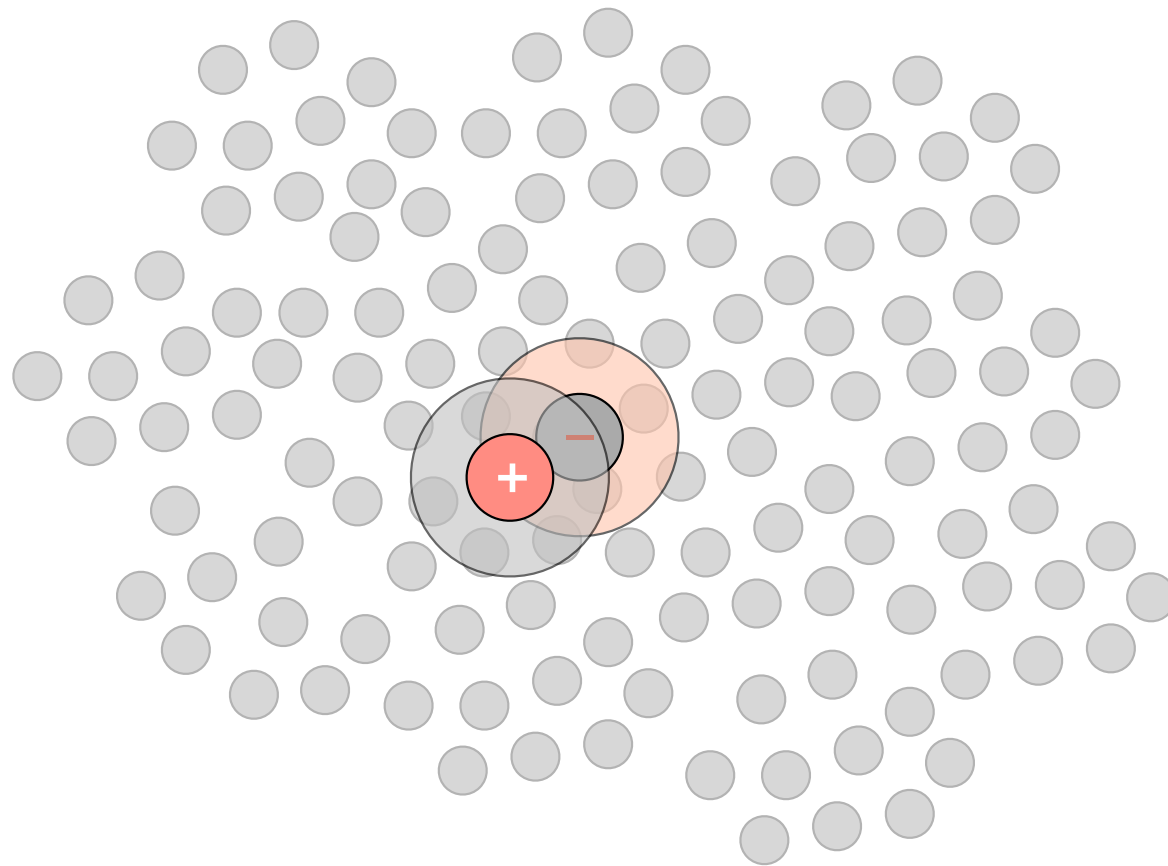
Cross-Section of Retina from side



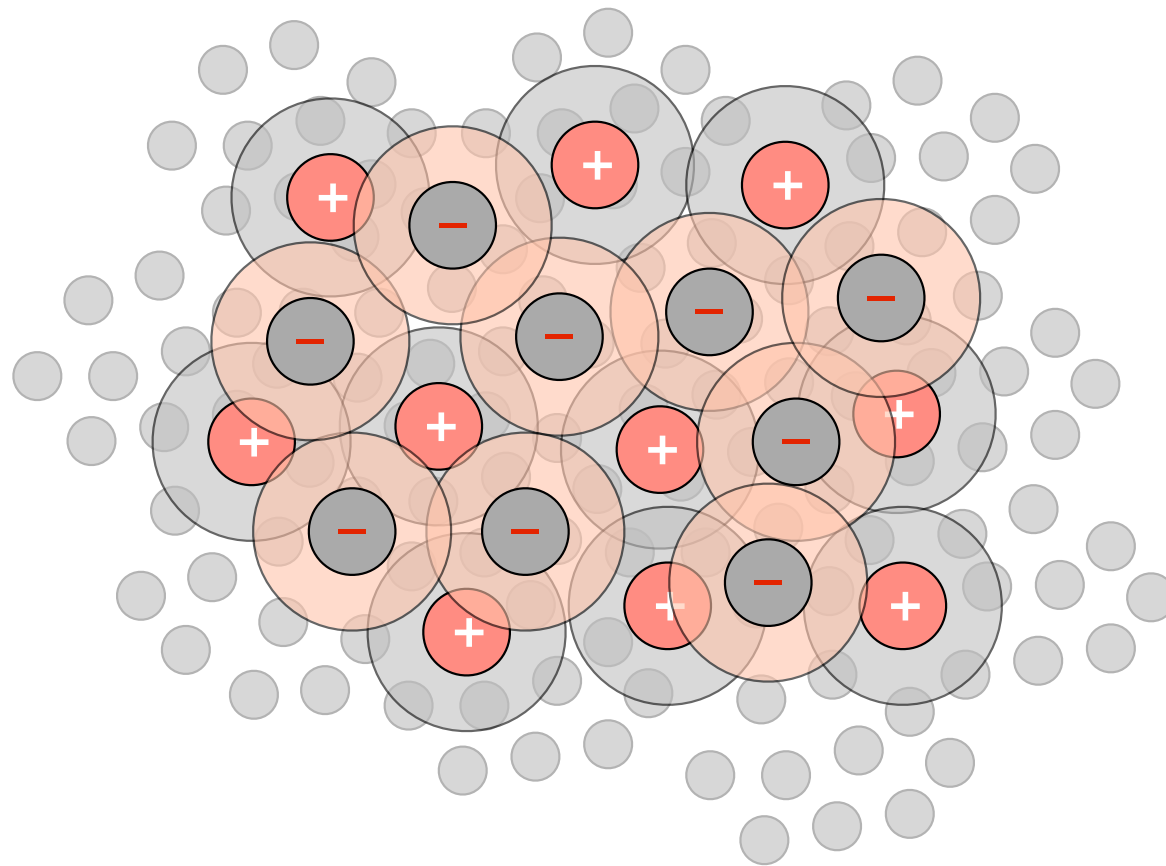
Looking Down on Retina

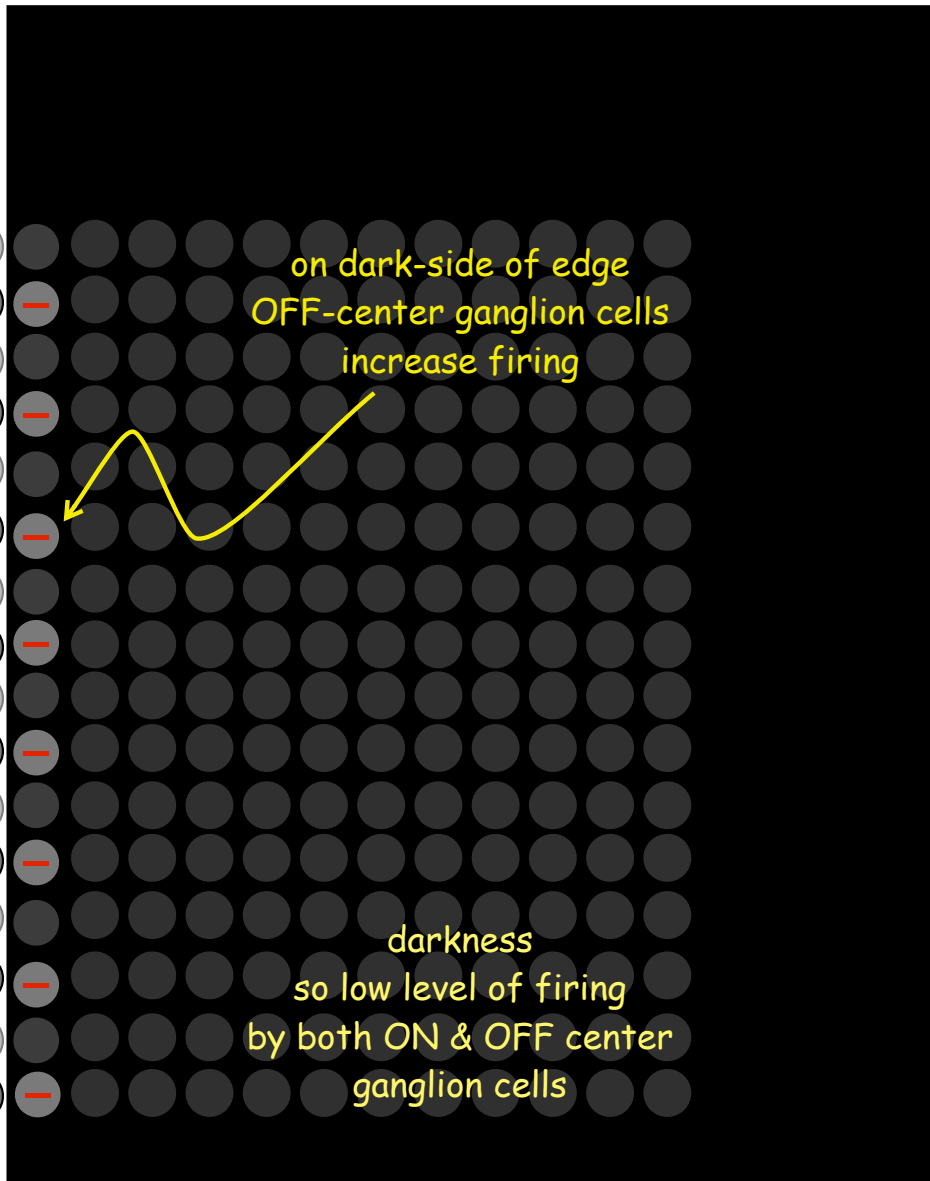
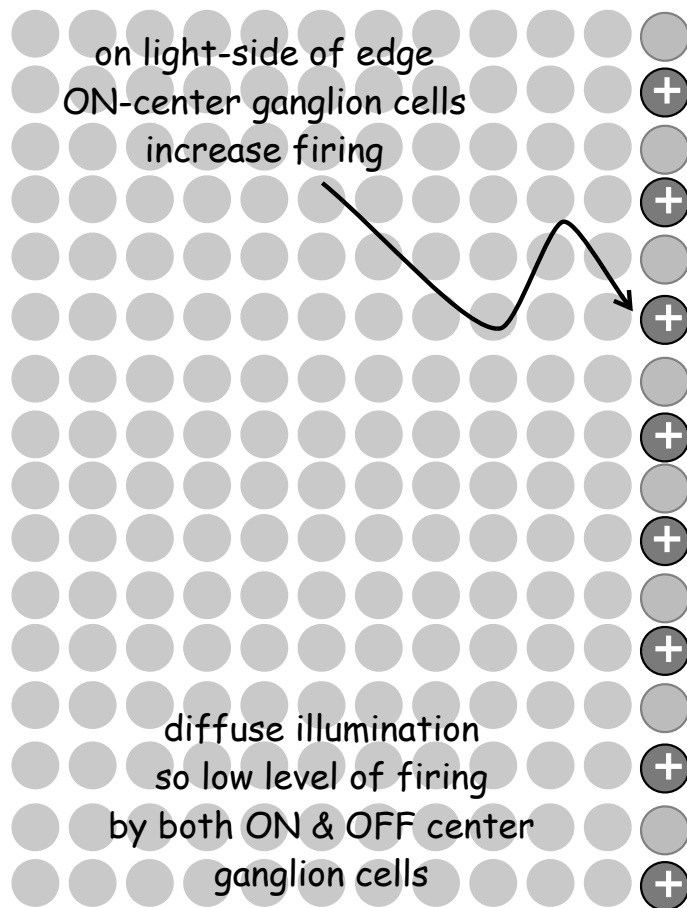


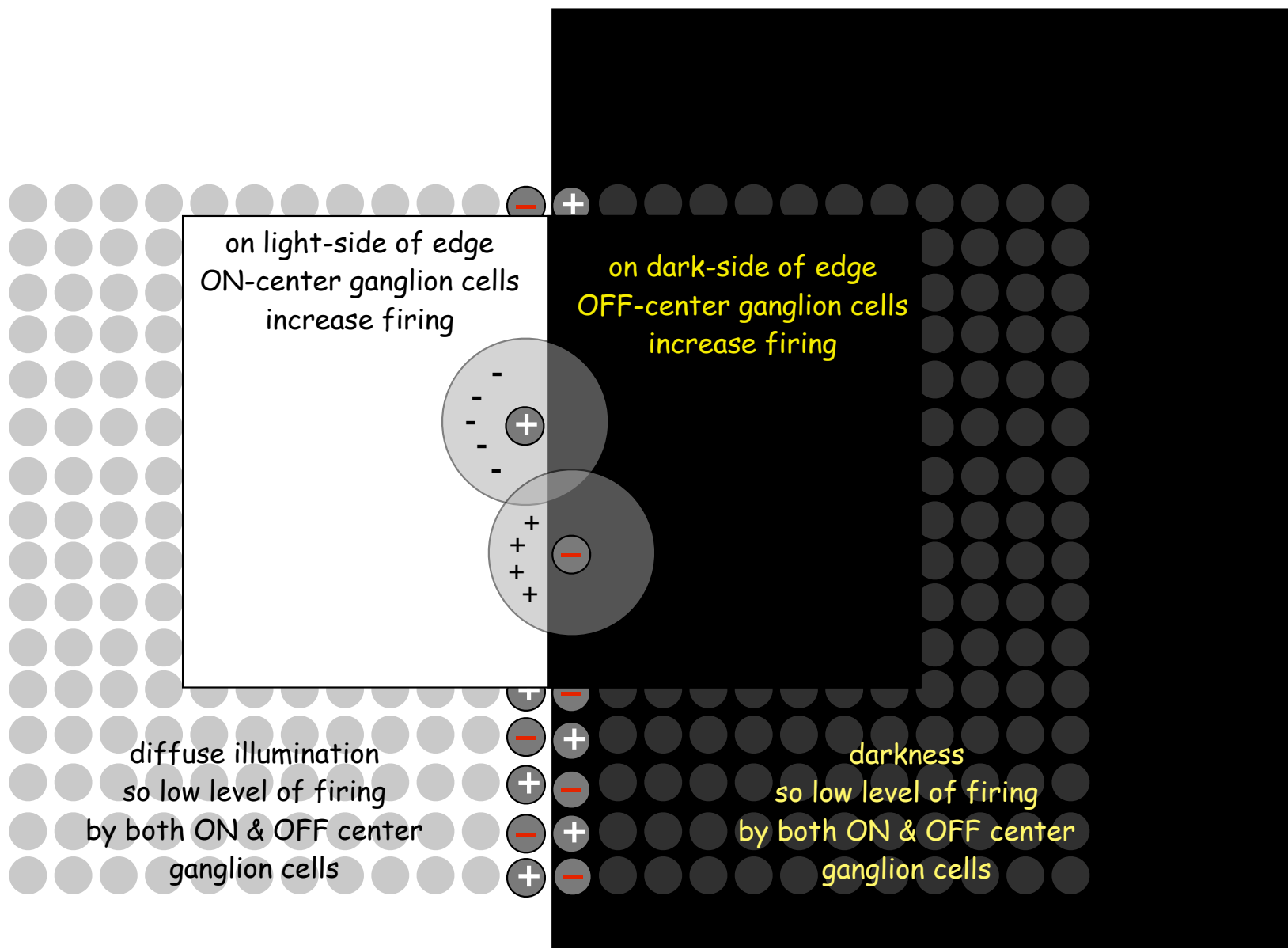
Overlapping Receptive Fields of On-Center & Off-Center Ganglion Cells

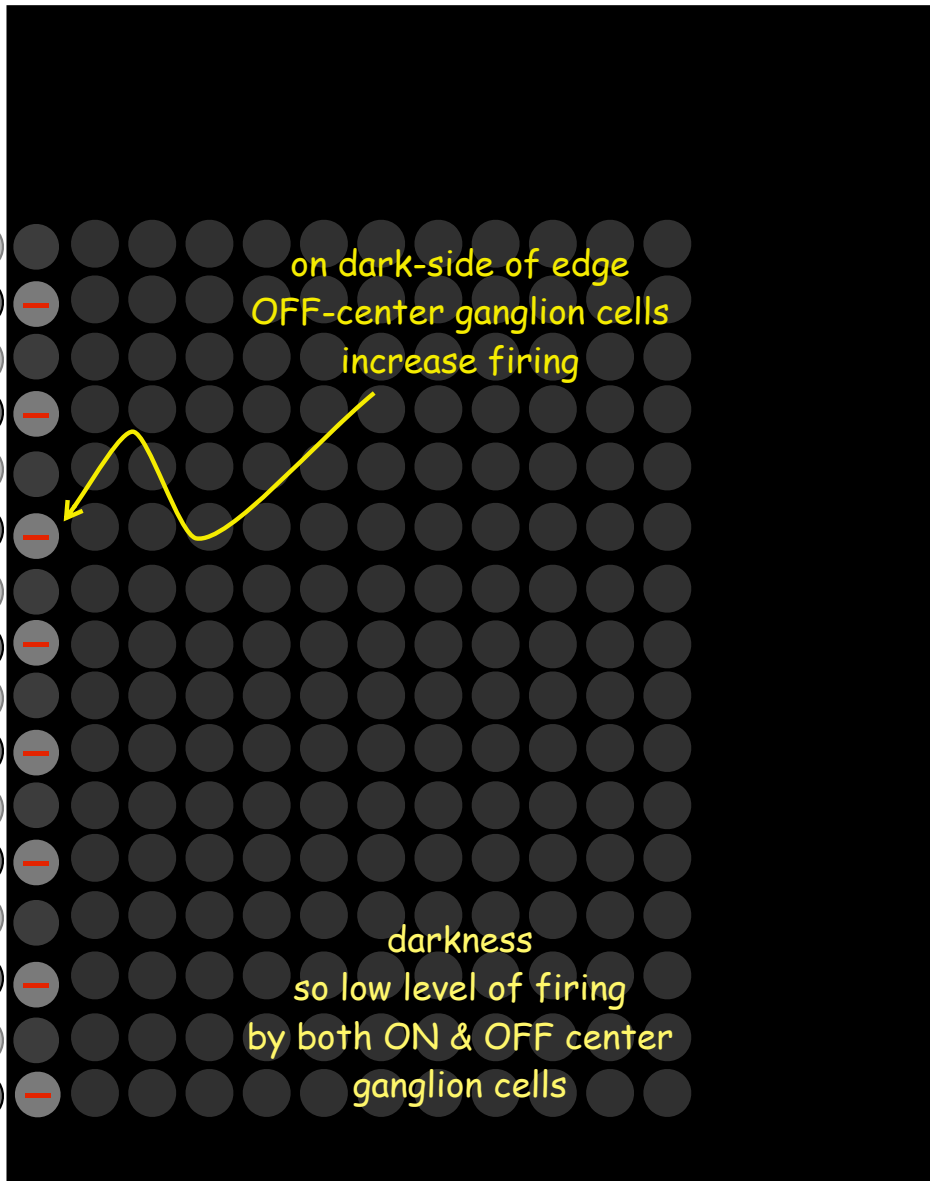
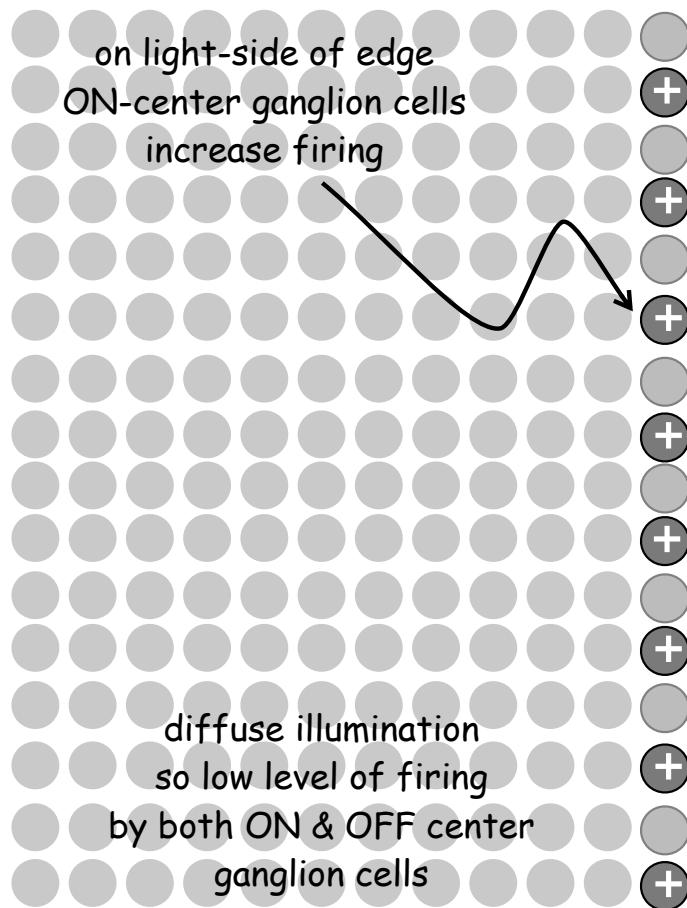


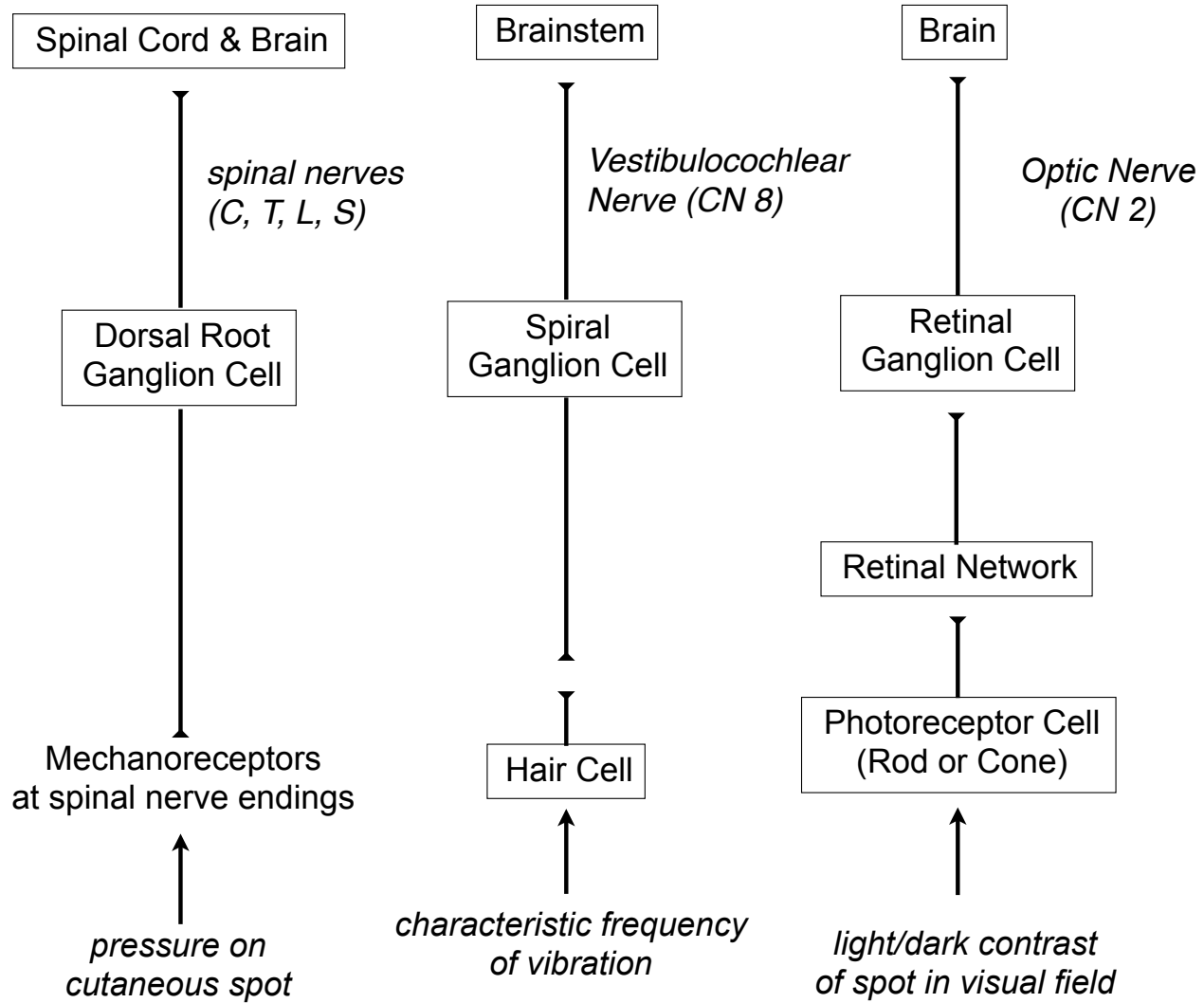
Overlapping Receptive Fields of On-Center & Off-Center Ganglion Cells











Optic Nerve Projections

Optic nerves meet, enter the brain, and cross at the **optic chiasm**. After optic chiasm, the nerve fibers are called the **optic tract**.

Optic nerve from each eye projects partly to contralateral cortex, partly to ipsilateral cortex.

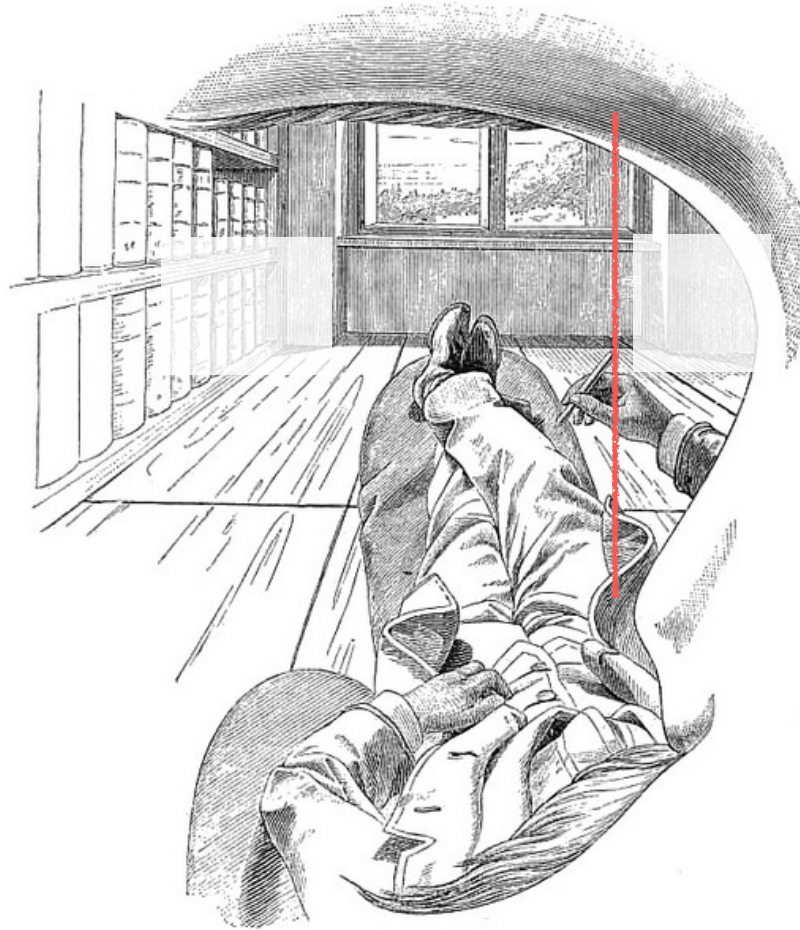
Ganglion cell axons are sorted so that:

Cells responsive to **left** visual field (from nose to the left) project to **right** cortex.

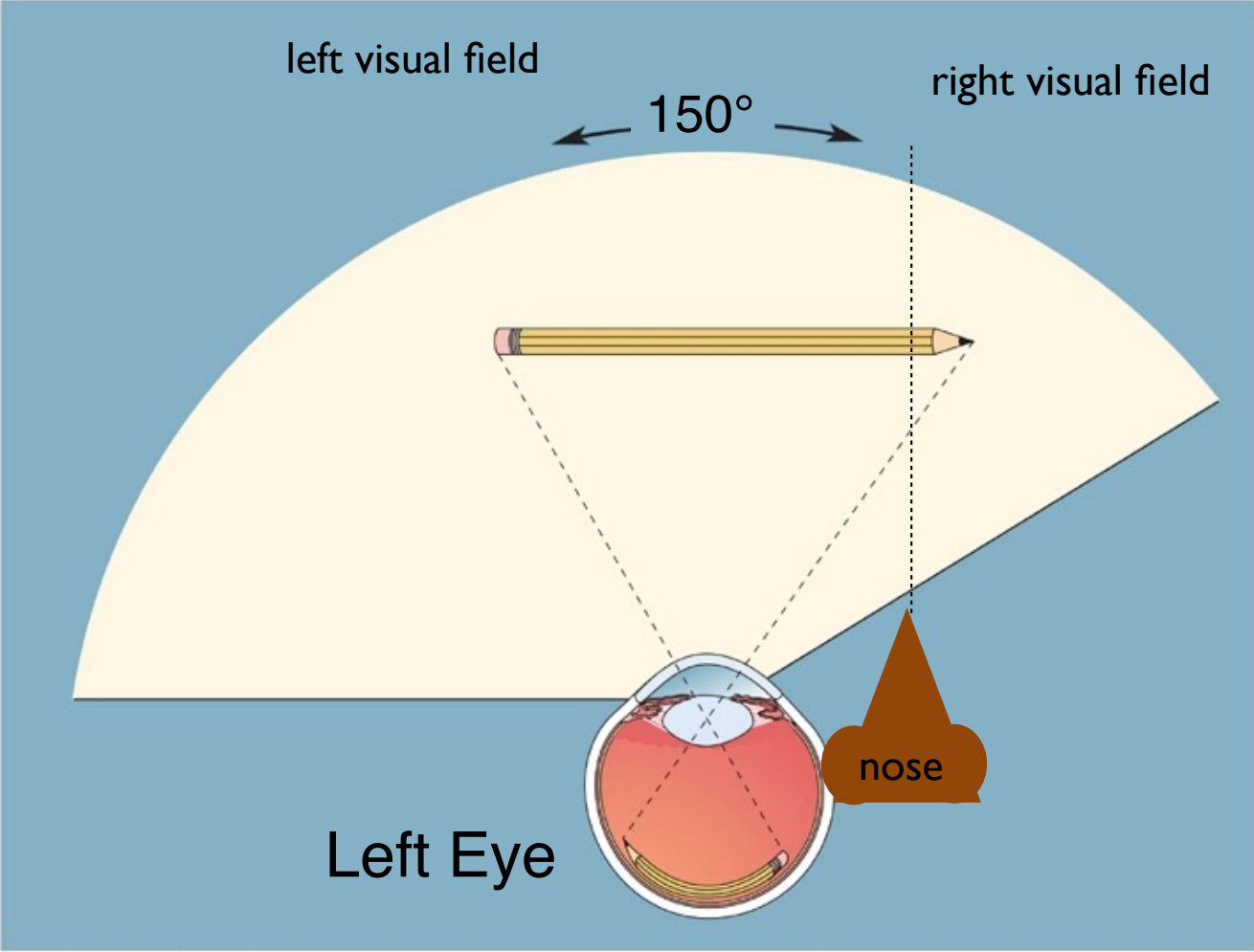
Cells responsive to **right** visual field (from nose to the right) project to **left** cortex.

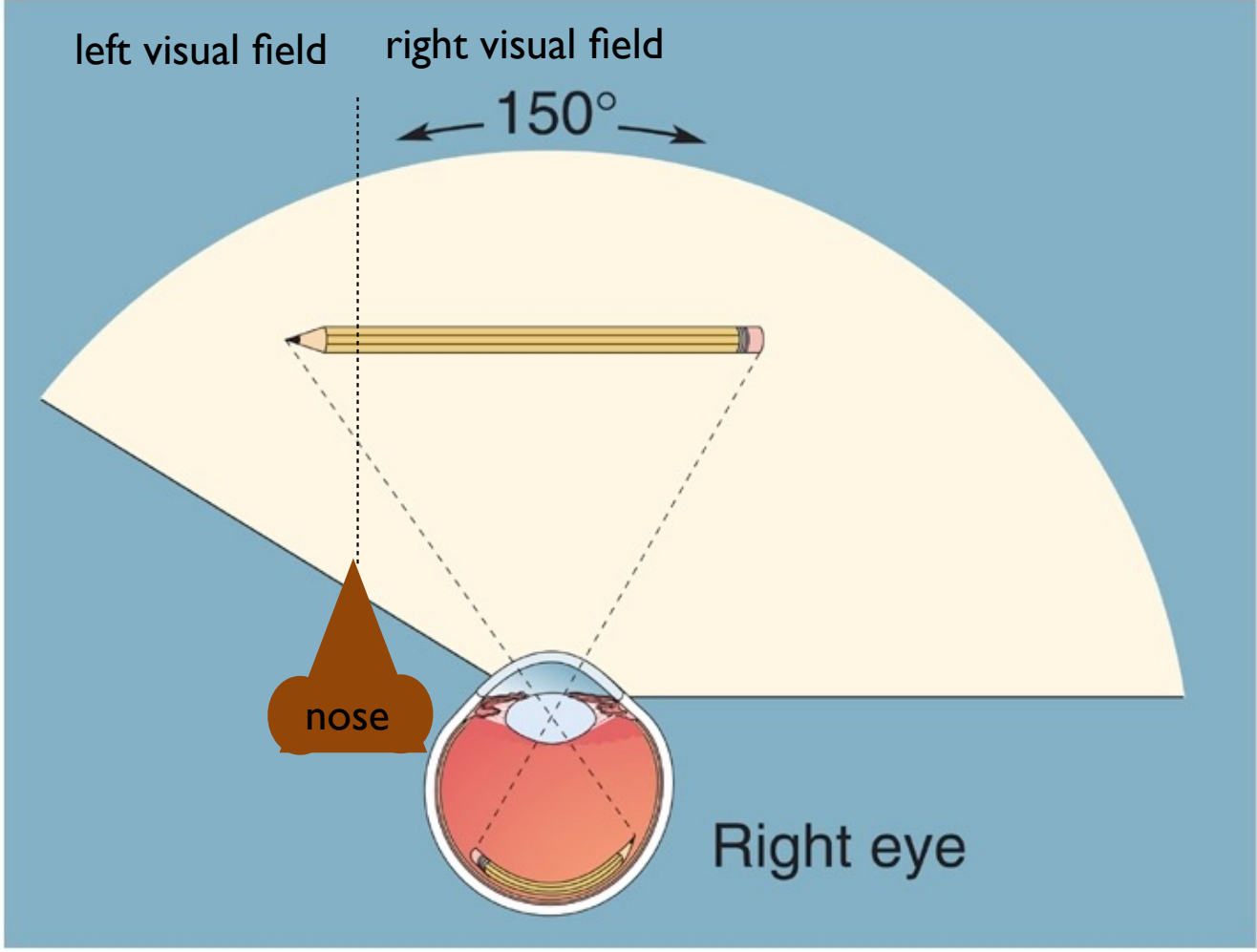
So damage to **left** visual cortex causes loss of sight off all of **right** visual field (from nose to the right).

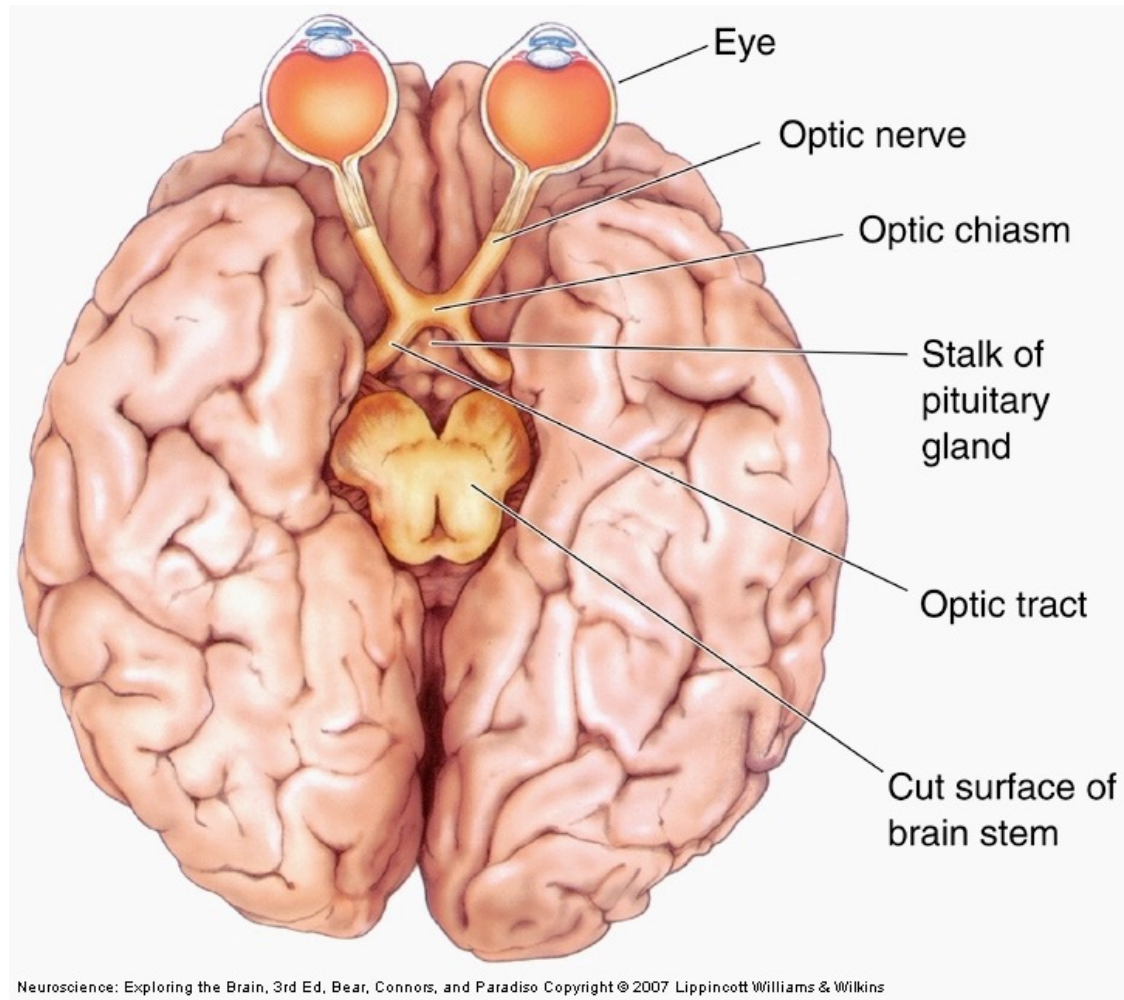
Self-Portrait by Ernst Mach (1886)



Figur 1.
“View from the left eye”







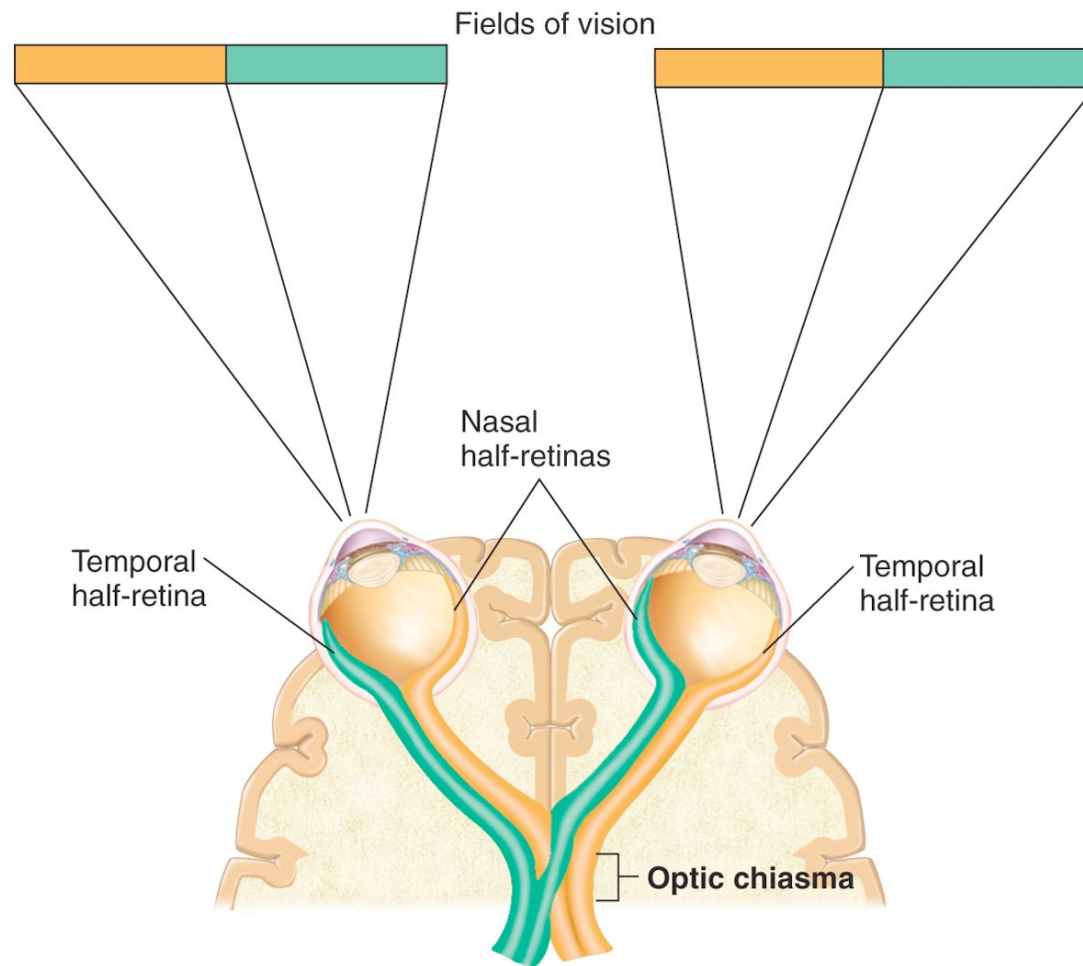


Figure 10.32

left of nose -> rightside of brain

right of nose -> leftside of brain

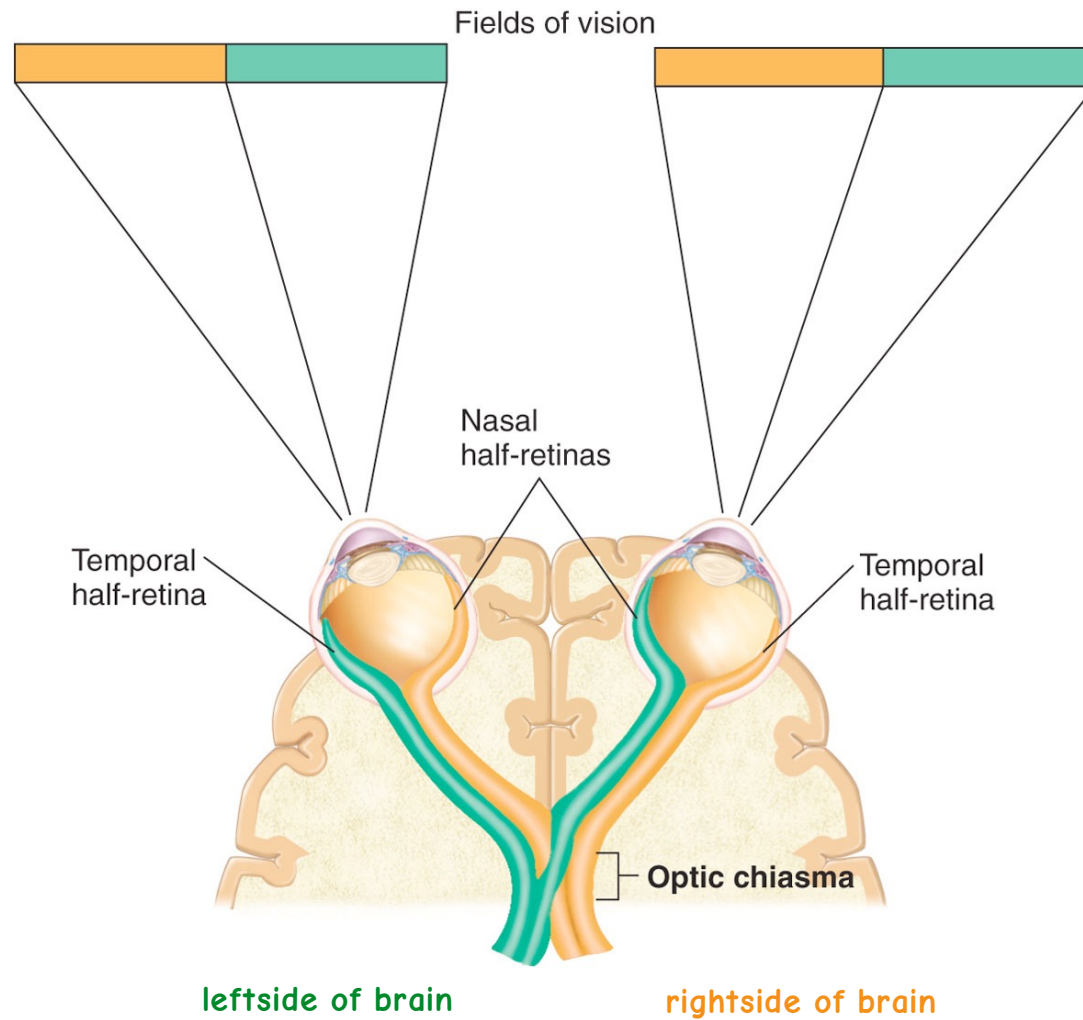
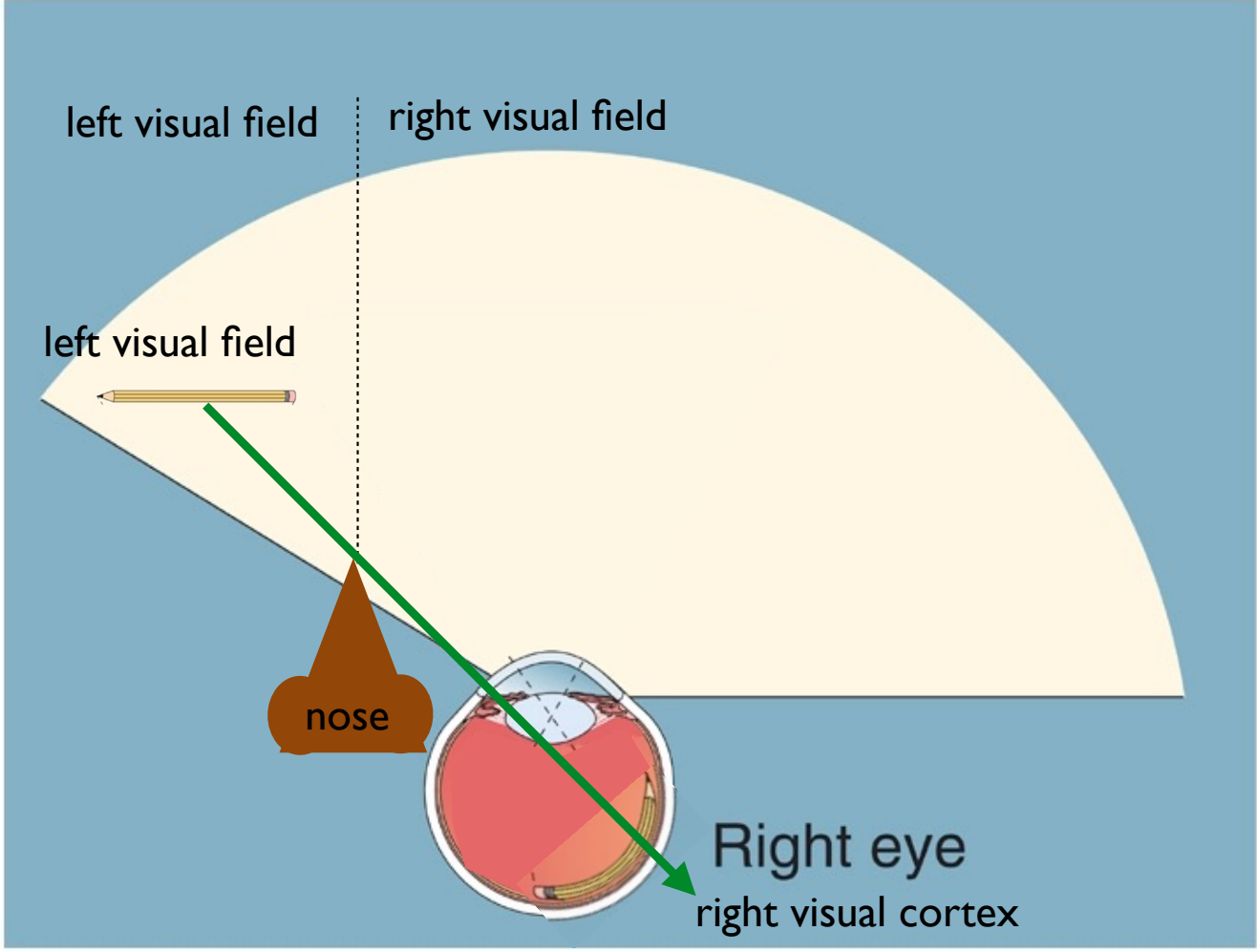


Figure 10.32



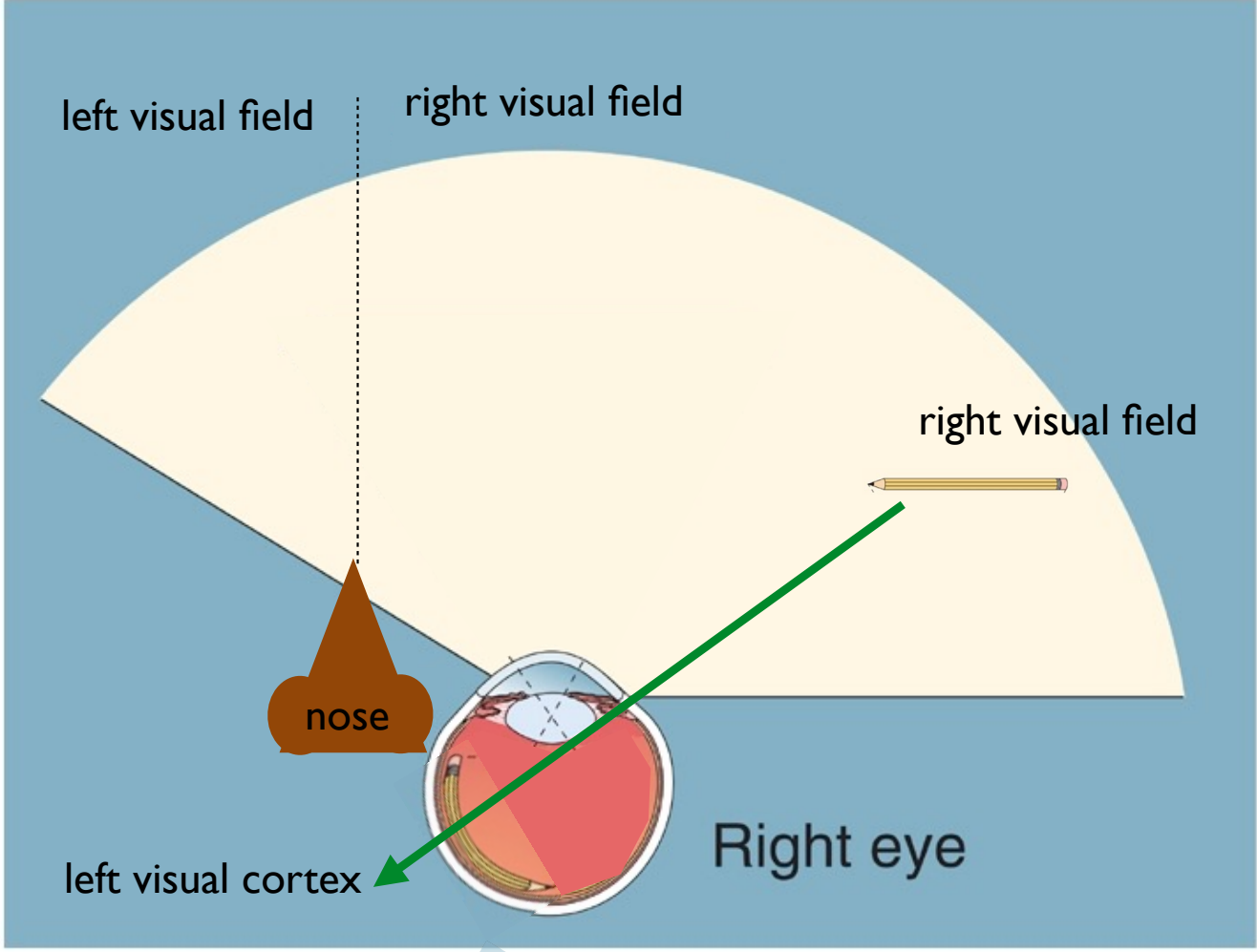
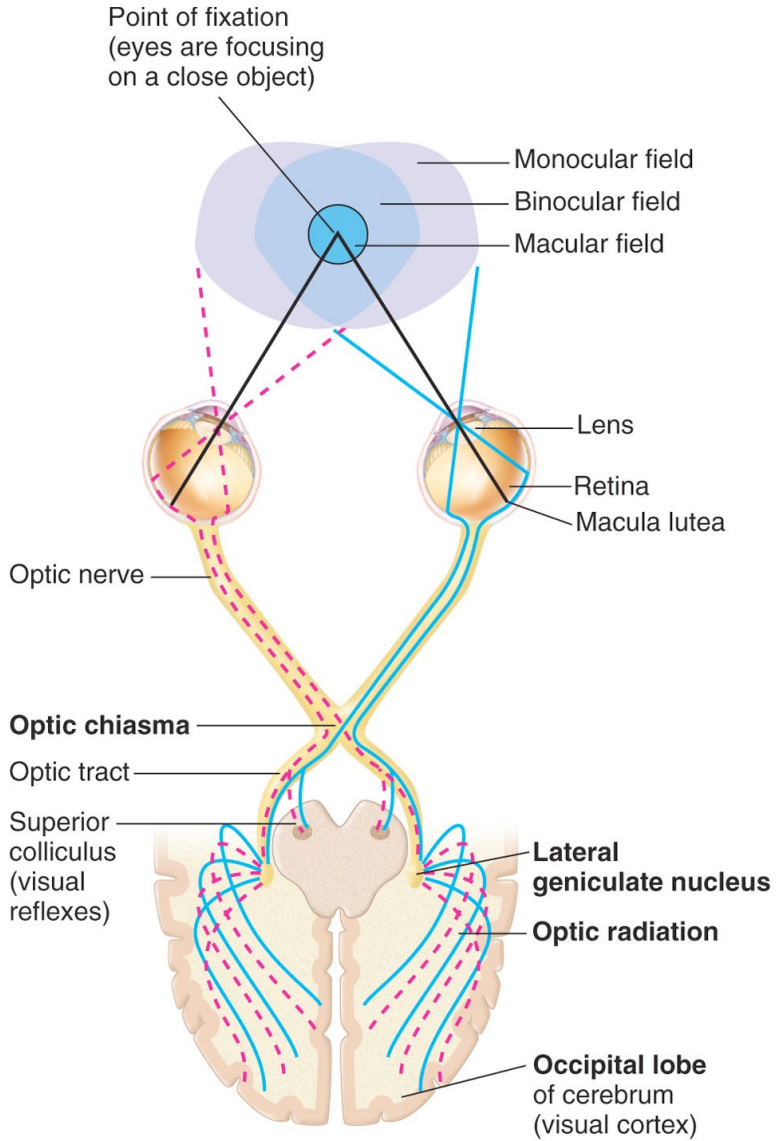
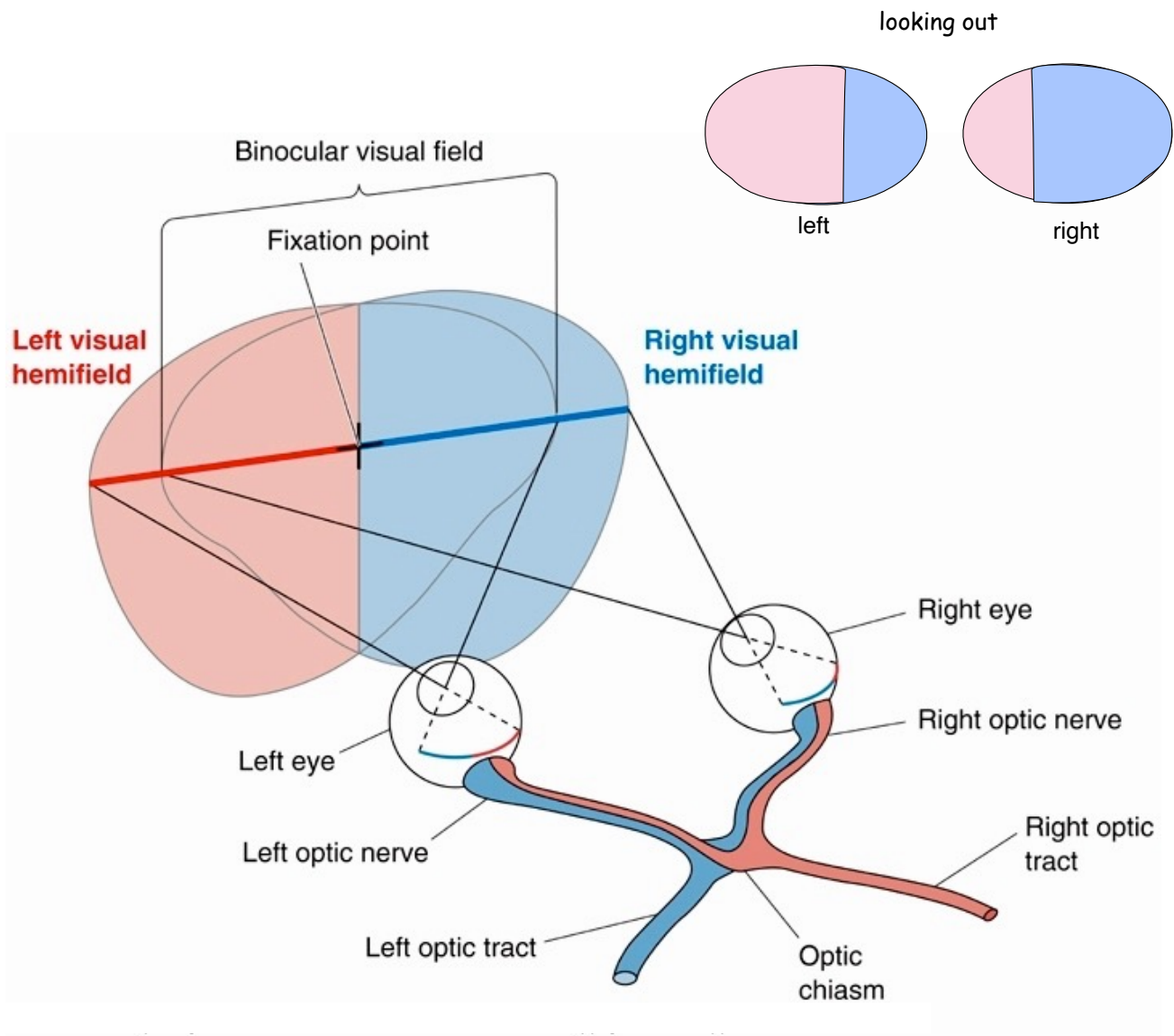
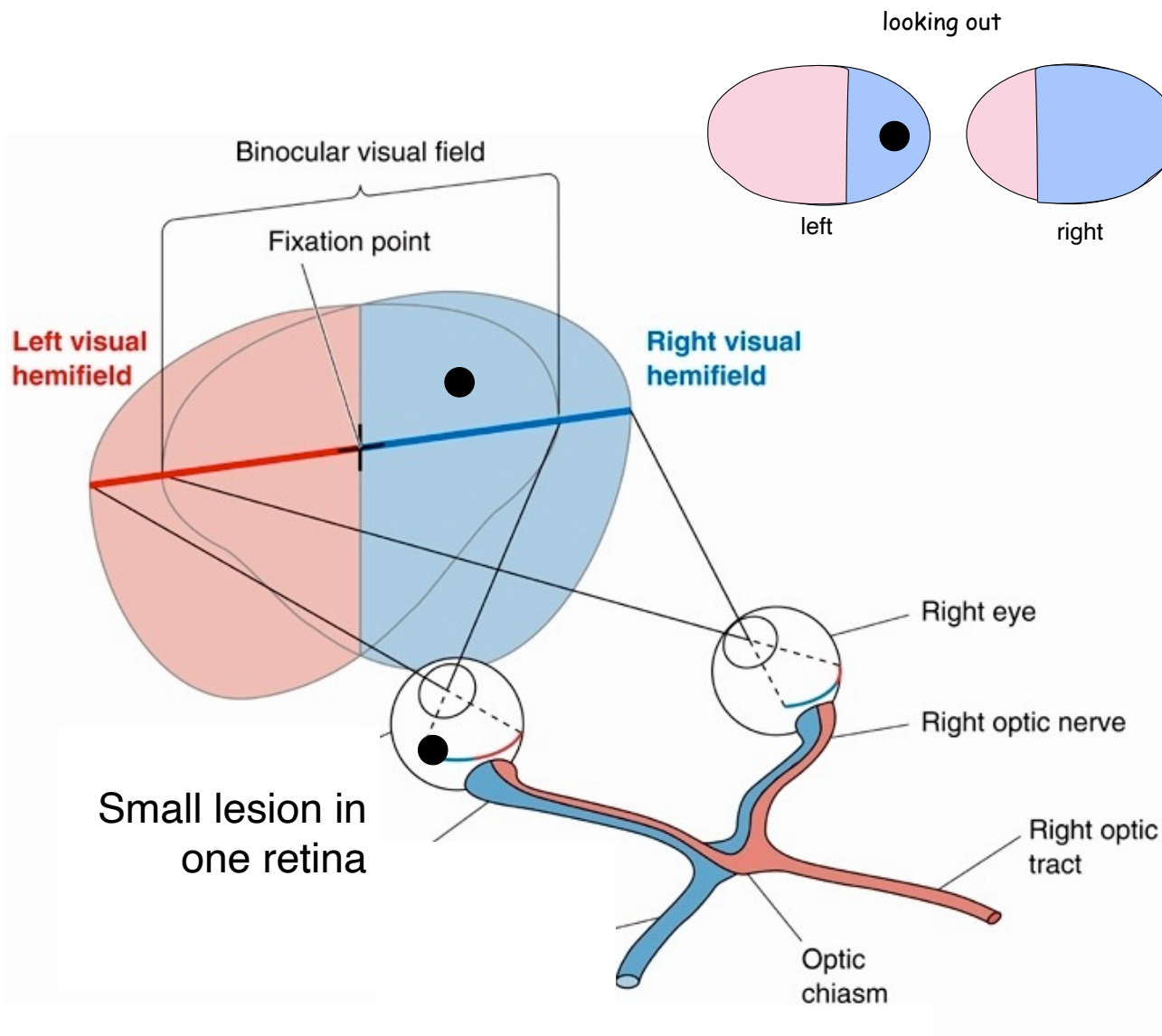
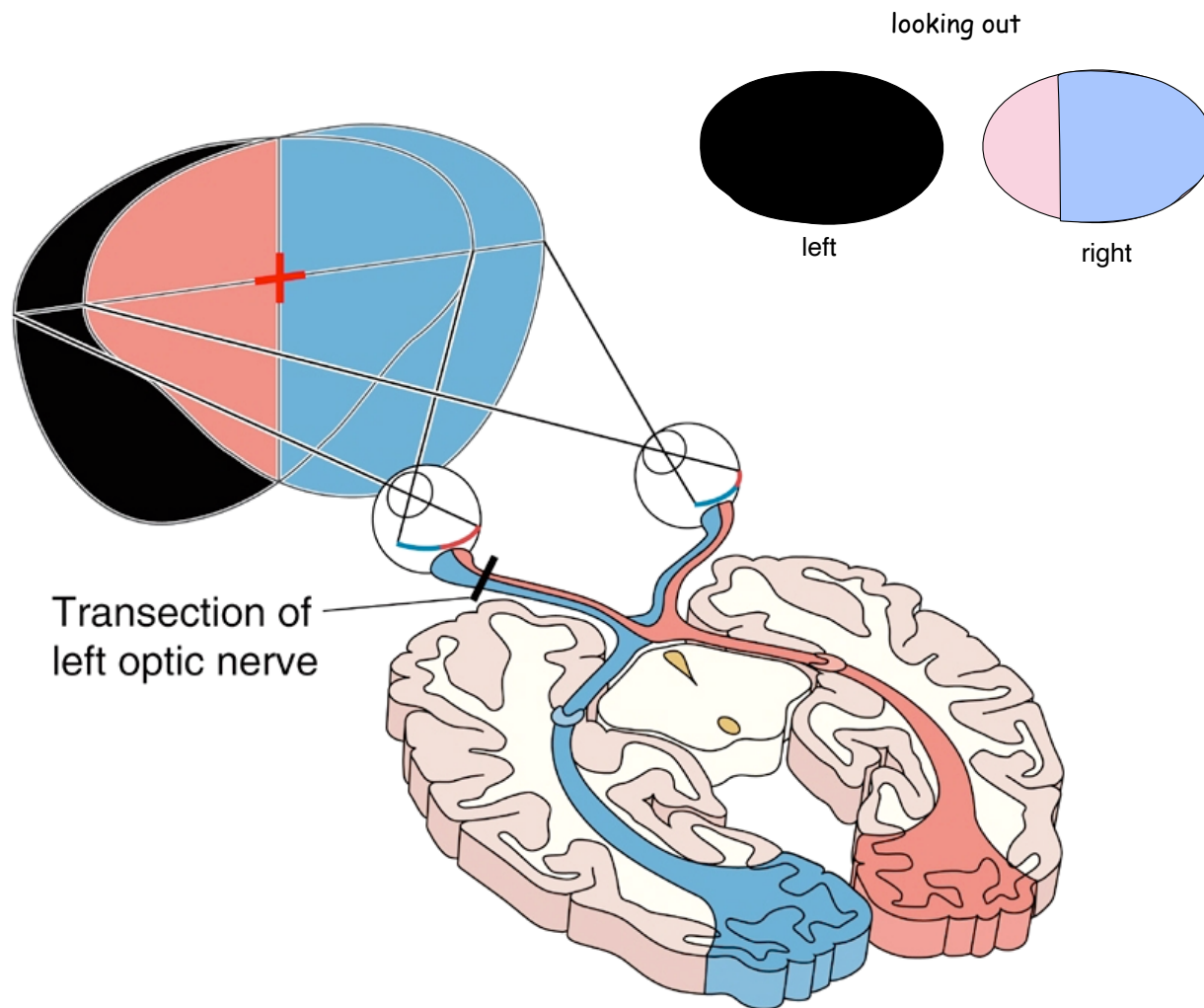


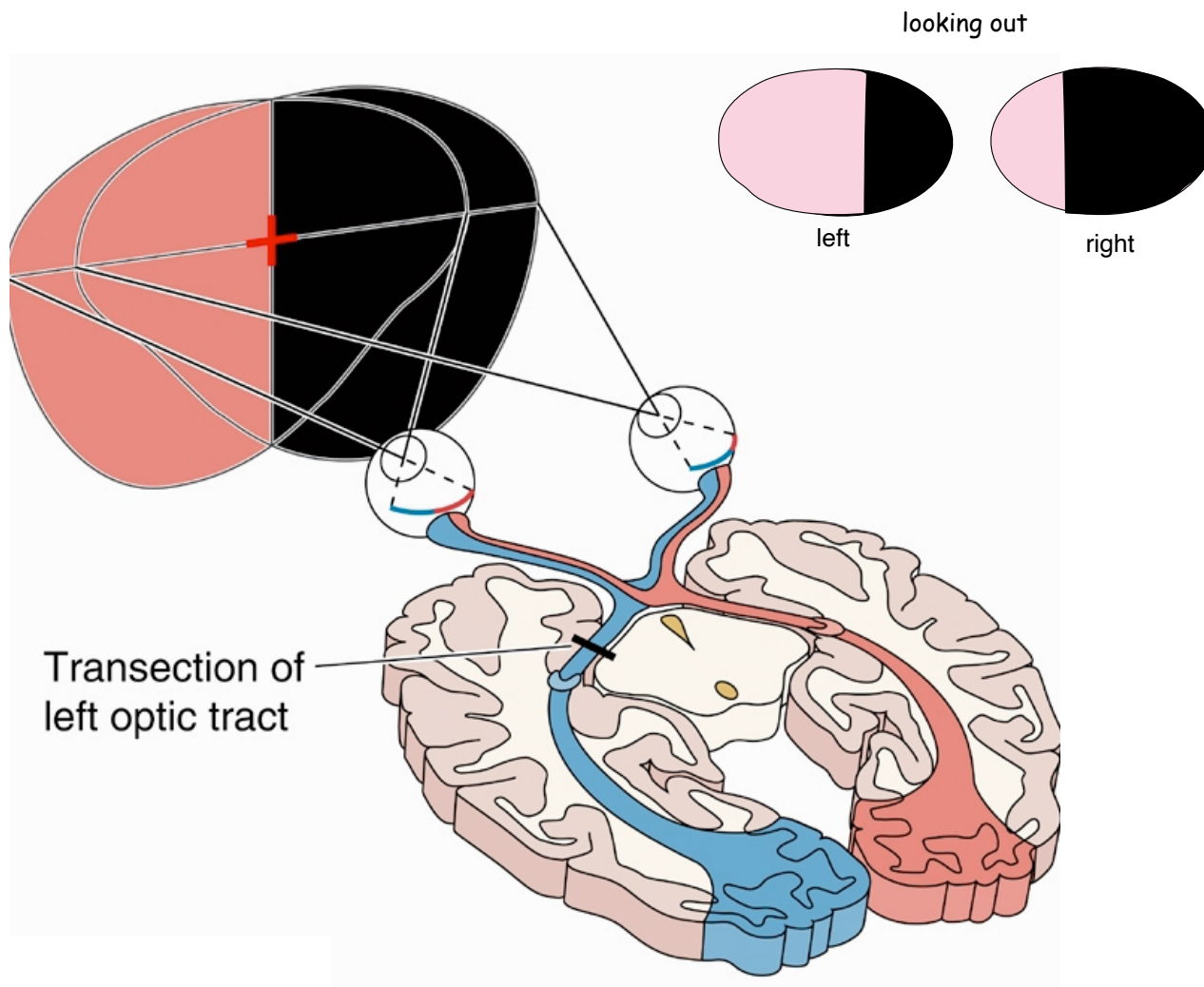
Figure 10.45

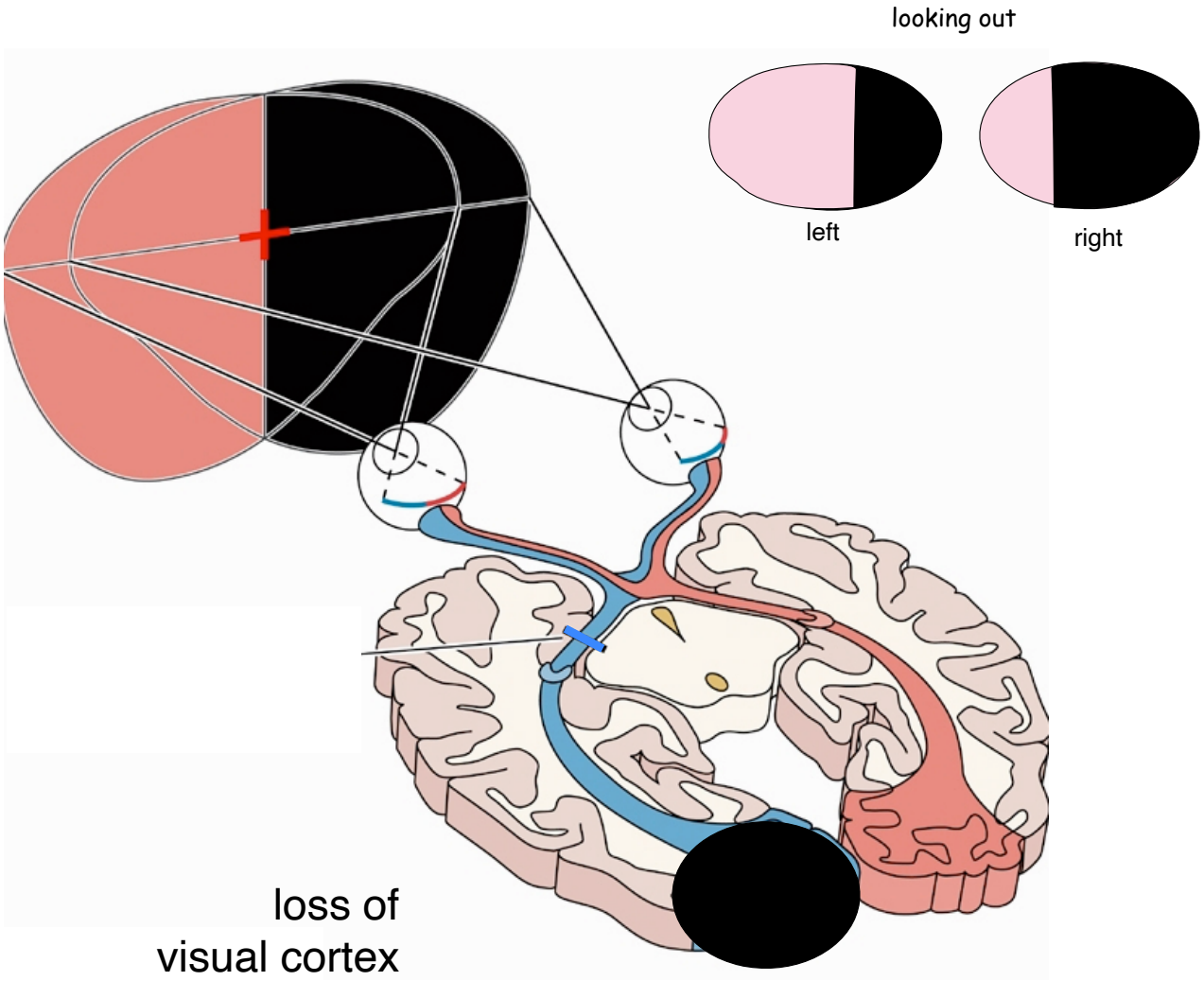


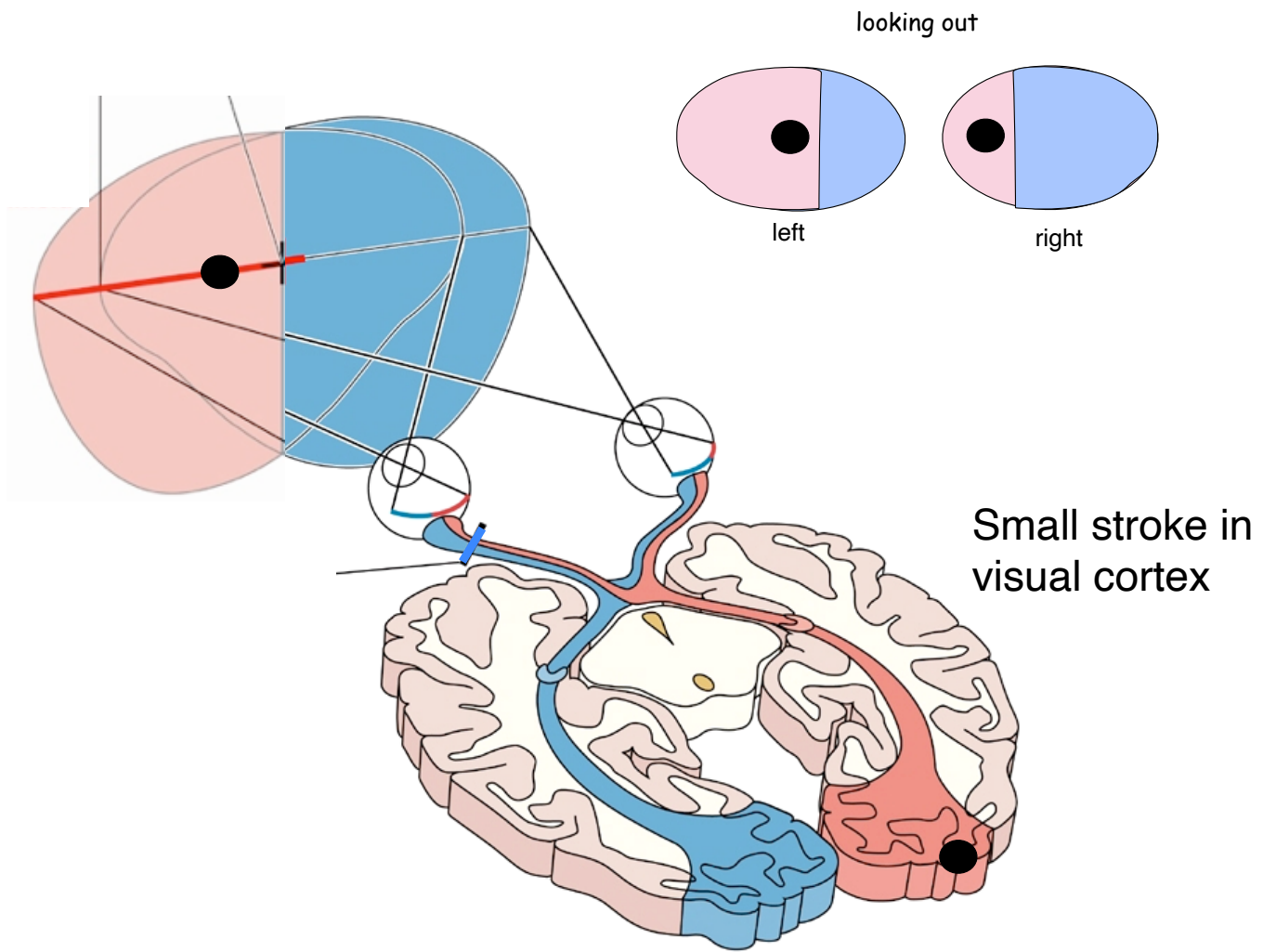


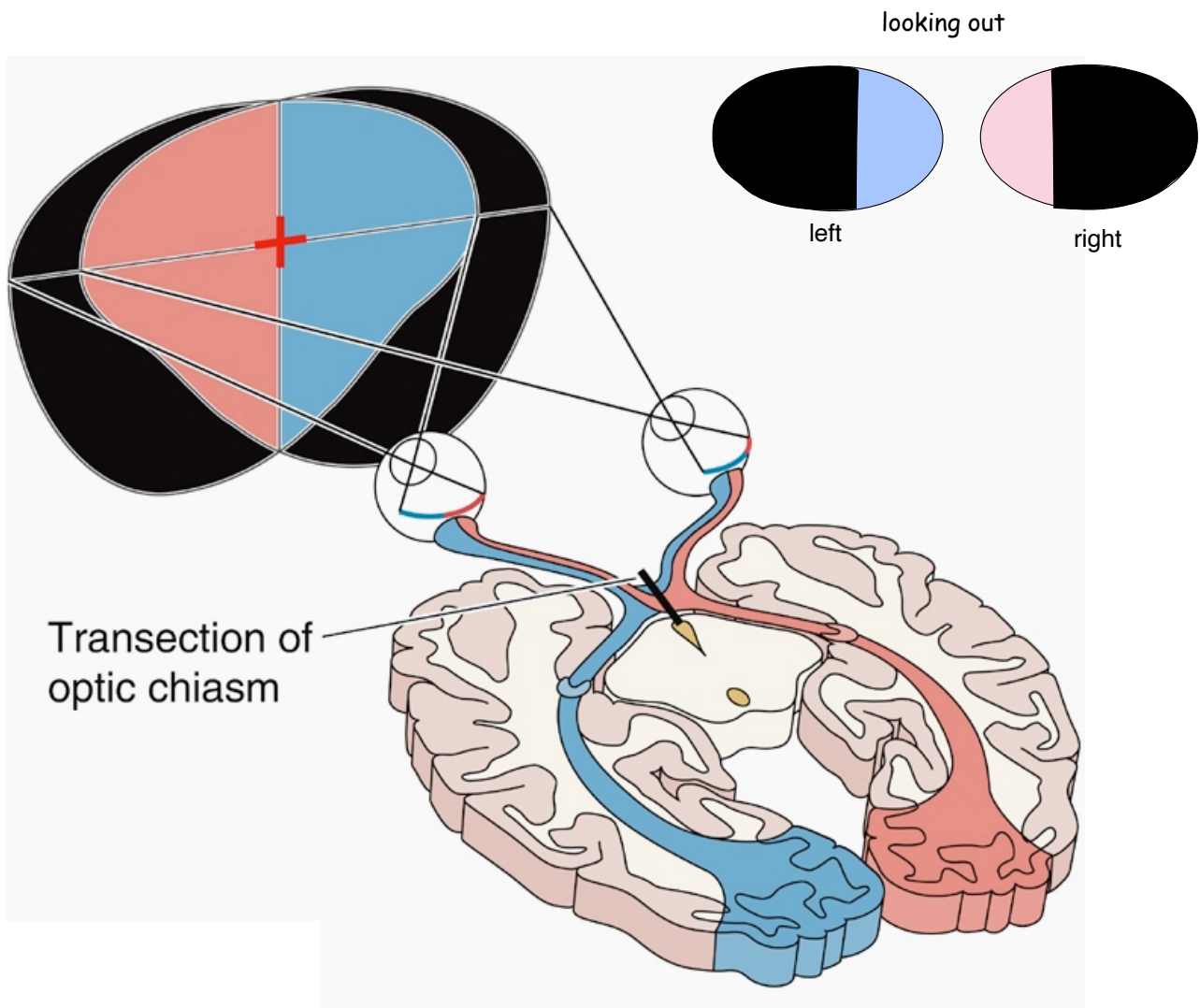












Feature Extraction by Visual Cortex

Primary Visual Cortex (V1) contains simple and complex cells

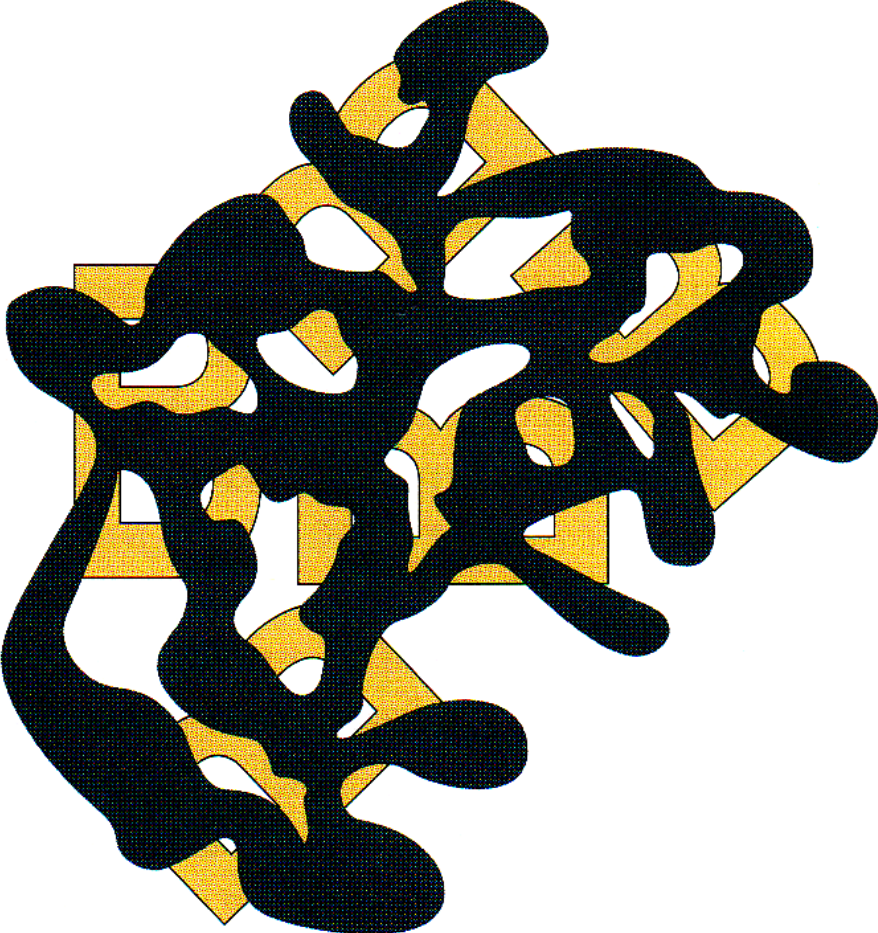
Simple cells

respond to orientation of stimulus at a specific spot in visual field; built up from input of ganglion cells

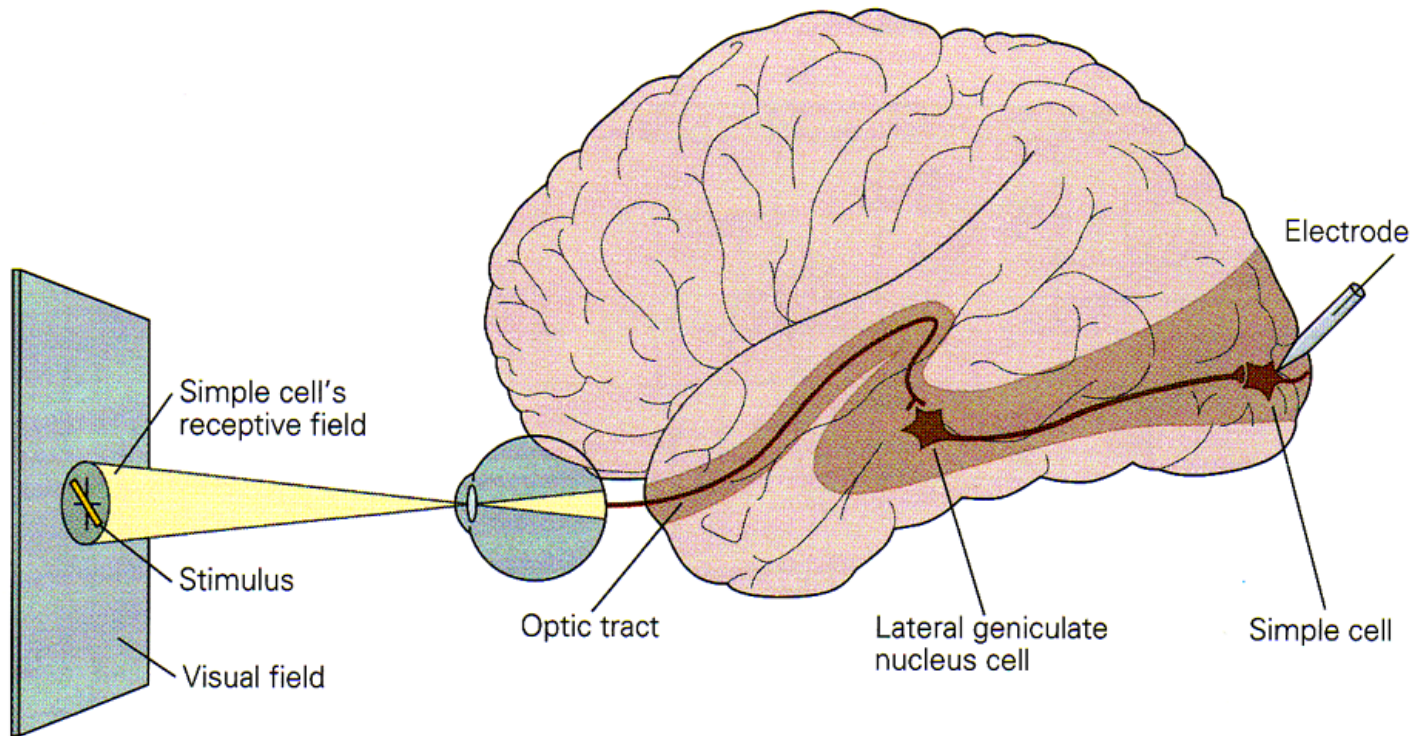
Complex cells

respond to orientation & direction of movement anywhere in the field; built up from input of simple cells

More to vision than just edges

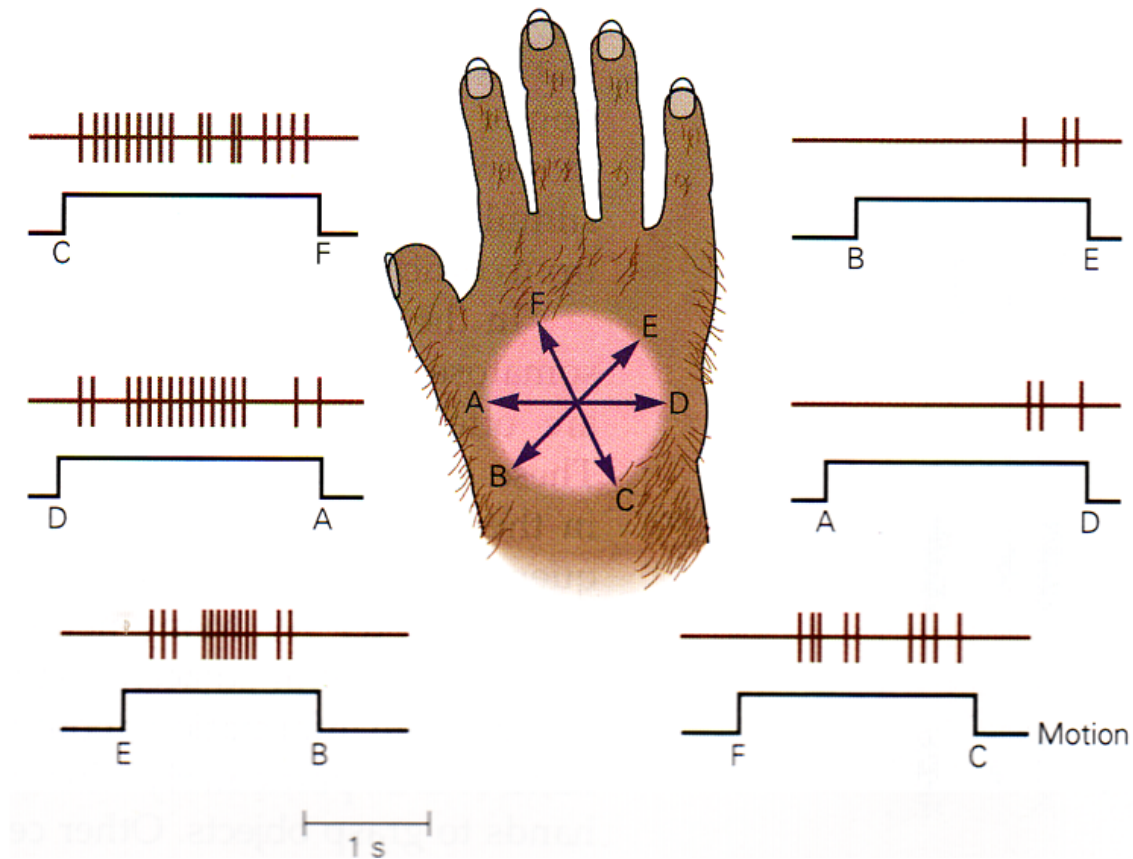


Testing the Cortical Response



Feature extraction by cortical neurons

Directional movement neuron

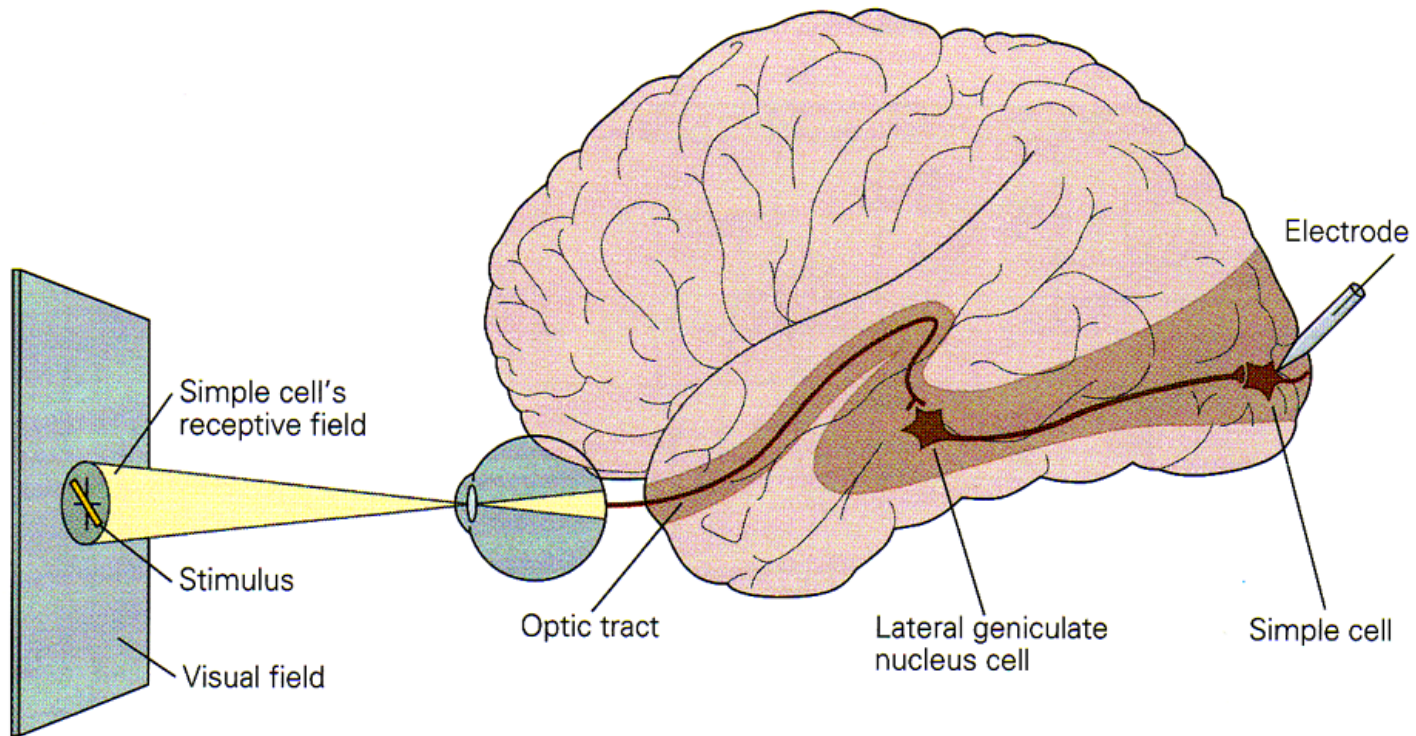


Hubel & Weisel Video

**Recording from visual cortex of cat while it
looks at visual stimulus on projection
screen**



Testing the Cortical Response





Simple Cell Response to Bar of Light

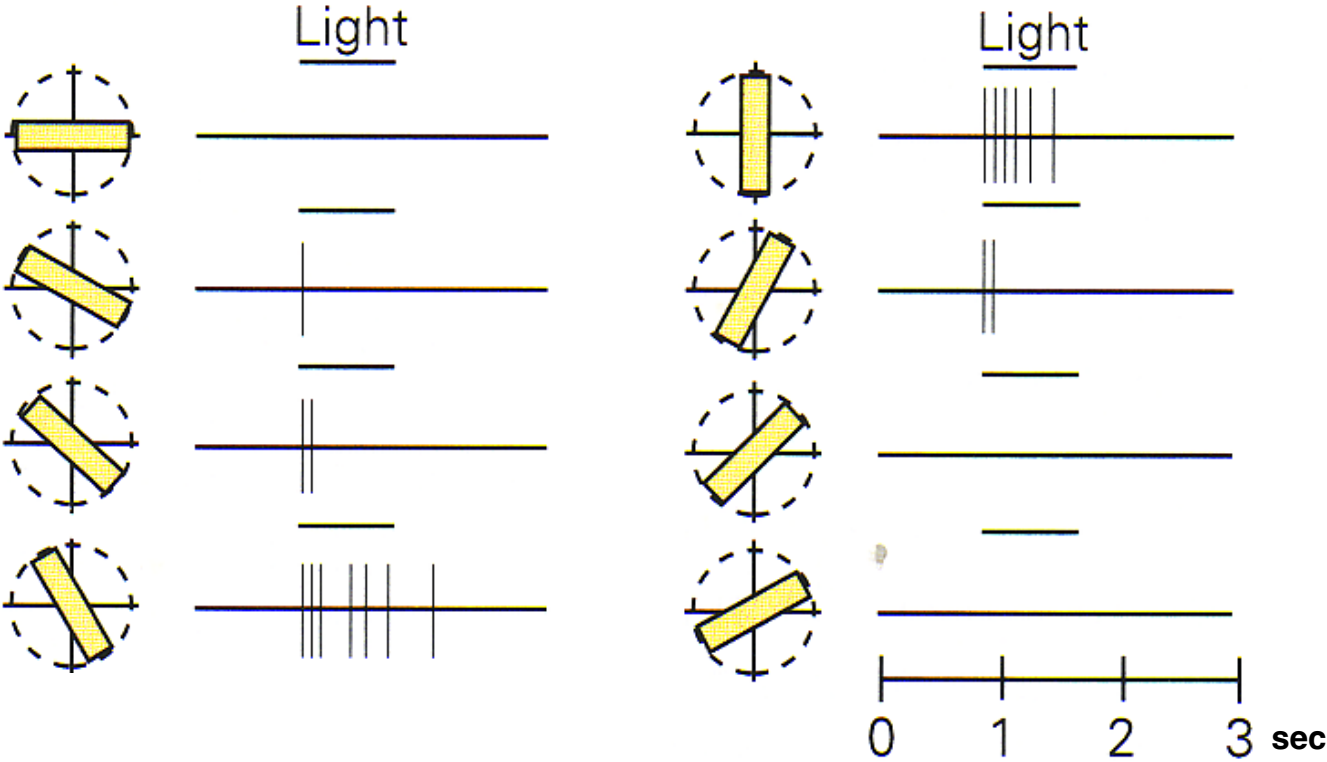
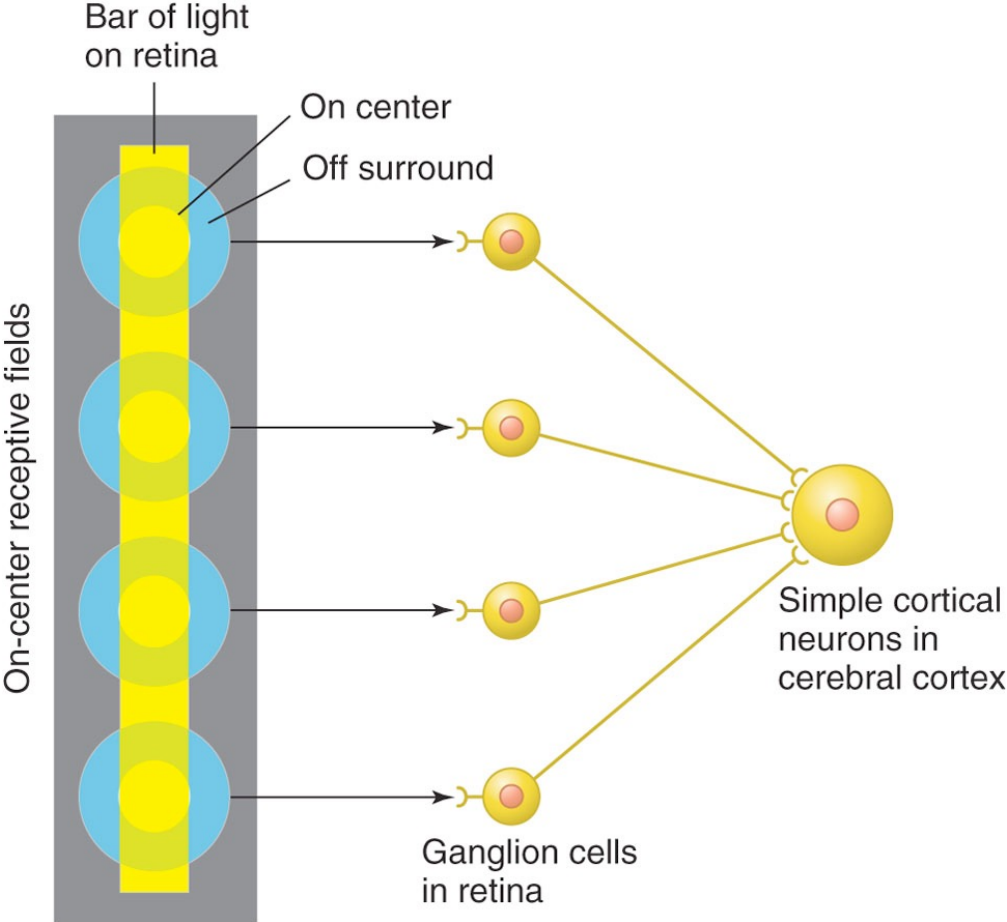
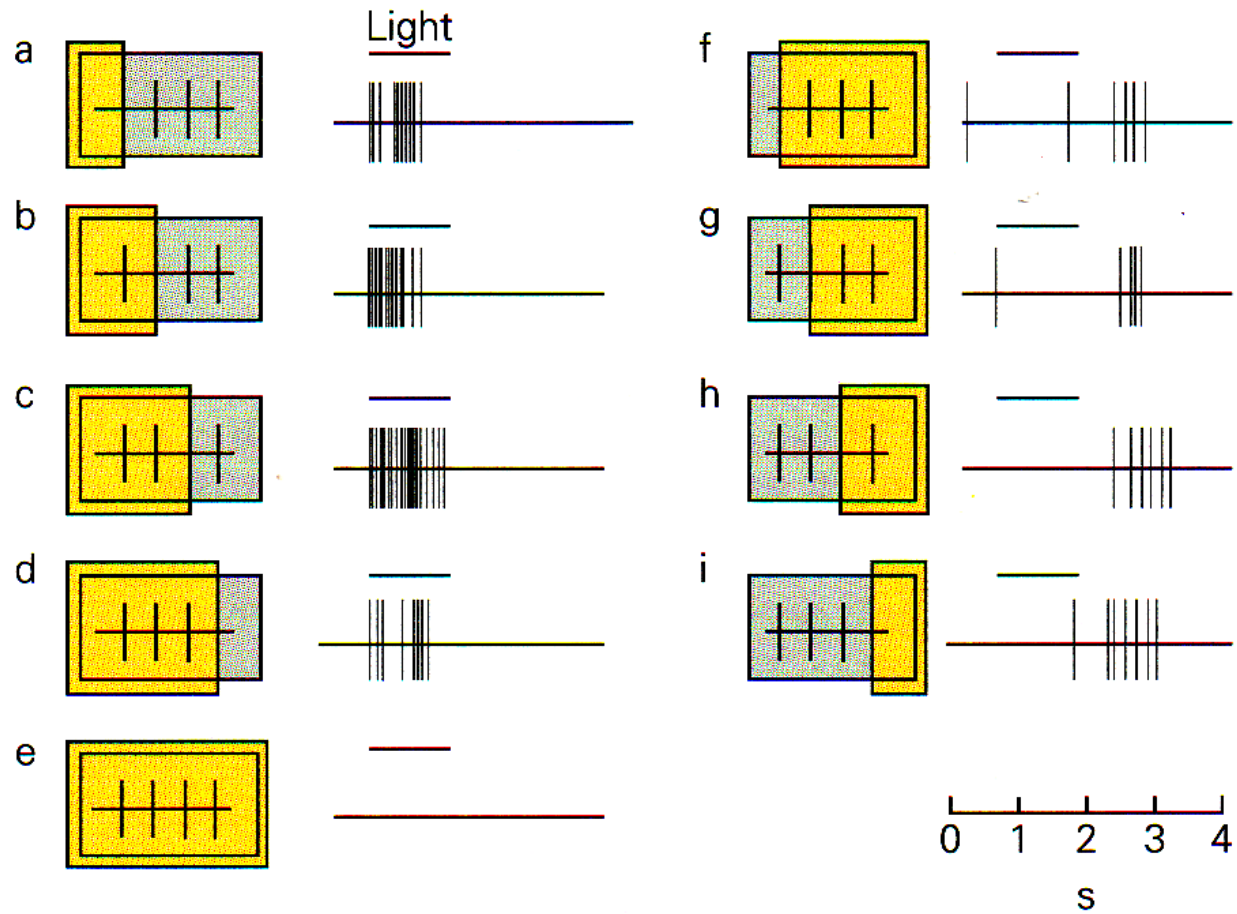


Figure 10.48



Complex Cell responds to bar of light moving in specific direction



Feature Extraction by Visual Cortex

Extrastriate Cortices receives input from visual cortex V1

Dorsal Pathway (Visual Cortex -> Parietal Cortex)

Action or spatial tasks - “where” info

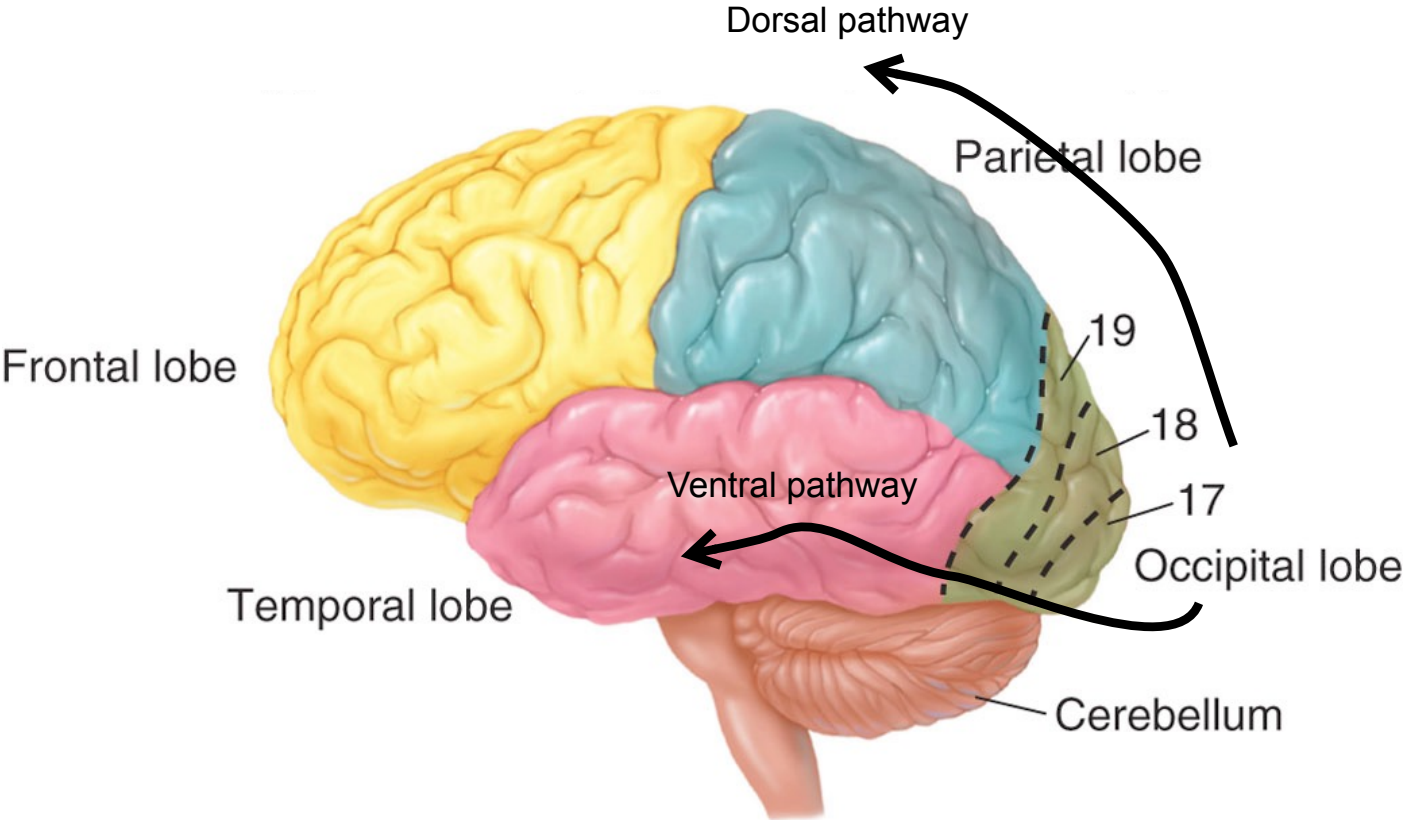
Lesions -> can't pick up or orient objects

Ventral Pathway (Visual Cortex -> Temporal Lobe, speech centers)

Form recognition - “what info”

Lesions -> can't recognize or describe objects & orientations, but visually guided motor responses okay

Figure 10.46

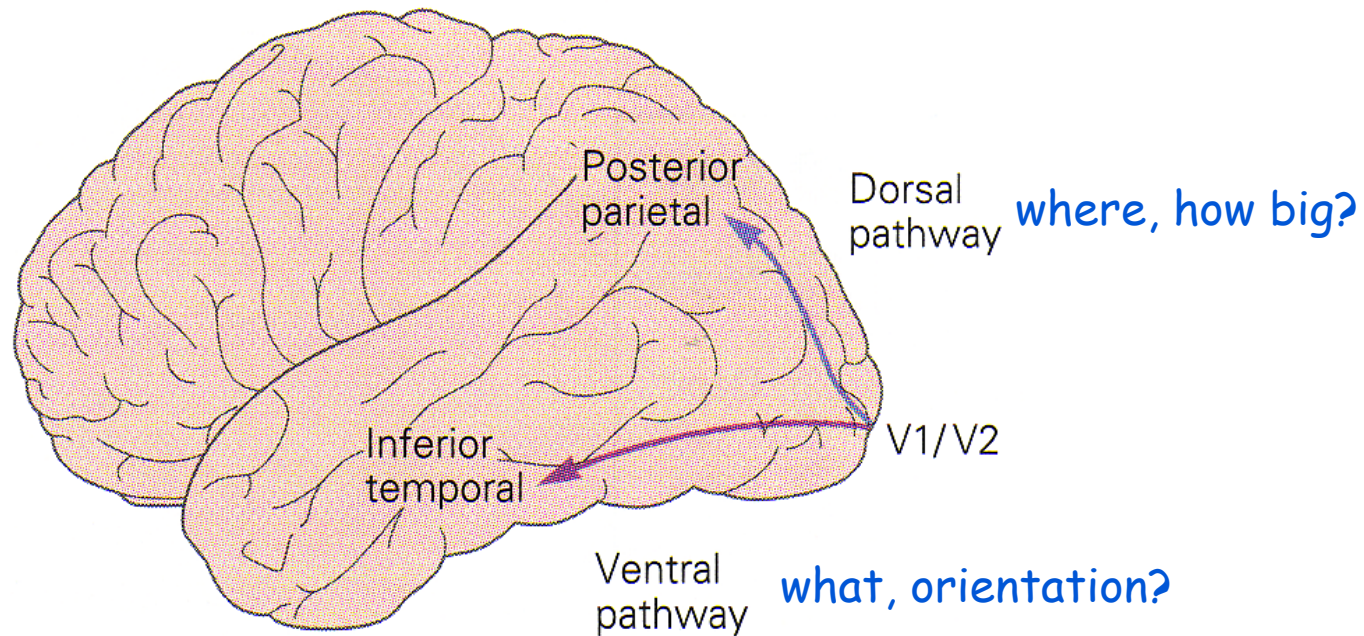


Extrastriate pathways beyond V1 for visual info:

Dorsal Pathway (Parietal Pathway)

Action or spatial tasks - “where” info

Lesions -> can't pick up or orient objects

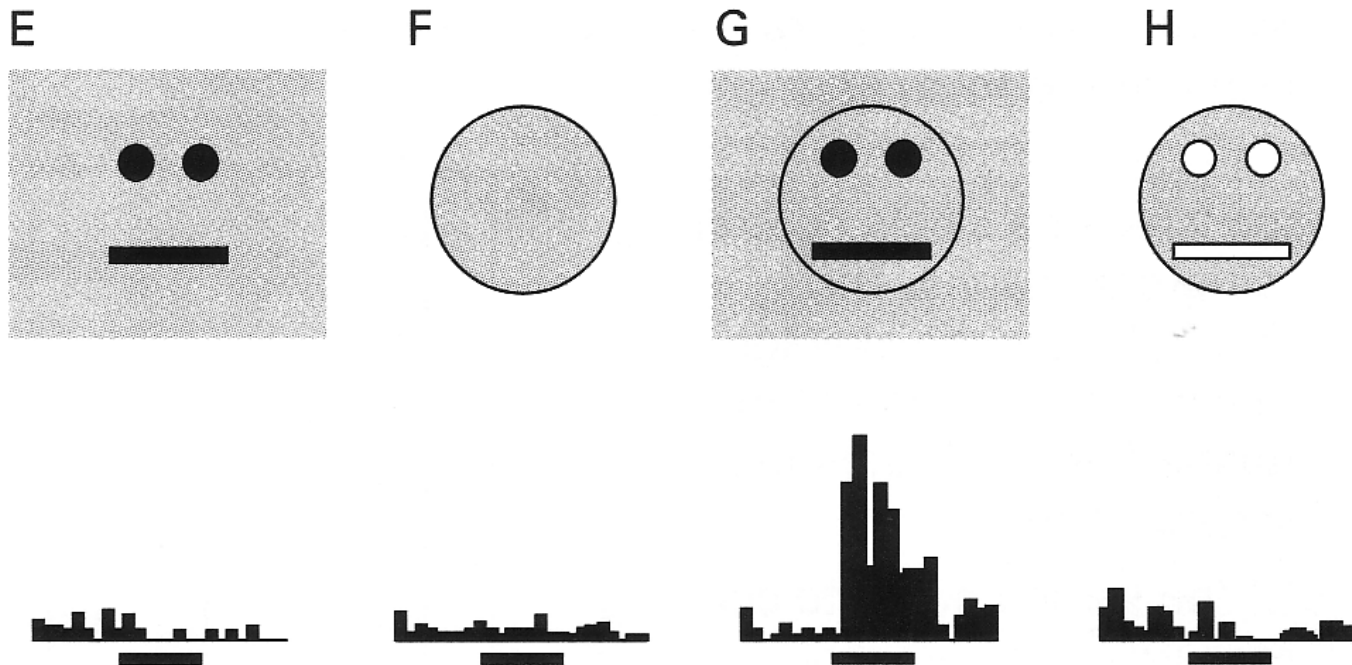


Ventral Pathway (Temporal Pathway)

Form recognition - “what info”

Lesions -> can't recognize or describe objects & orientations, but motor okay

Beyond the visual cortex: shape detection in temporal cortex

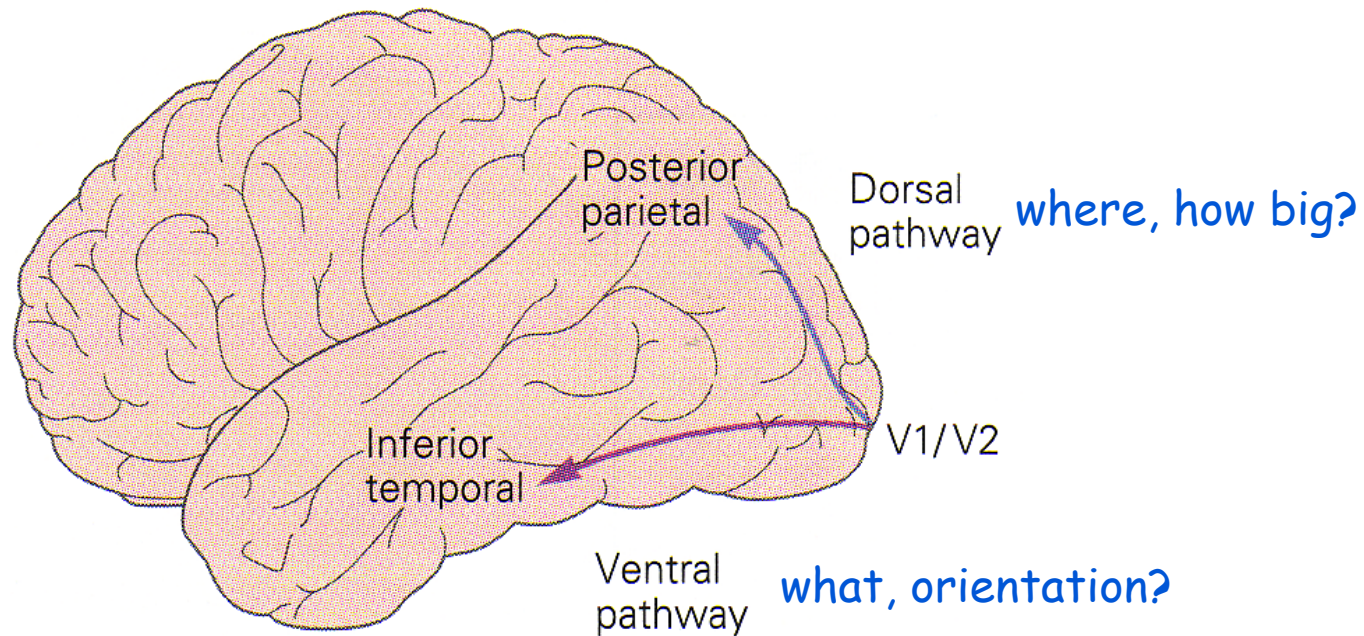


Extrastriate pathways beyond V1 for visual info:

Dorsal Pathway (Parietal Pathway)

Action or spatial tasks - “where” info

Lesions -> can't pick up or orient objects



Ventral Pathway (Temporal Pathway)

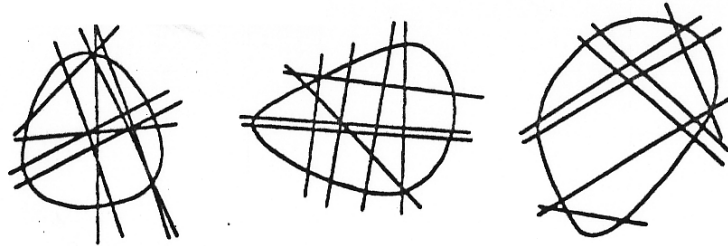
Form recognition - “what info”

Lesions -> can't recognize or describe objects & orientations, but motor okay

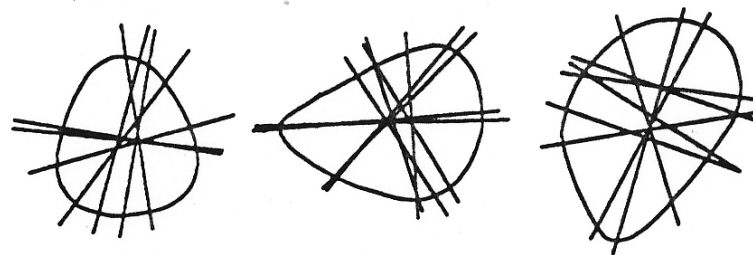
Task -- pick up an object

Patients with dorsal lesions cannot use vision to place their fingers in the right place to pick up an object

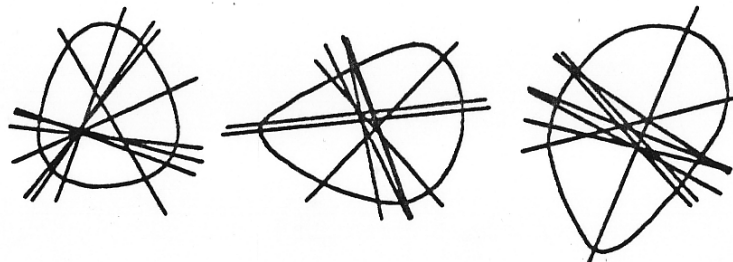
DORSAL
LESION
RV



VENTRAL
LESION
DF



Control



so dorsal pathway required for visual motor skills

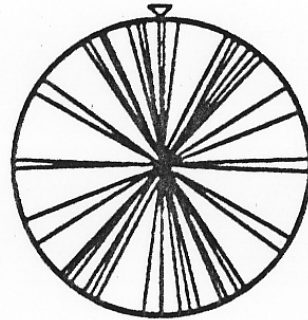
Ventral lesion:

can't recognize orientation of card, but can move card to correct orientation

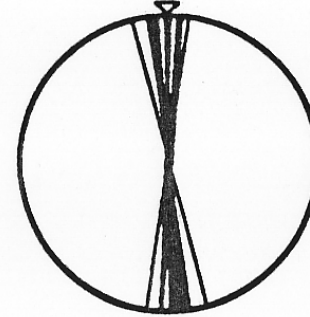
ask patient to describe the orientation of a "mail slot"

Ventral lesion

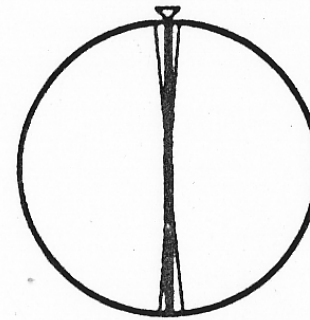
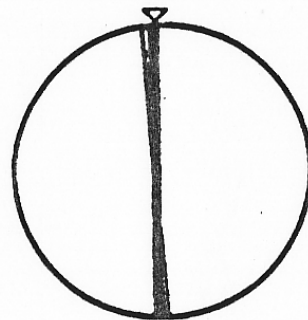
Perceptual Orientation Matching



Visuomotor "Posting"

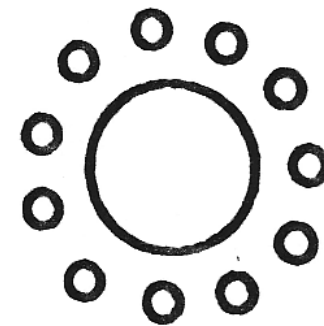
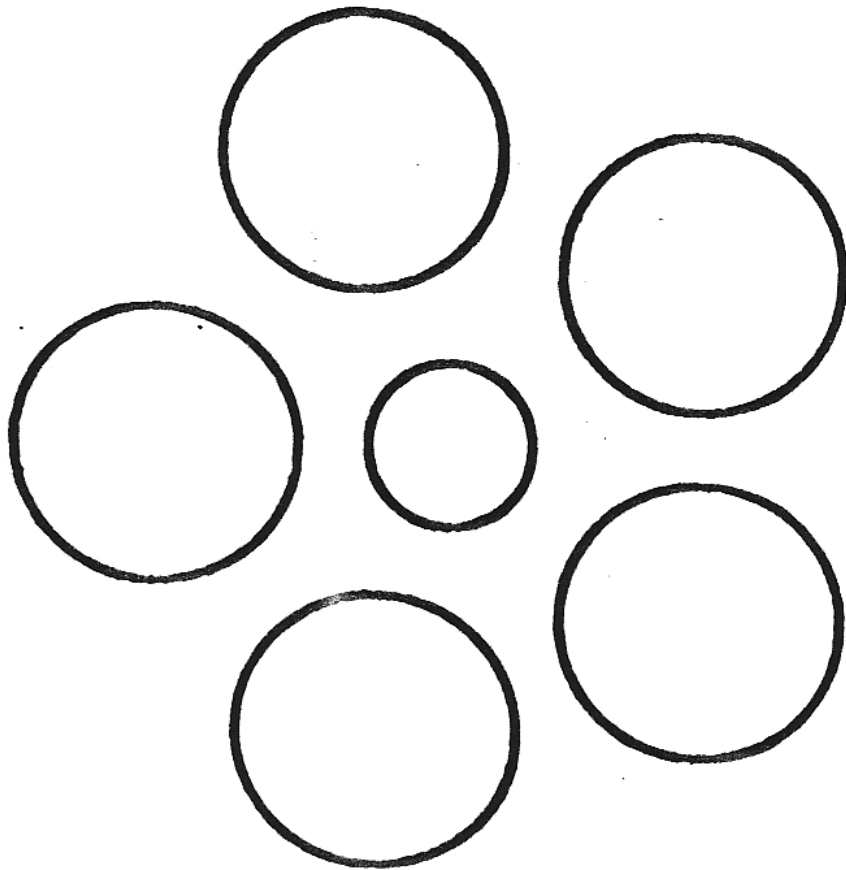


Control



so ventral pathway required for perception of visual scene

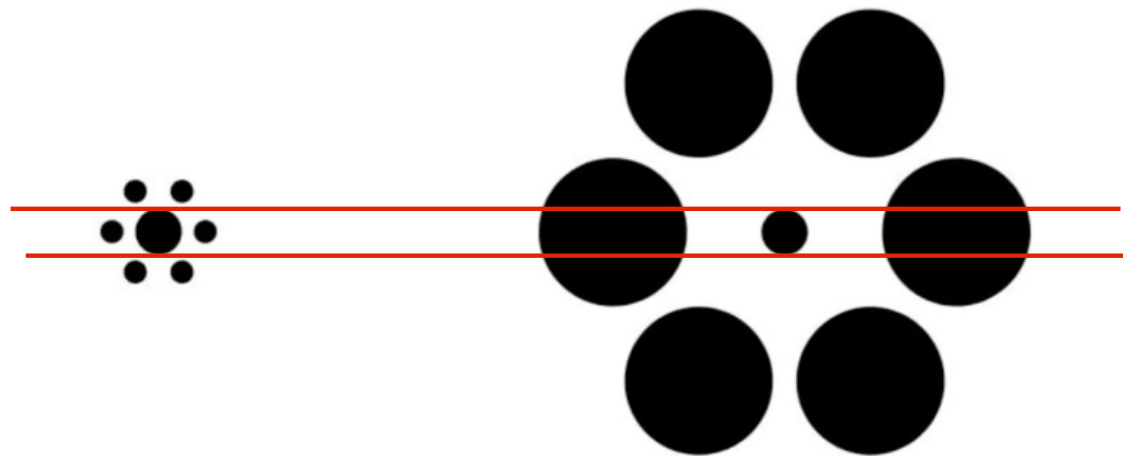
Normal people have these two pathways



Ebbinghaus illusion

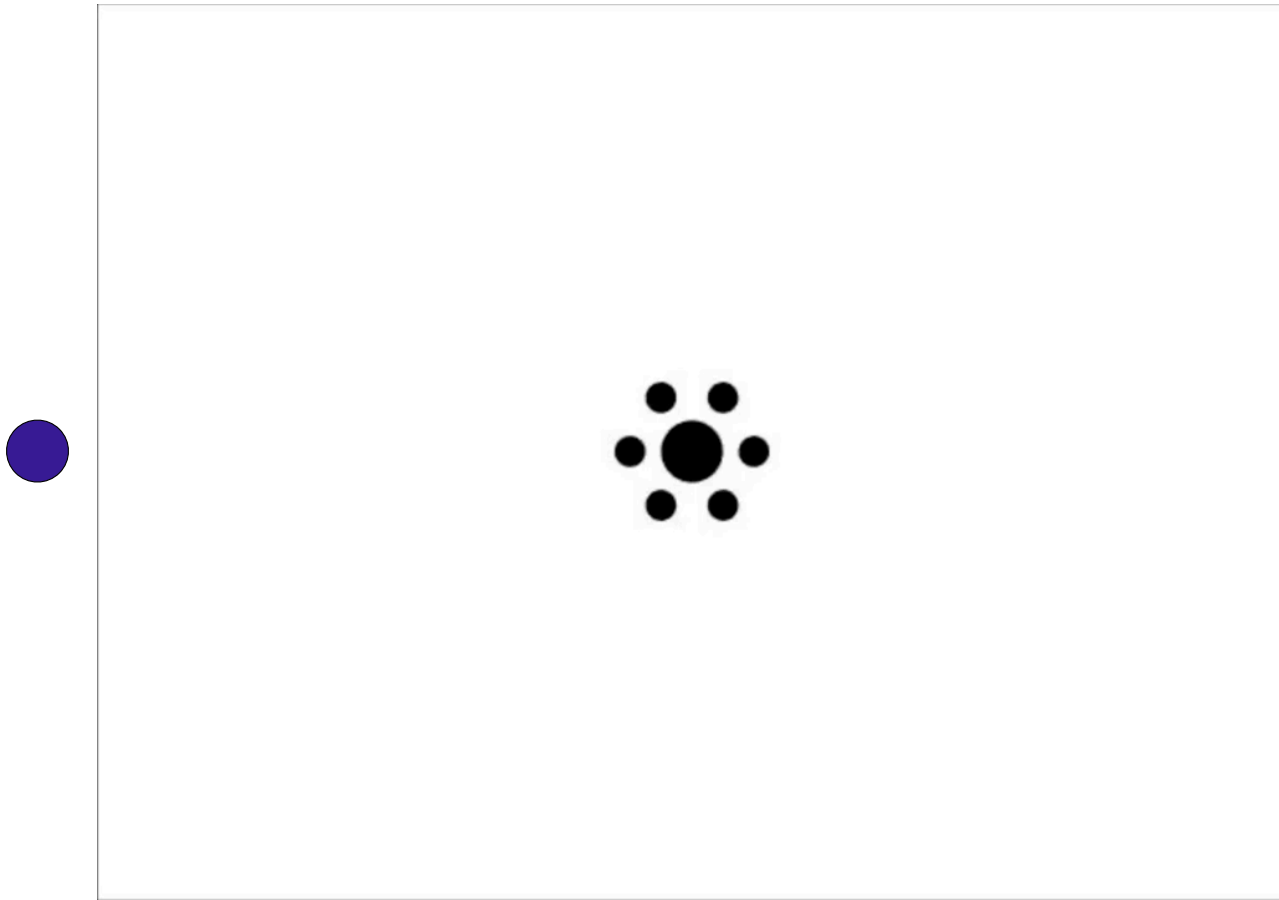
ventral pathway sees two different sizes

Normal people have these two pathways



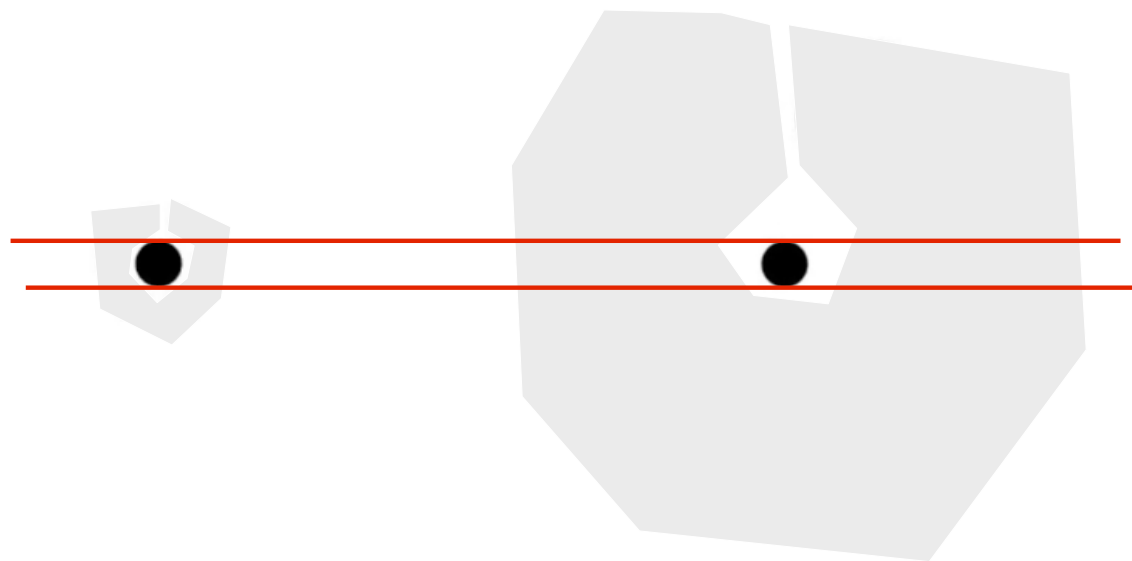
Ebbinghaus illusion

ventral pathway sees two different sizes



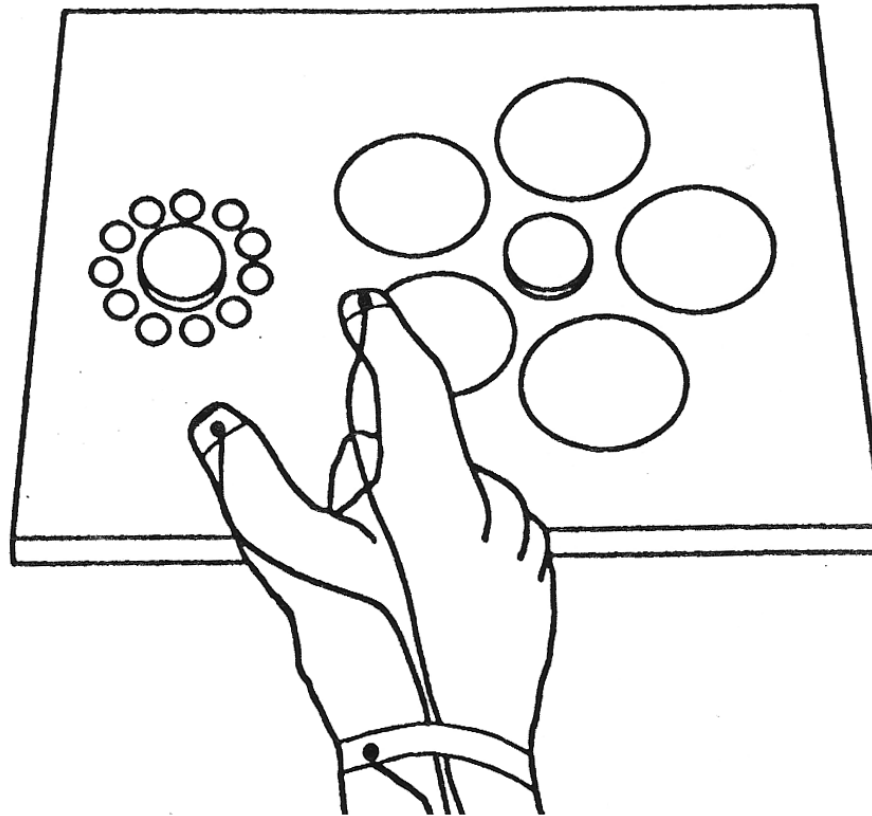
Ebbinghaus illusion

ventral pathway sees two different sizes



“Physical” Ebbinghaus

Ask subject to pick up the middle disk, and measure how they separate their thumb and finger



finger separation anticipates same disc size even though discs “look” different

dorsal pathway sees same sizes