Physiology

Modified no.7

الكاتب: سارة عمر و عمر صمادي

المدقق: ميس قشوع و أحمد رشيد

الدكتور: فاطمة ريالات

بسم الله الرحمن الرحيم

Neurophysiology

Vision III

Color code

Black	Slides
Blue	Doctor
Light blue	Additional info
Red	Important

Cones

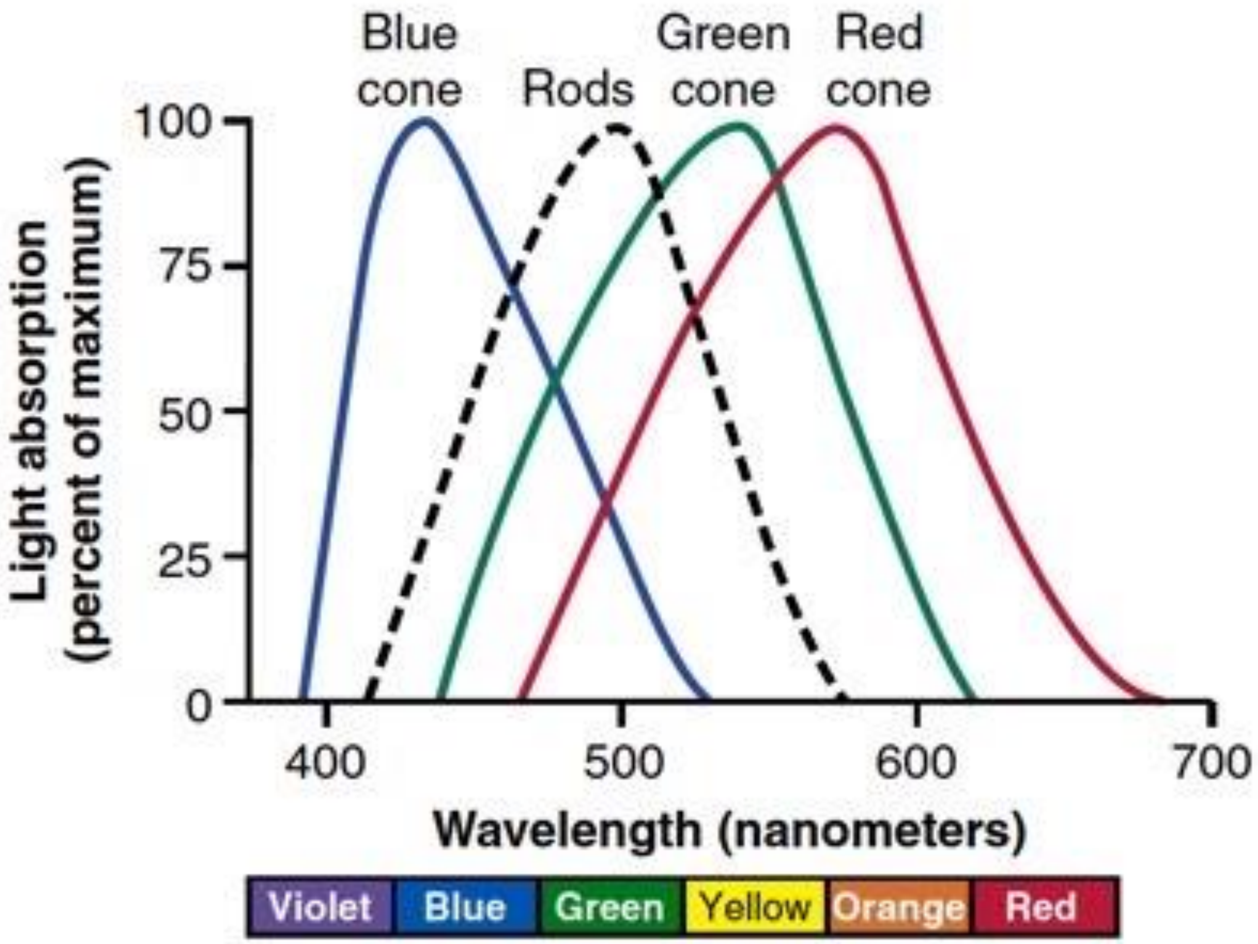
- photochemicals in the cones have almost exactly the same chemical composition as that of rhodopsin in the rods.

Cones and rods have the same mechanism

- 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



Color vision

Cones are responsible for Color Vision, since there are 3 types of cones , Red, green and blue

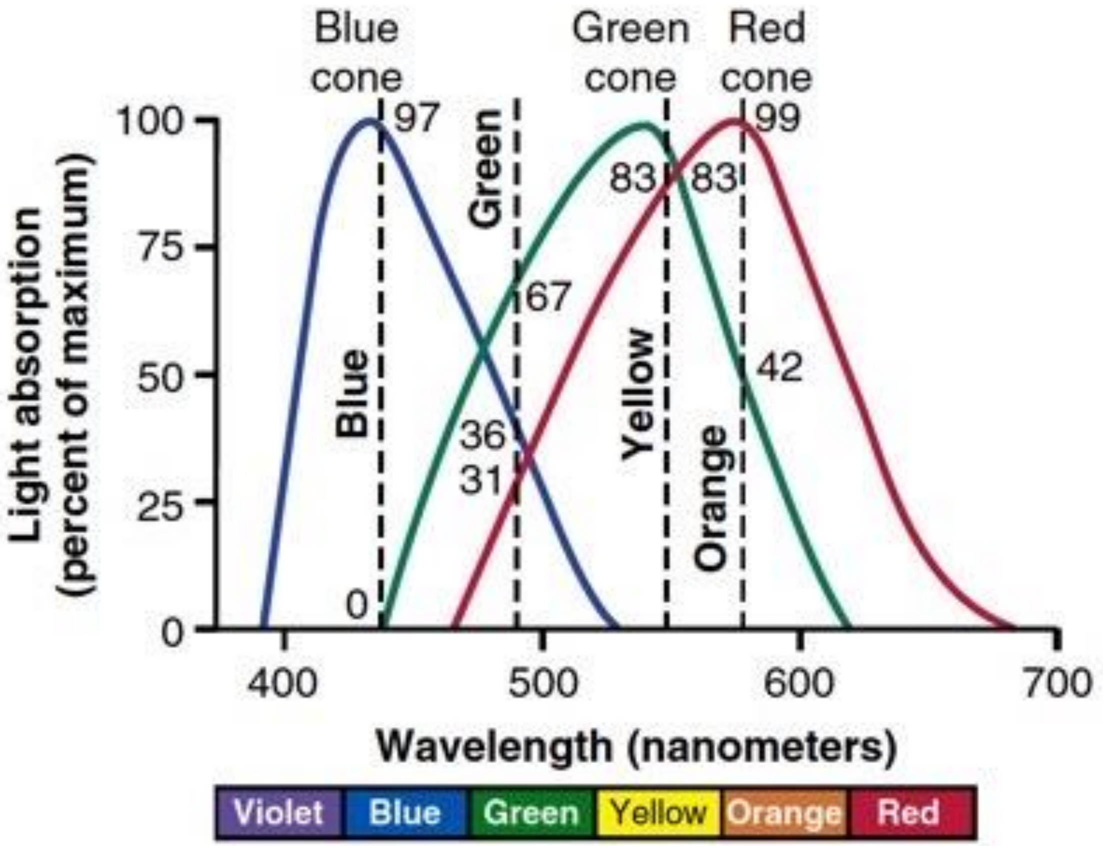
- Each cone type is most effectively activated by a particular wavelength of light in the range of color indicated by its name.
- cones also respond in varying degrees to other wavelengths.

How do we see many colors , when there are only 3 types of cones , Red, green and blue???

- 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.

Answer: Different combinations of stimulation of these 3 types of cones
Check the example in the next slide

- Mixing ratios of stimulation rather than pigments
- 83% Green stimulation + 83% Red stimulation + 0% blue stimulation= Yellow
- 67% Green stimulation + 31% Red stimulation + 36% blue stimulation= Green
- Each cone has a peak in which at certain wavelength there will be a maximal absorption =100% stimulation



<u>the ratios of stimulation of the three types of cones.</u>

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

Color vision

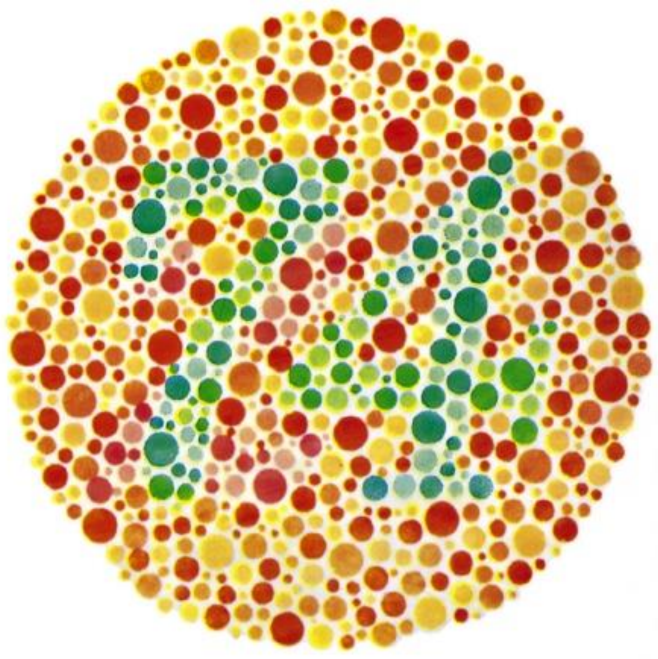
Cones are responsible for **Color Vision**, since there are 3 types of cones , Red, green and blue

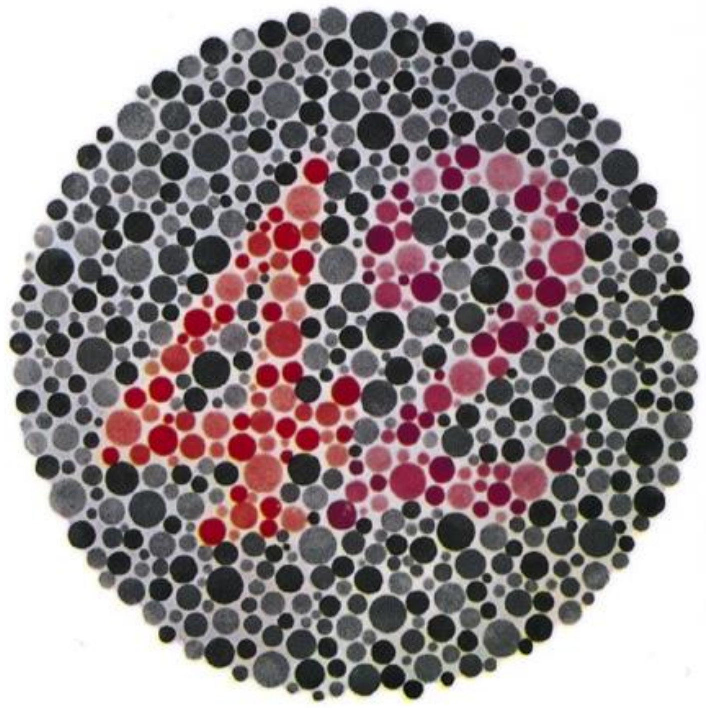
- Each photopigment maximally absorbs a particular wavelength but also absorbs a range of wavelengths shorter and longer than this peak absorption.

- 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.

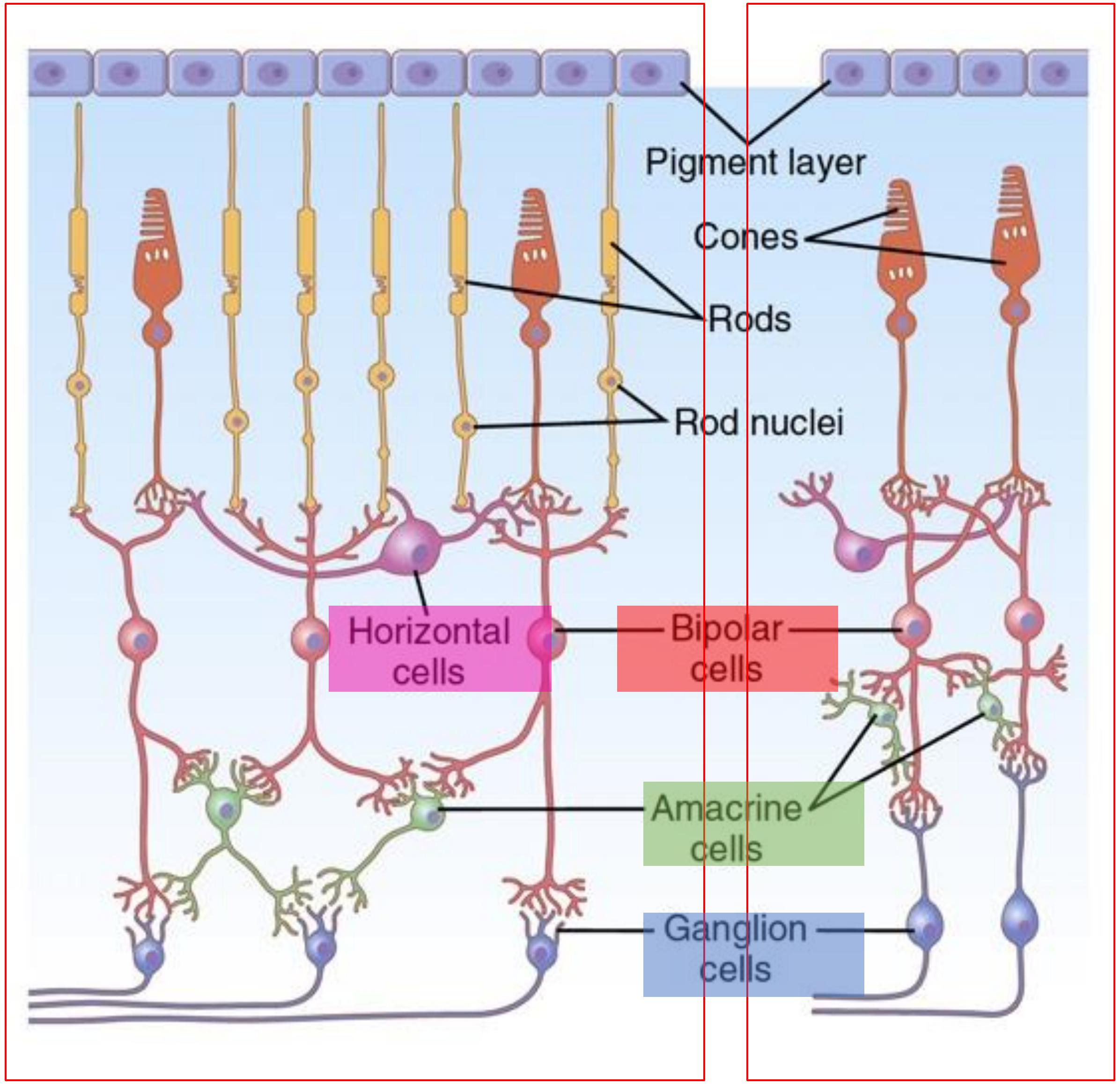
- When there is a problem in one type of these cones -mostly green-, this leads to color blindness, this problem is X-linked so it is more common in males than females.
- People with color blindness can see color, however not a bright spectrum of colors as normal people.





Peripheral retina

Central retina (Fovea)
Has Cones only



Acuity and Contrast

- Cones Synapse directly with bipolar cells (1:1), provides acuity in the central retina.

- **Horizontal** cells in the **inner** plexiform layer, spread horizontally. They provide lateral inhibition which is super important especially in the fovea because they make the image we see sharper.
- **Amacrine** cells in the **inner** plexiform layer, also provide lateral inhibition.

Sensitivity

- On the other hand multiple **rods** synapse with one bipolar cell (multiple rods: 1 bipolar nerve) this characteristic is called **conversion**. Which makes the rods more sensitive to light than cones, what does that mean?

- A low intensity of light will be detected by rods then at the level of convergence there will be spatial summation.

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.

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.

Light adaptation

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

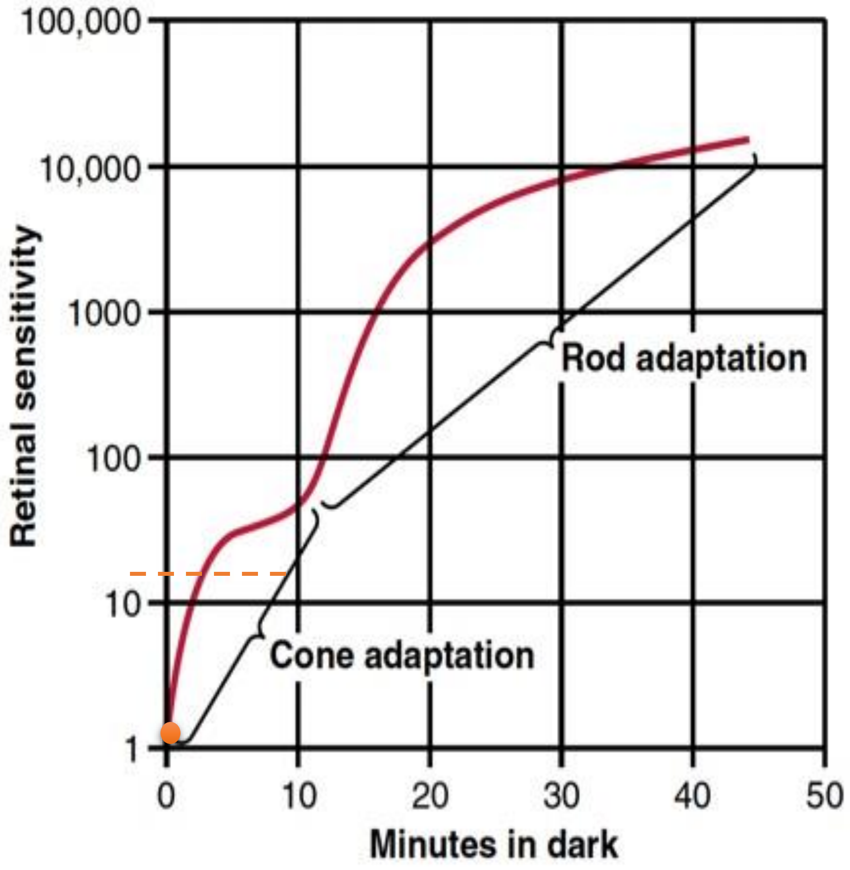
- As some of the **photopigments** are rapidly **broken down** by the intense light, **the sensitivity of the eyes decreases** and **normal** contrasts can **again** be detected, a process known as **light adaptation.**

Dark adaptation

Moving from light to dark

- **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.



Dark adaptation

- When moving to a dark room, the retinal sensitivity is almost zero because the photosensitive material is consumed.
- **The first phase** in dark adaptation is due to the **cones** because they regenerate photochemicals more **rapidly** than rods. However, they are **less sensitive**, as you can see in the figure, they increases the **sensitivity** to less than 100 folds.
- **The second phase** is due to rods, as they play the main role in increasing the **sensitivity.**

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.

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

Recall:

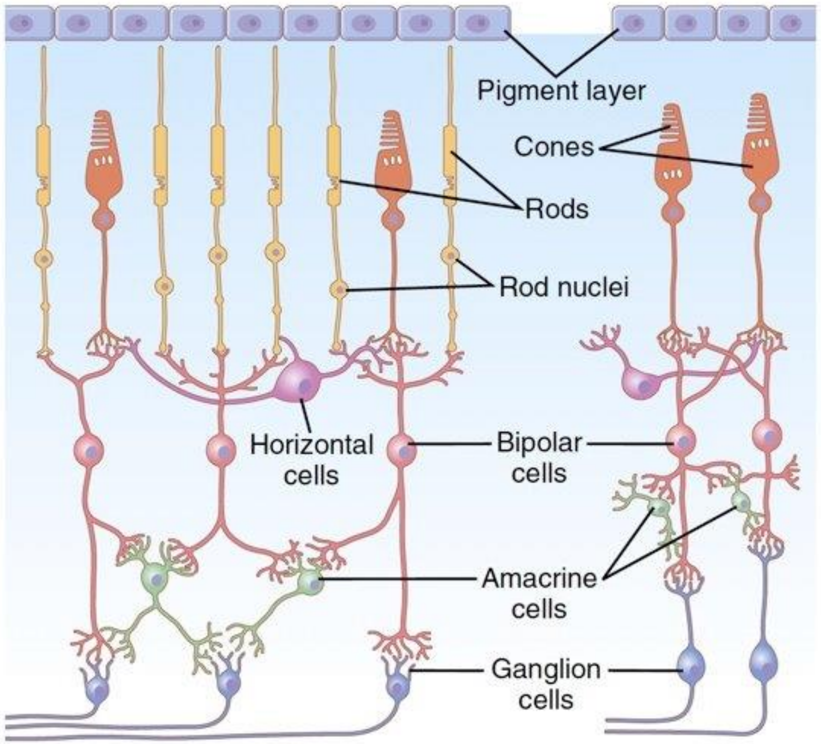
- Photoreceptor Signalling Mechanism: Photoreceptors **hyperpolarize** in **light** → **stop** releasing **glutamate** → signals **light** presence (no signal sent).
- Photoreceptors depolarize in darkness → **release glutamate** → glutamate acts on bipolar cells→ signals **darkness**.

- However, it is not always the case: the key theory suggests that there are **two types of bipolar cells**, based on their response to glutamate. This distinction arises because glutamate binds to two types of receptors:

1. **Excitatory bipolar cells**, **ionotropic** receptors cause **depolarization**, leading to signal transmission→ signals Light.

2. **Inhibitory bipolar** cells utilize **metabotropic** receptors, which **hyperpolarize** the cell, reducing signal transmission→ signals Dark.

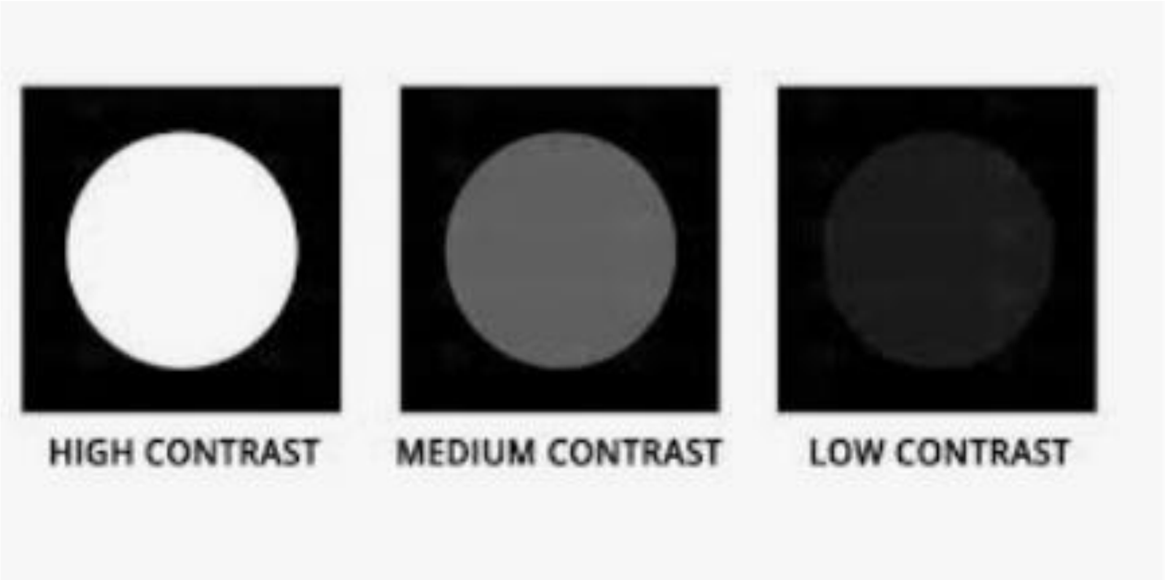
This dual mechanism (excitation and inhibition of bipolar cells) plays a crucial role in enhancing **image contrast** by allowing the retina to differentiate between light and dark regions more effectively.



Another mechanism mediated by **horizontal cells**, which enhance image contrast by **lateral inhibition.** They modulate the signal reaching bipolar cells by inhibiting neighboring photoreceptors, which alters glutamate release. This lateral inhibition enhances contrast by **making some bipolar cells more excited and others more inhibited, sharpening edge and_image contrast.**

على سبيل المثال عنا حيط ابيض سادة و بعدين علقنا عليه ساعة سوداء

When the whole wall is white – Plain white- There is no contrast only small numbers of receptors will be excited. When the clock is added, there will be a contrast between the edges of the clock and the wall, these edges will increase the stimulation of the visual System in general.



Action potential in the retina

- At the end, all signals converge onto ganglion cells

- The only **retinal neurons** that always transmit visual signals via **action potentials** are the **ganglion cells.** The **other cells** including, bipolar cells and photoreceptors, have **graded potential** which is important in determining the intensity of the stimulus and the different degrees of the stimulation enhancing the contrast 👇👇

- 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.

- There are many types of ganglion cells in the retina, the most important of which are P cells and M cells.

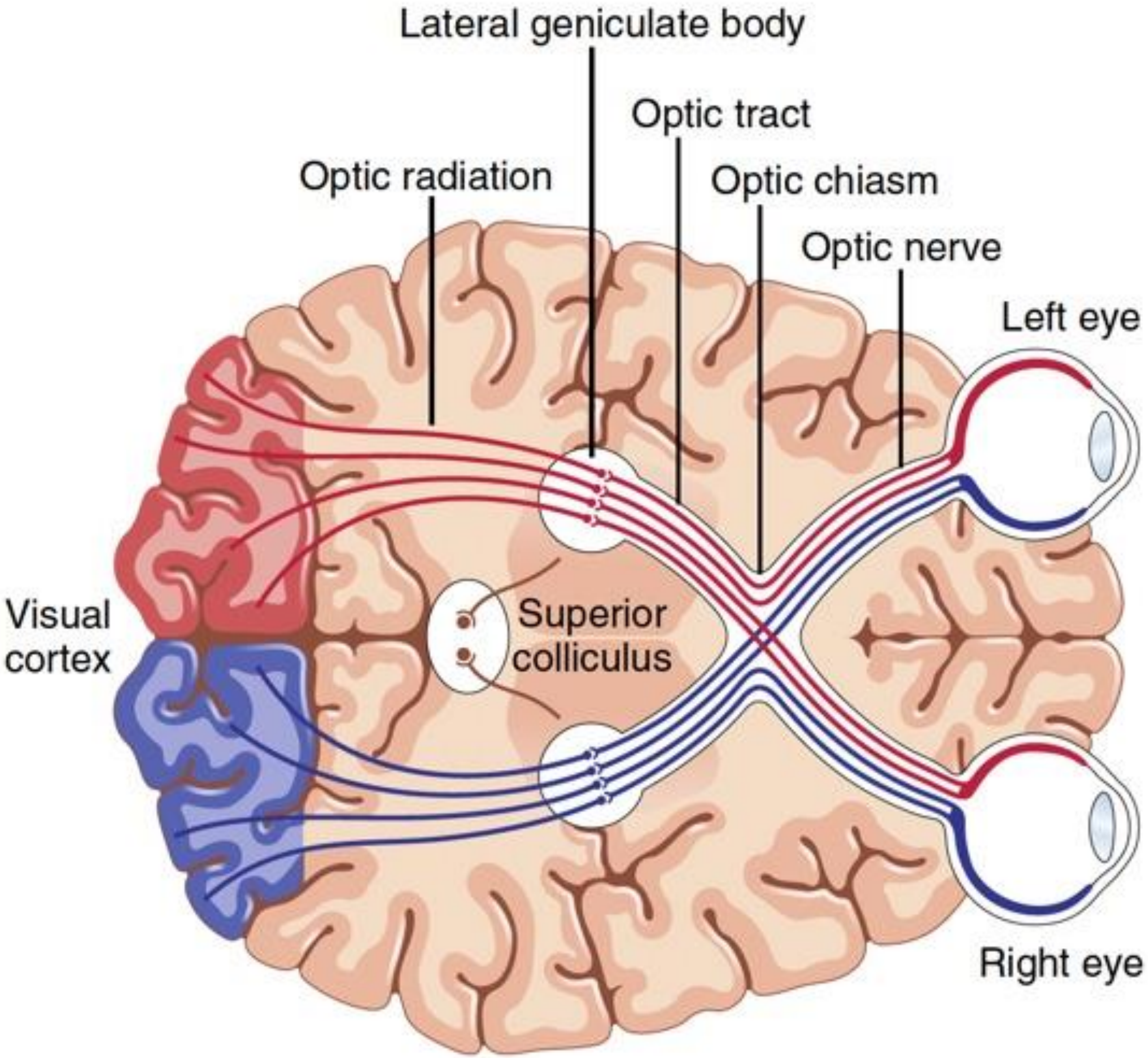
- **P cells:** P stands for (Parvocellular), meaning they are **small**, so they have **slow conduction velocity**, with a more **sustained** signal. These cells are related to detailed and colored vision, for that; they are most abundant in the **fovea.**

- **M cells:** M stands for (Magnocellular) because they are **large.** They are **high velocity** induction cells, but at the expense of being **not very specific.** These cells are very important in seeing moving objects. That's why our perception of moving objects is not very detailed and specific.

- P and M ganglion cells will form fibers that will reach the thalamus, specifically the dorso-lateral geniculate nuclei (or lateral geniculate body). These nuclei consist of different layers. Of these layers, there is the magno layer (where M fibers pass) and the parvo layer (where P fibers pass). This nucleus is very well organized to help with precepting the image very accurately.

- What's also special about these nuclei is that each one gets fibers from both eyes to help with matching the two images from both eyes (although the matching process happens in the visual cortex) because, as we know, our eyes don't see the exact same picture. This is important to form one holistic image.
- Matching the image from each eye is also very important to recognize the depth and distance of viewed objects. This also helps with forming the 3d shaped image. This is called **stereopsis**.

Try to look at a far object using one eye, then switch to the other, notice how both images are very similar. Now do the same thing on a close object, notice how images now are different, this is how our visual cortex feels the depth and distance of object.



Another important function for the lateral geniculate body is **adaptation,** it chooses what parts of the image to ignore and what to consciously percieve.

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.**

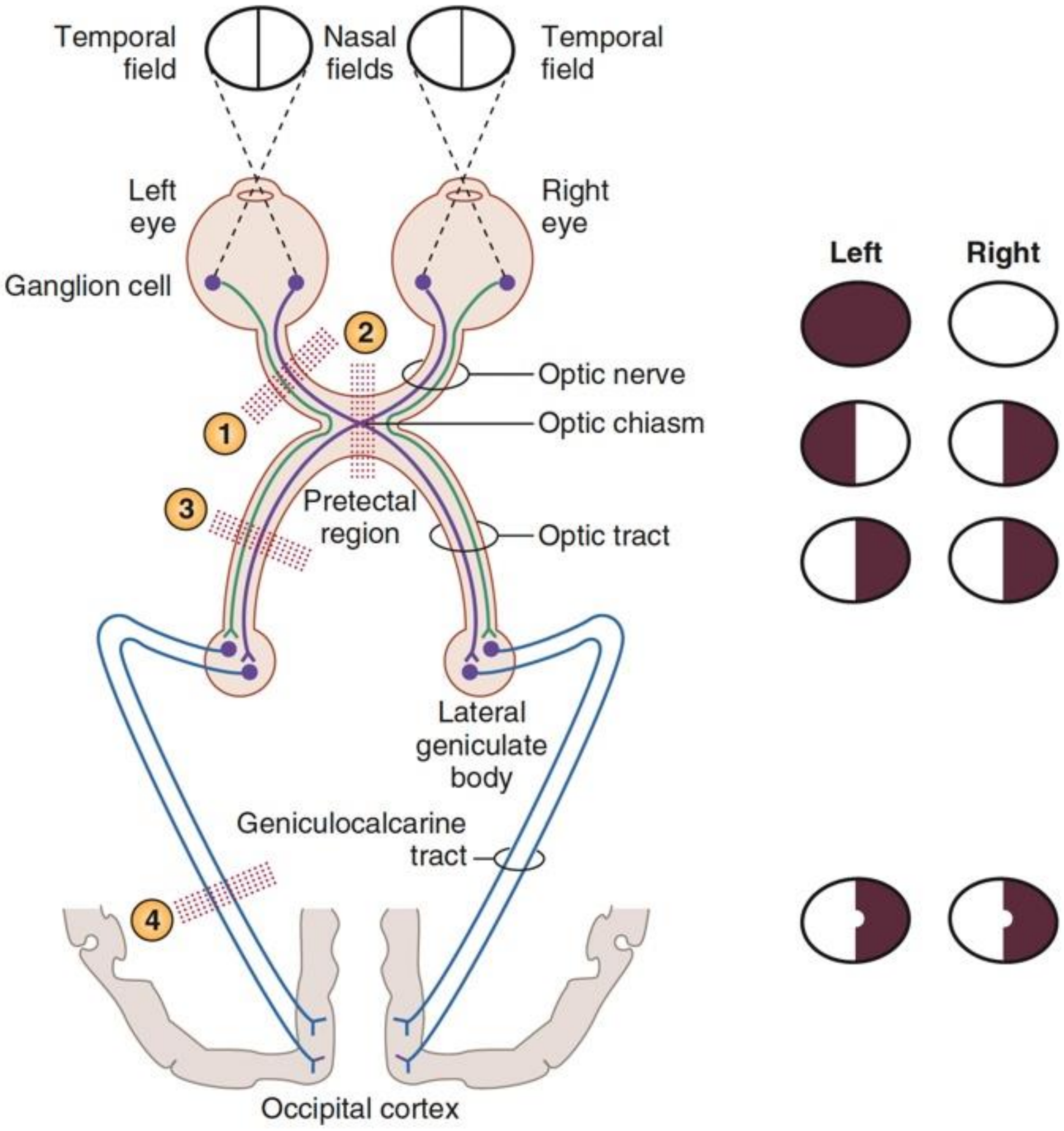
- These cells appear to send signals mainly to nonvisual areas of the brain, particularly the suprachiasmatic nucleus of the hypothalamus, the master circadian pacemaker.

We conclude that not all visual inputs will end up in the visual cortex

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.

LESIONS OF OPTIC PATHWAYS



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.

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.

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.

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

Another example of signals that don't end up in the visual cortex is the 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.

- So the superior colliculus is the main point for integration between visual input and eye movement.
- We also have a pretectal nucleus that helps with pupillary reflexes, constrict in bright light and dilate in dim light, this is also another form of adaptation.

At the level of receptors

At the level of CNS

So for now, we learned 3 types of visual adaptation:

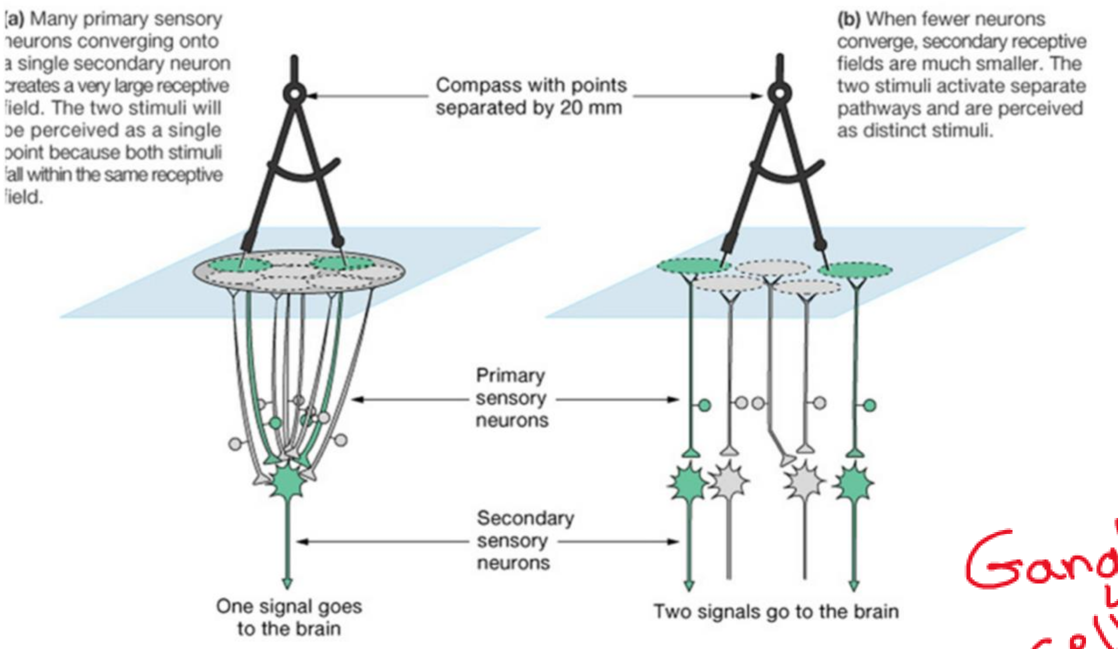
1. At the level of the receptor, by altering the level of photopigments in each receptor based on the brightness of the light getting to the eye. (the most important).

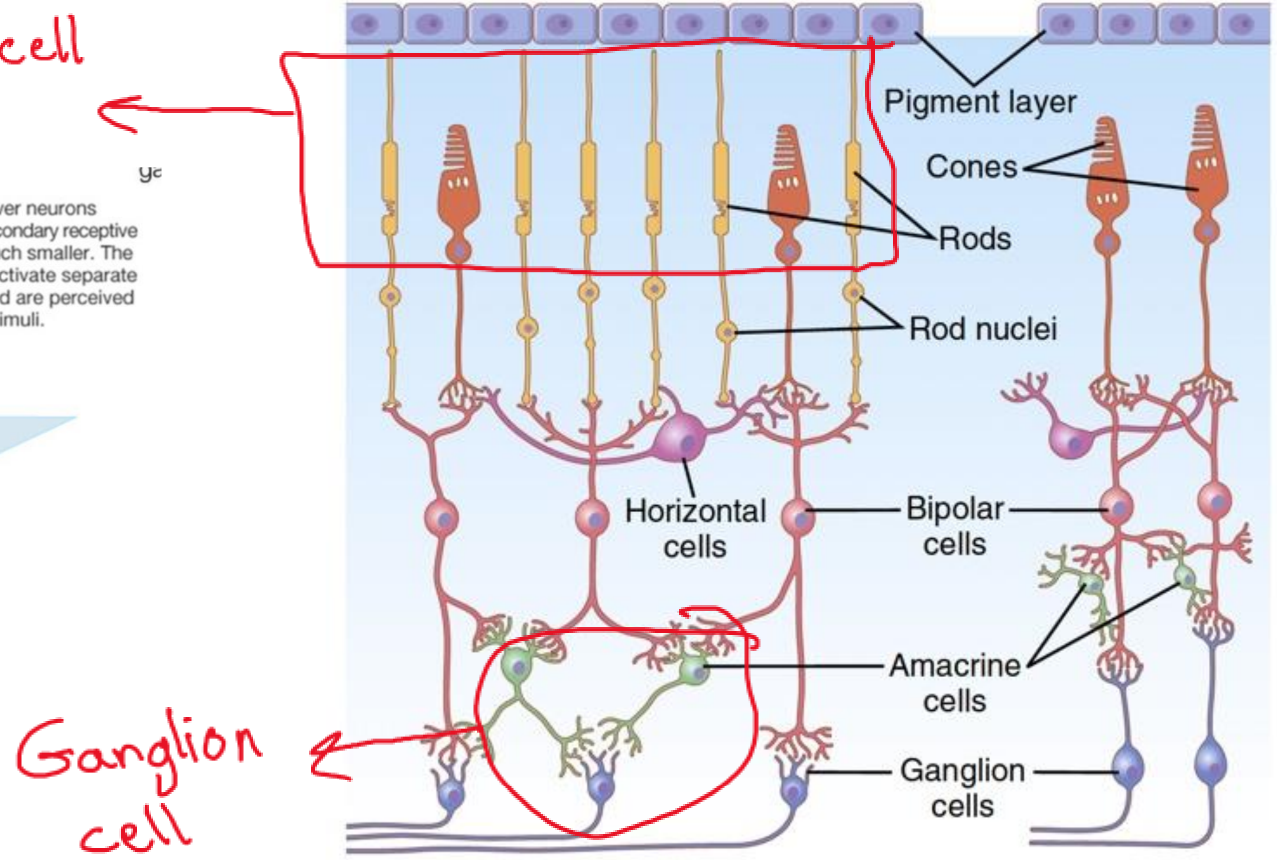
2. In the lateral geniculate body by choosing to ignore non-important parts of the image.

3. In the pretectal nucleus by controlling the diameter of the pupil to accommodate for the brightness coming to the eye.

Let's revise some concepts of somatic sensation.
Each second order neuron in somatic sensation in the skin has a receptive field, this receptive field exists because many primary neurons are synapsing with that secondary neuron.

Ganglion cells in the eye (which are similar to secondary neurons) have the same concept because there are multiple photoreceptors connected to one ganglion cells



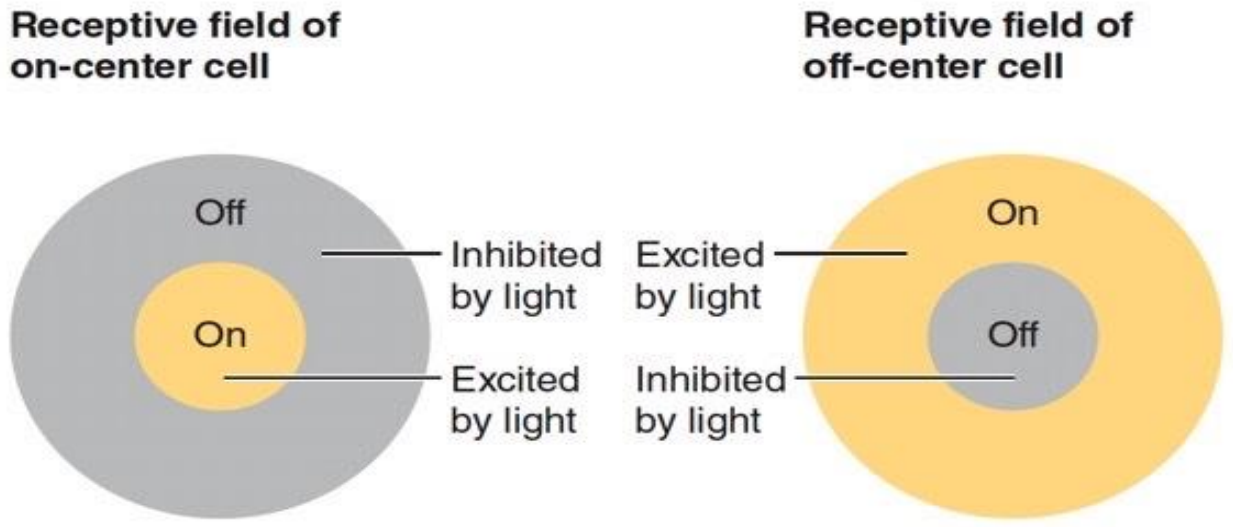


In the eye, we have two types of receptive field, an on-center field, and an off-center field:

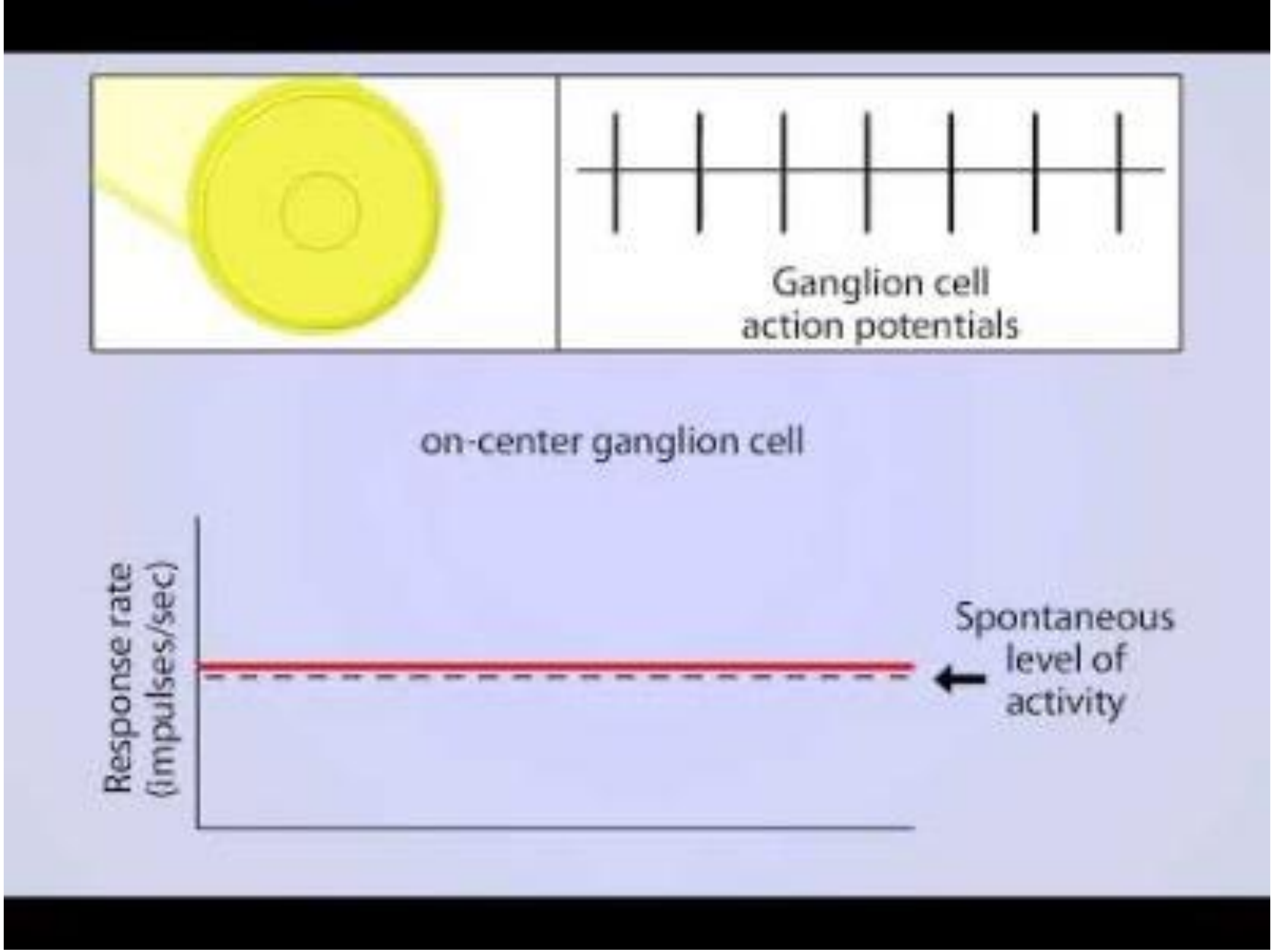
- On-center fields: they are **highly stimulated** if the light hits only the **center** of the field, and they are **highly inhibited** if the light hits only the **periphery** of the field. If light hits both of them at the same time we will get mild stimulation.

- Off-center fields: they are **highly stimulated** if the light hits only the **periphery** of the field, and they are **highly inhibited** if the light hits only the **center** of the field. If light hits both of them at the same time we will get mild stimulation.

- The type of the receptive field is determined by the ganglion cell itself, so we have on-center cells and we have off-center cells.



This video is from Dr. Fatima, it explained the concept very well



The link for the video : https://youtu.be/4TeBArOVGwg

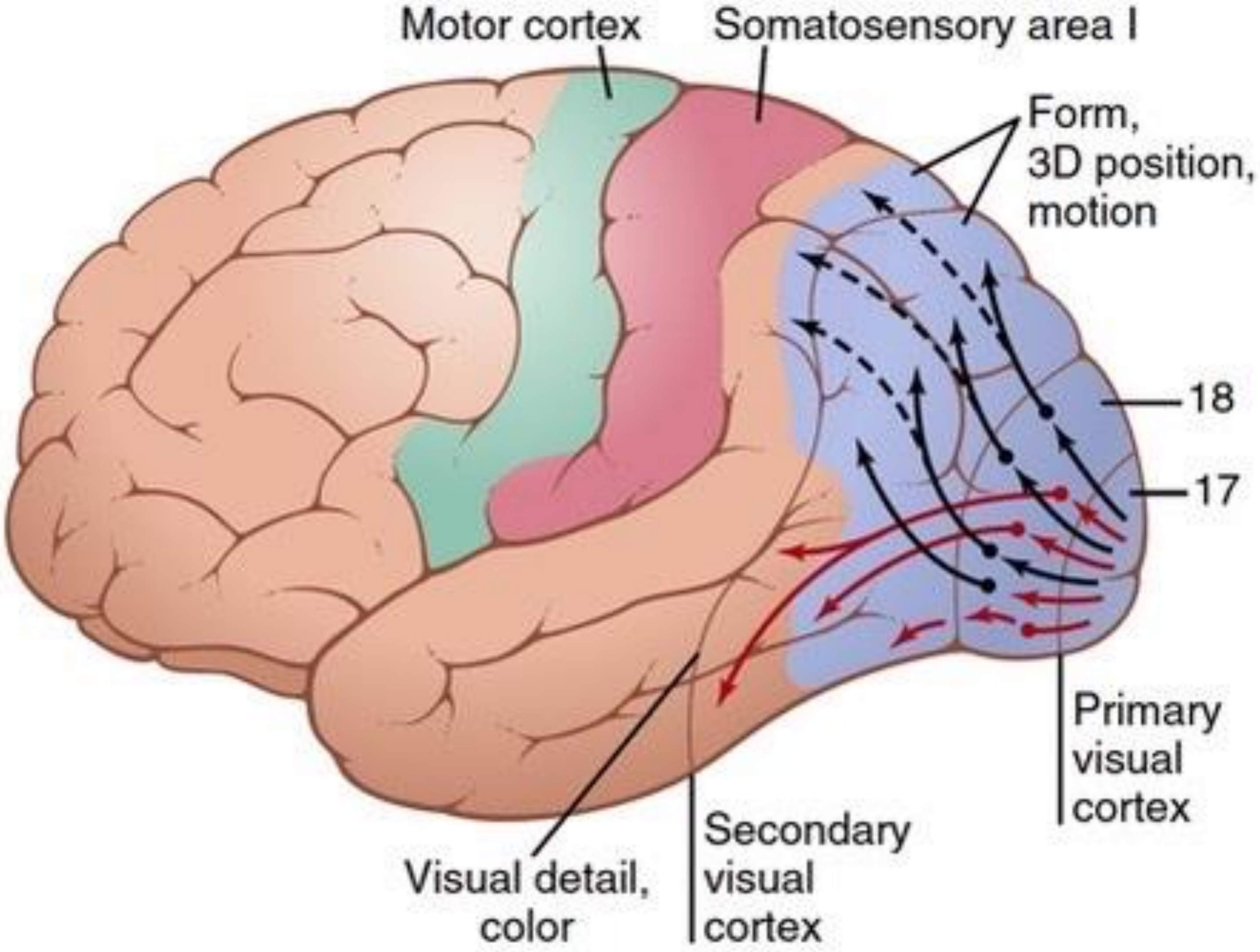
Extra image and explanation

What is the benefit of this feature?

It helps with emphasizing the contrast of light coming from object, this is very important for perception of edges of objects so we can get to see the exact shape of an object, without this feature, everything would have looked blurry and obscure.

High contrast

Low contrast



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

- The visual cortex in the occipital lobe is divided to primary visual cortex and secondary visual cortex.

- Secondary is further divided into two parts: one important for colored detailed vision (parvocellular fibers end up here), and the other is important for 3D vision and motion (magnocellular fibers end up here).

- Inside the visual cortex we have many types of cells responsible for processing of images.

- One type is simple cells, they are responsible for detecting shapes and their direction.

- On other type are complex cells, they help with understanding the motion and displacement of objects.

- There are many other types of cells in the visual cortex but we are not required to know them because visual processing is a very complex concept.

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.

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.

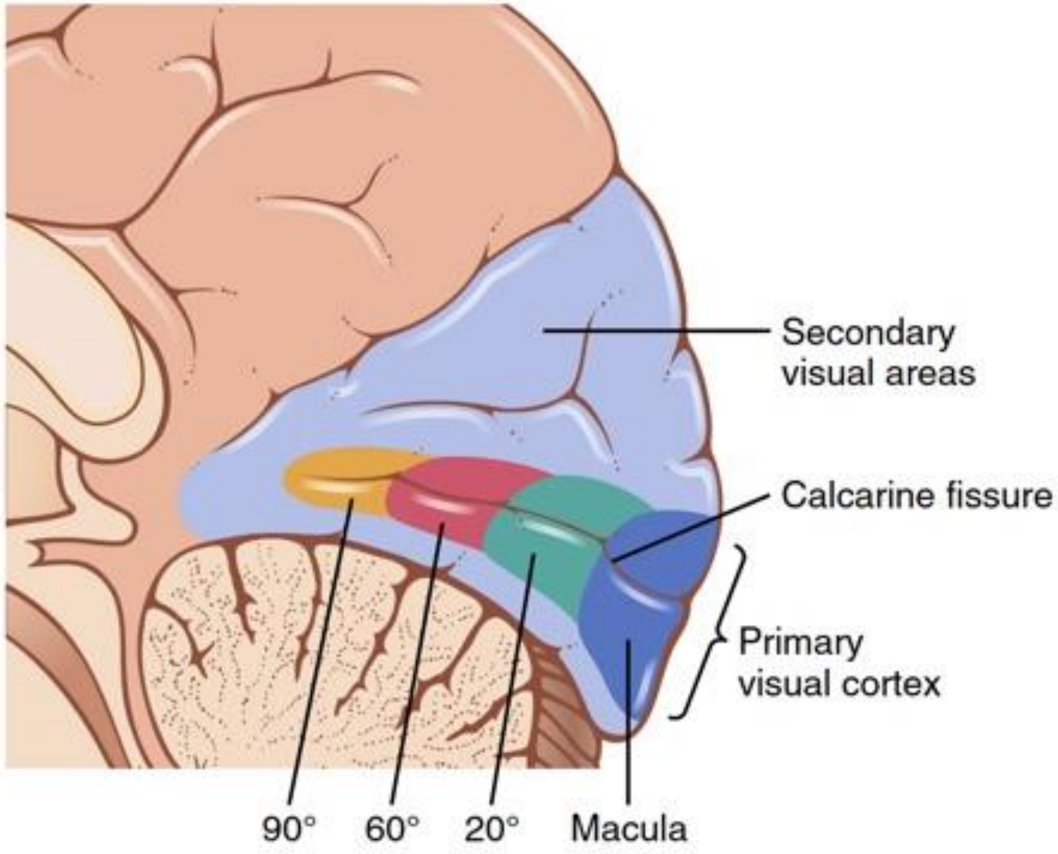
Visual pathways

- 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.



Just like the map for somatic sensation in the cortex, we have a map for the retina in the visual cortex, of course the biggest part corresponds to the macula.

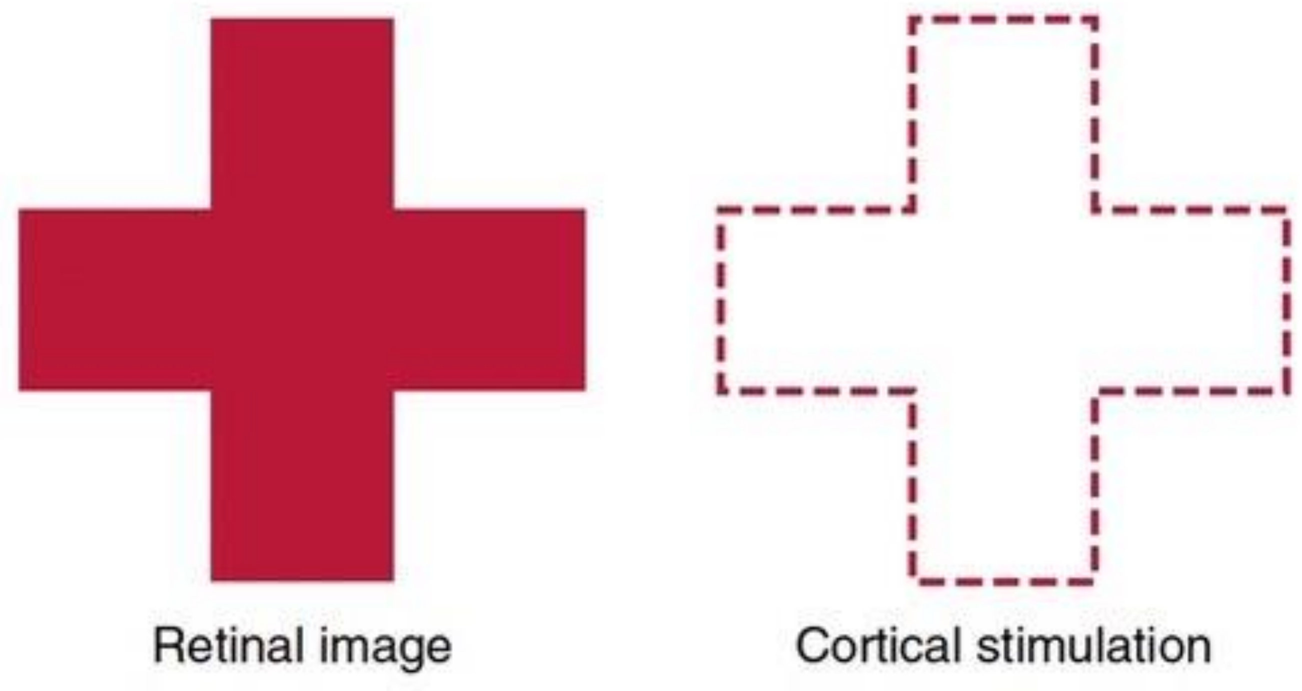
In this picture, the degrees means how far this part of the retina is from the macula

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.



This image is to show that the visual cortex focuses on the borders between the object and the background.

اللهم إنّا نسألك لذَّة النظر إلى وجهك الكريم والشوق إلى لقائك، بلا ضرَّاء مُضرة ولا فتنة مُضلة

VERSIONS	SLIDE #	BEFORE CORRECTION	AFTER CORRECTION
V1→ V2			
V2→V3			

امسح الرمز و شاركنا بأفكارك لتحسين أدائنا !!