



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

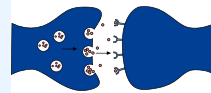


Vision (Pt.3)

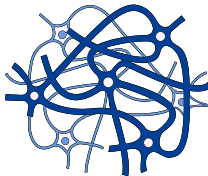
MID | Lecture 7

﴿ إِنِّي تَوَكَّلْتُ عَلَى اللَّهِ رَبِّي وَرَبِّكُمْ مَا مِنْ دَابَّةٍ إِلَّا هُوَ آخِذٌ بِنَاصِيَتِهَا إِنَّ رَبِّي عَلَى صِرَاطٍ مُسْتَقِيمٍ ﴾

Written by: Aya Ghalayini
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Reviewed by: Lubna Alhourani



رحلة اليقين مع سورة يس

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

أَلَمْ يَرَوْا كَمْ أَهْلَكْنَا قَبْلَهُمْ مِّنَ الْقُرُونِ أَنَّهُمْ إِلَيْهِمْ لَا يَرْجِعُونَ (٣١) وَإِن كُلٌّ لَّمَّا جَمِيعٌ لَّدَيْنَا مُحْضَرُونَ (٣٢)

يقول تعالى: ألم ير هؤلاء ويعتبروا بمن قبلهم من القرون المكذبة، التي أهلكها الله تعالى وأوقع بها عقابها، وأن جميعهم قد باد وهلك، فلم يرجع إلى الدنيا، ولن يرجع إليها، وسيعيد الله الجميع خلقا جديدا، ويبعثهم بعد موتهم، ويحضرون بين يديه تعالى، ليحكم بينهم بحكمه العدل الذي لا يظلم مثقال ذرة { وَإِن تَكُ حَسَنَةً يُضَاعِفْهَا وَيُؤْتِ مِنْ لَدُنْهُ أَجْرًا عَظِيمًا }

Neurophysiology

Vision III

Fatima Ryalat, MD, PhD

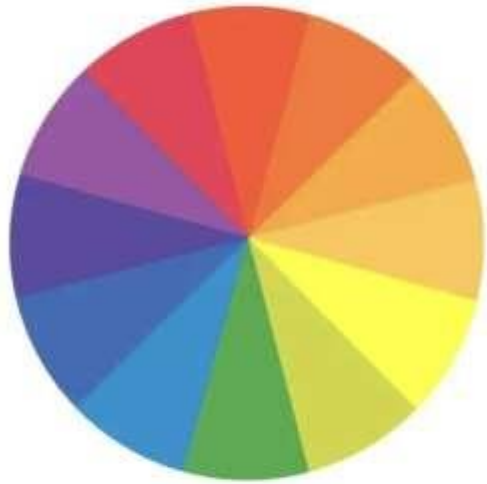
Assistant Professor, Department of Physiology and Biochemistry
School of Medicine, University of Jordan

Introduction to color blindness:

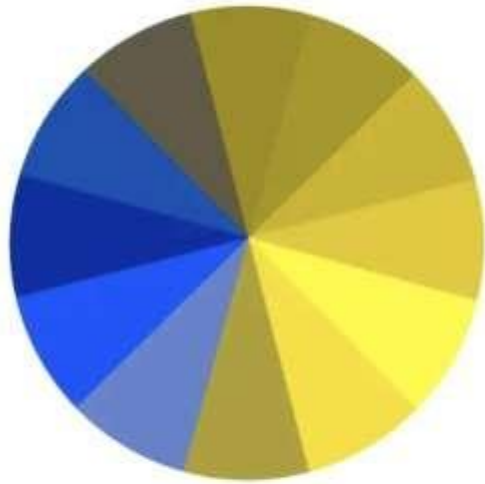
Color blindness doesn't mean a complete inability to see colors; rather, it refers to a defect in normal color discrimination. Individuals with color vision deficiency can still see colors, but they interpret certain wavelengths differently due to abnormalities in the visual system, so the way they interpret and differentiate them differs from that of individuals with normal trichromatic vision.

- Usually color blindness is X-linked recessive (more common in males than females).

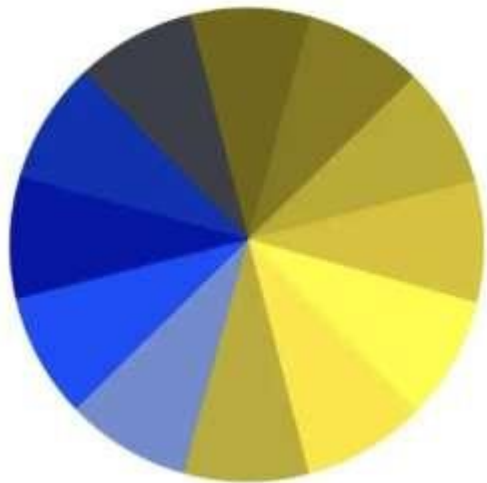
Normal vision



Deuteranopia



Protanopia



Tritanopia

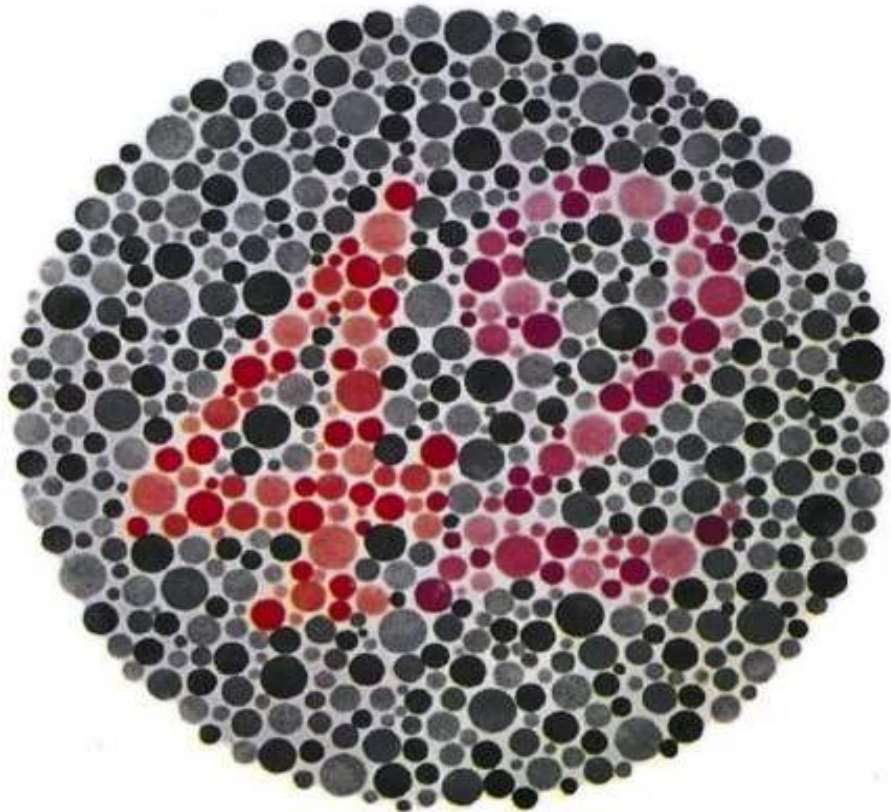
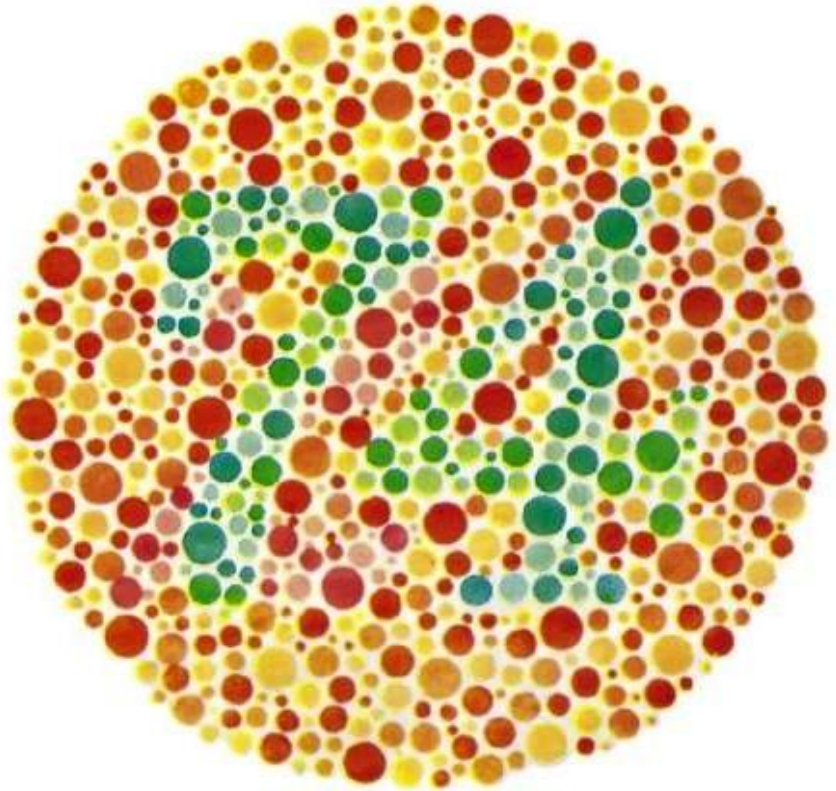


As shown in the image, red and green may appear very similar to individuals with color blindness. Therefore, when driving, they should not only rely on color perception but also on the fixed position of traffic signals (where red is positioned at the top and green at the bottom).



Extra image

The **Ishihara test** is used to detect color blindness; it consists of plates made of colored dots forming numbers or patterns that individuals with red-green color vision deficiency may not be able to see correctly.



Trichromatic Theory: as discussed before, there are three types of photoreceptor cones in retina and each is sensitive to a different range of wavelengths. The S-cones respond primarily to short wavelengths (blue), the M-cones to medium wavelengths (green), and the L-cones to long wavelengths (red). The perception of any color is not the result of a single cone type activity, but rather the relative activation of all three types.

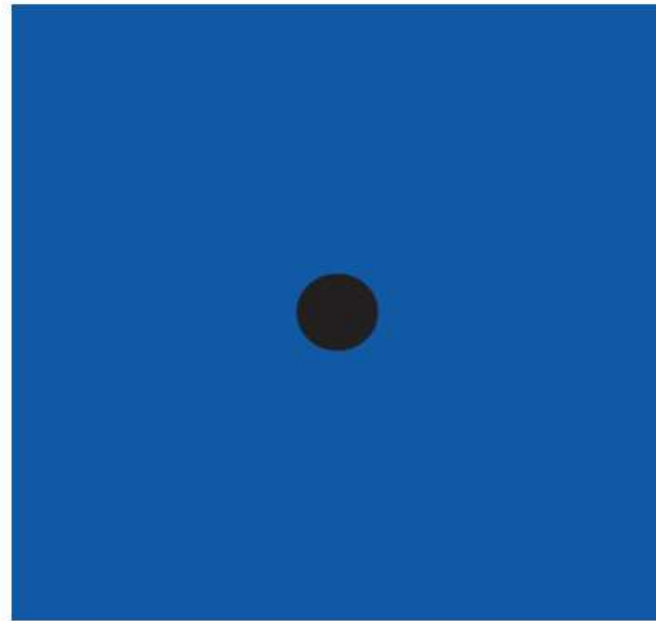
After the cones are stimulated by light⁽¹⁾, their signals are transmitted to bipolar cells⁽²⁾ and then to ganglion cells in the retina⁽³⁾. **It is at this stage that the opponent color processing begins.** The opponent ganglion cells get activated⁽⁴⁾, and then their signals travel through the optic nerve to the lateral geniculate nucleus (LGN)⁽⁵⁾ and finally⁽⁶⁾ reach the visual cortex (V1). In the visual cortex, the brain integrates these signals from multiple opponent channels to produce the final perception of color.

Opponent Color Theory:

Certain pairs of colors are processed in opposition: red vs. green, blue vs. yellow, and sometimes black vs. white (for brightness). The opponent cells are excited by one color in the pair and inhibited by the other. For example, a red-green opponent cell is excited by red and inhibited by green, while a blue-yellow cell is excited by blue and inhibited by yellow. **The opponent cells are excited by one color in the pair and inhibited by the other, this sharpens color discrimination and avoids impossible color blends.**

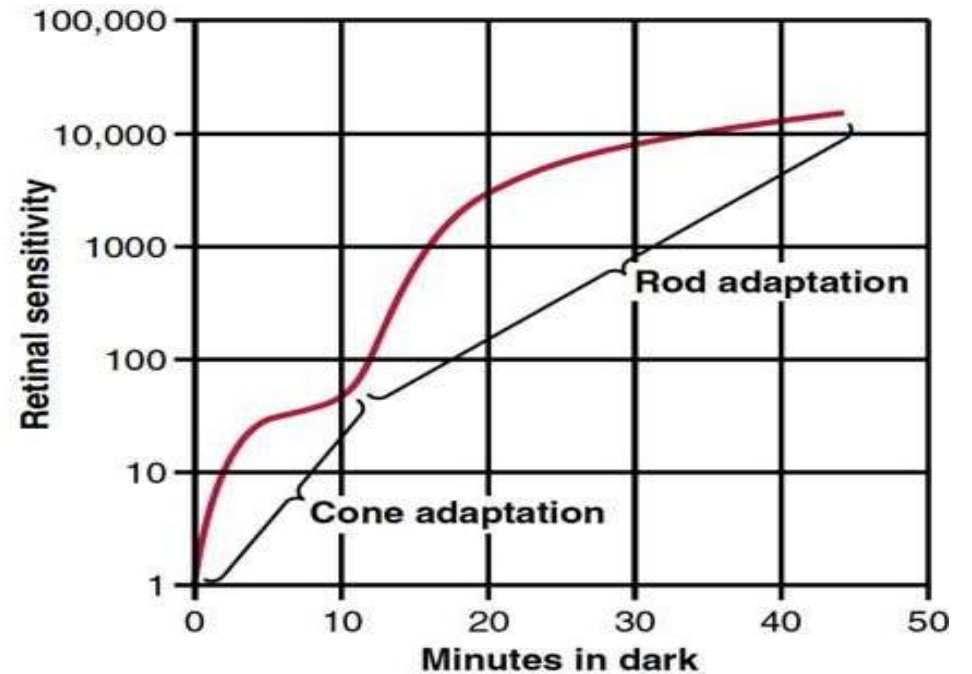
Opponent color theory

When you stare at the blue area in this picture for a while and then look at a white non-contrast background, you'll see yellow shadows. This happens because the blue-yellow opponent cells become fatigued, so the opposite color (yellow) dominates in perception.



Dark adaptation (receptor level)

- 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.



When you enter a dark room from a bright area, your eyes need time to adjust, and at first, the room appears very dark. In **bright** light, photoreceptors are activated, and their photopigments are depleted, so they require time to regenerate. **Cones regenerate faster than rods**, so during the first 10 minutes, cones dominate vision but remain **less sensitive in low light**. **Rods** take longer to recover, reaching **maximum** sensitivity after about 30 minutes, which allows clear dark night vision once rods adaptation is complete.

Light adaptation (receptor level)

- 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.

In dark environments, the photoreceptors and photopigments are not being significantly consumed or bleached. As a result they remain highly sensitive and ready to respond strongly to incoming light signals. Therefore, when sudden intense light appears, you will feel the sensation of a dazzling light.

Adaptation

These adaptive measures (**at the receptor level**) are also enhanced by **pupillary reflexes** that adjust the amount of available light permitted to enter the eye.

Light → Pupil Constriction

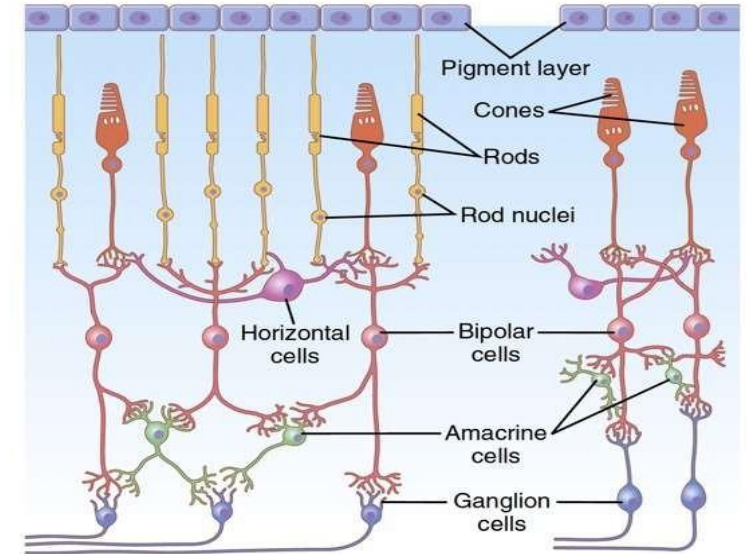
Dark → Pupil Dilation

The other mechanism is **neural adaptation**, involving the neurons in the successive stages of the visual chain in the retina and in the brain.

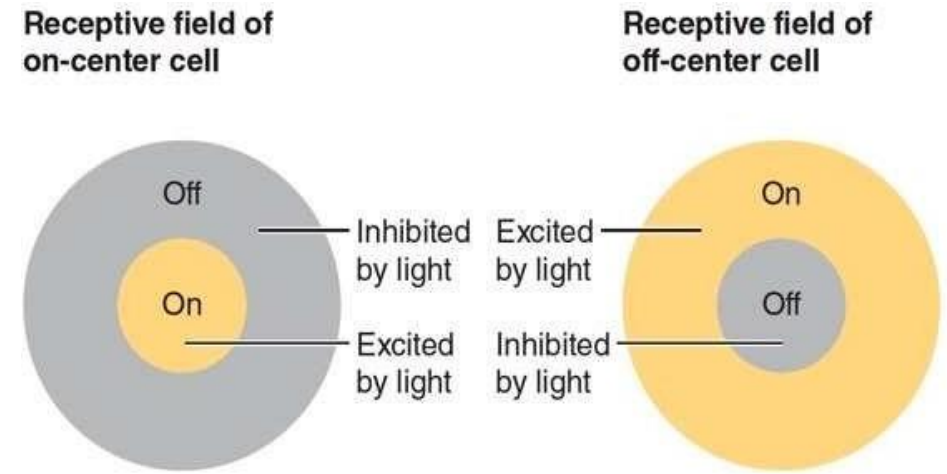
In retina, photoreceptors respond to light by hyperpolarizing, which reduces the release of the neurotransmitter glutamate. This change in glutamate availability determines how bipolar cells respond.

Bipolar cells, which are highly influenced by their type of receptor, can be classified as **On-center** or **Off-center** depending on their reaction to light:

- **Off-center bipolar cells** are excited by **glutamate** in the dark through **ionotropic receptors**, and when light hits, glutamate release decreases and they hyperpolarize (inactive). They are called “off” because **light causes inhibition**.
- **On-centre bipolar cells** have **metabotropic receptors**. In the dark, glutamate release is continuous, and the cells are hyperpolarized (inactive). When light hits, glutamate release decreases, and cells depolarize (active). So they’re called on-centre because they depolarize when light hits.



In addition, bipolar cells are organized in a **center-surround structure**, where **On-center cells have Off-surround regions** and **Off-center cells have On-surround regions**. This organization is mediated by **horizontal cells**, which provide **lateral inhibition** to sharpen spatial contrast and enhance visual resolution.



Bipolar cells transmit **graded potentials rather than action potentials**. The **magnitude** of these graded potentials reflects the **intensity** of the light stimulus and is passed on to the **retinal ganglion cells, which are the only retinal neurons capable of generating action potentials**. Retinal ganglion cells also maintain the On-center and Off-center organization established by the bipolar cells and transmit visual information through the optic nerve to the brain. **Amacrine cells** further modulate the signal between bipolar and ganglion cells, contributing to temporal and spatial processing.

- Receptor type on bipolar cell → Bipolar cell response (excite or inhibit)
- Center-surround arrangement → Contrast enhancement
- Ganglion cell → converts graded potential to action potential

Horizontal cells

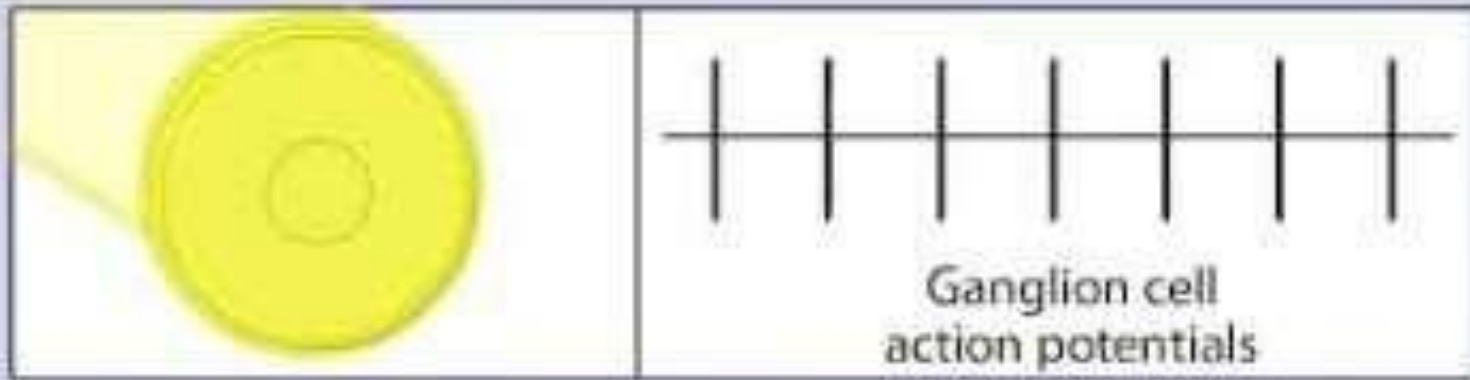
- The outputs of the horizontal cells are always inhibitory. Therefore, this lateral connection provides the same phenomenon of lateral inhibition that is important in helping to ensure transmission of visual patterns with proper visual contrast.
- This process is essential to allow high visual accuracy in transmitting contrast borders in the visual image.

Amacrine cells

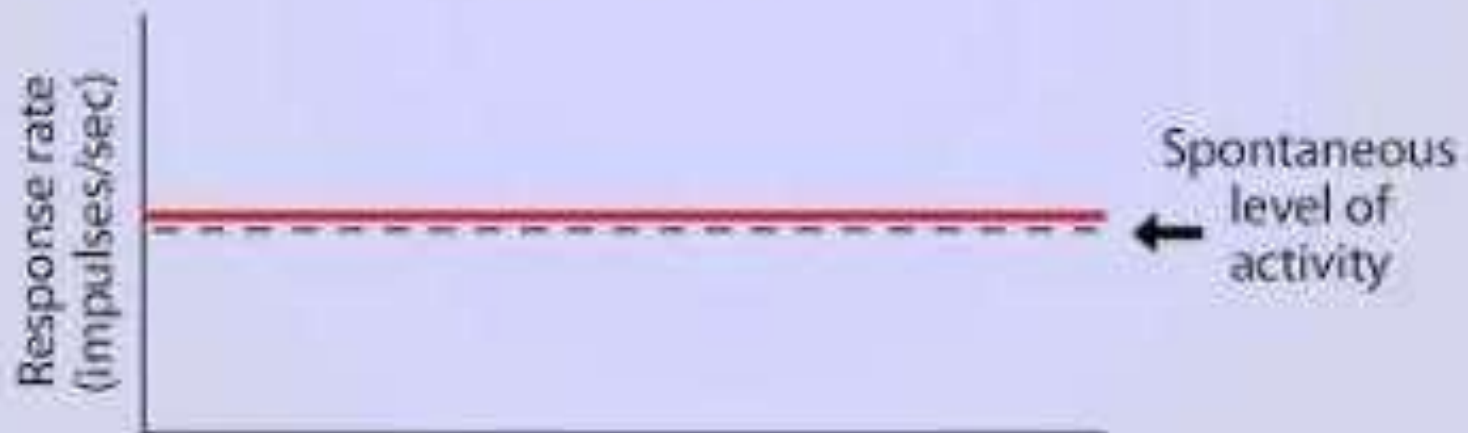
- Some of the amacrine cells probably provide additional lateral inhibition and further enhancement of visual contrast in the inner plexiform layer of the retina as well.

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.



on-center ganglion cell



Retinal Ganglion cells

Retinal ganglion cells come in different types with distinct functions. As discussed previously, the color opponent ganglionic cells are a type of RGCs. In addition to these standard RGCs, there is a special type known as intrinsically photosensitive retinal ganglion cells (ipRGCs).

These cells contain their own photopigment, **melanopsin**, allowing them to respond directly to light without relying on input from rods or cones. So, when activated by light, they can transmit signals independently to the brain, **bypassing** traditional photoreceptor pathways.

The primary role of melanopsin-containing RGCs is in regulating circadian rhythms; Light detected by ipRGCs sends signals to **suprachiasmatic nucleus (SCN)** in the hypothalamus (which functions as the **body's central clock**), and from there, the body controls the secretion of **melatonin** (sleep inducing hormone).

- During daylight, light input **inhibits** melatonin production, keeping the body alert.
- At night or in darkness, the reduction in light **stimulates** melatonin secretion, promoting sleep.

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.

Explained more in the coming slides

Retinal Ganglion cells

- The main functions of M and P cells are obvious from their differences:
- The **P cells are small cells with small receptive field (detailed vision) and slower conduction velocity which explains why they** 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 from their name are large cells which means they have fast conduction of the signal along with a large receptive field (a lot of summation) which explains why they** are highly sensitive to rapid movement visual signals and to low-contrast stimuli **respectively**.

Retinal Ganglion cells

- The signals from M cells travel to the thalamus, specifically to the **lateral geniculate nucleus**, which is responsible for visual processing. This nucleus is highly organized and consists of **six layers**. One of these layers is the M layer, which receives signals from magnocellular retinal ganglion cells. Similarly, another layer is designated for parvocellular cells, ensuring that signals from these cells are directed to the appropriate layer.
- The organization extends further along the visual pathway. There are two types of fibers corresponding to the nasal and temporal visual fields. Light rays from the temporal visual field strike the nasal retina, while rays from the nasal visual field strike the temporal retina.
- The fibers from both retinal regions exit the eye together as the **optic nerve**. Upon reaching the **optic chiasm**, only the **nasal fibers cross** to the opposite side, while the temporal fibers continue on the same side. As a result, the fibers arriving at the lateral geniculate nucleus consist of ipsilateral temporal fibers and contralateral nasal fibers. Each of these groups includes both P and M cells.

Retinal Ganglion cells

- To preserve information about the side and eye of origin, separate layers exist for nasal P, nasal M, temporal P, and temporal M cells. This detailed organization ensures that signals are transmitted from the thalamus to the visual cortex in an orderly and precise manner.
- The thalamus acts as the gateway to the cortex. It retains signals until permission is granted for them to proceed to the visual cortex. This control prevents overwhelming the visual cortex when it is occupied with other priorities. Permission for signal transmission is granted through backward feedback from the visual cortex or the reticular formation.

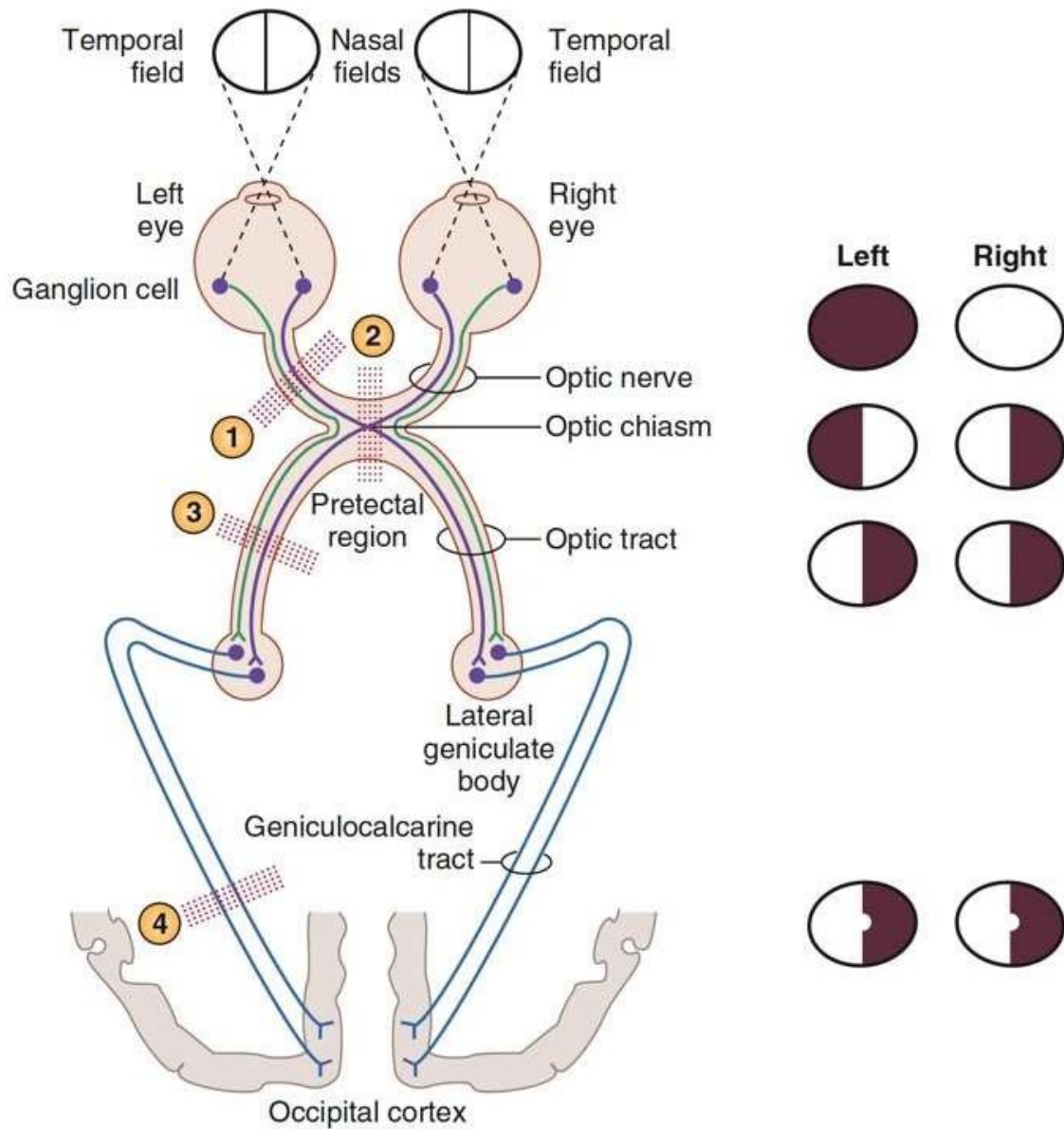
Retinal Ganglion cells

- 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.

Color opponent 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.

LESIONS OF OPTIC PATHWAYS



Explained more in the coming slides

Lesions of the optic pathway

- The visual field of each eye exceeds 90 degrees, resulting in an overlap between the two visual fields. As previously noted, light from the temporal visual field strikes the nasal retina, while light from the nasal visual field strikes the temporal retina. When examining a patient's visual field, identifying the location of a visual defect allows one to infer the site of the lesion within the CNS. This assessment is performed using a simple procedure known as the **confrontation test**.
- The test is conducted as follows: The examiner and the patient sit facing each other. The patient is asked to cover one eye, and the examiner covers the eye opposite to the patient's covered one. It is essential to instruct the patient to maintain eye contact and avoid moving their eye, as this test evaluates vision in a **fixed gaze**. The examiner then moves a finger from the periphery toward the center and asks the patient to indicate when they first see it. Assuming the examiner's visual field is normal, this method allows for comparison and assessment of the patient's visual field.
- When a visual field defect is present, it is classified as follows:
 - **Complete** vision loss in one eye is called **blindness**.
 - **Loss of half** of the visual field, either temporal or nasal, is termed **hemianopia**.
 - **Loss of one quarter** of the visual field is called **quadrantanopia**.

Lesions of the optic pathway

Looking back at the image in slide 26:

- If a lesion occurs at **point one** (the optic nerve), both nasal and temporal fibers are unable to transmit signals, resulting in **ipsilateral blindness**.
- If a lesion occurs at **point two** (the optic chiasm), the nasal fibers—which carry information from the temporal visual field—are affected. This results in loss of vision in the temporal half of both visual fields, leading to **tunnel or telescopic vision**. This condition is called **bitemporal hemianopia** and is most commonly caused by pituitary adenoma.
- If a lesion occurs at point three (the optic tract), it involves fibers that carry information from the same half of the visual field—specifically, the contralateral visual field. For example, a lesion of the left optic tract affects fibers from the left temporal retina (ipsilateral) and the right nasal retina (contralateral), both of which carry information from the right visual field. This results in loss of the right half of the visual field in both eyes, a condition called **right homonymous hemianopia**. Because the visual field loss is on the side opposite the lesion, it is described as a **contralateral homonymous hemianopia**.

Lesions of the optic pathway

- From the optic tract, fibers project to the **lateral geniculate nucleus** of the thalamus, which further organizes and distributes them. These fibers then continue as the optic radiations, traveling through the temporal and parietal lobes before reaching the **occipital lobe**, where the primary visual cortex is located. If a lesion occurs, the resulting defect is similar to that of an optic tract lesion—contralateral homonymous hemianopia—but with **macular sparing**. Macular sparing occurs because the macular region of the visual cortex receives **dual blood supply**; vascular lesions that are usually the cause of impaired cortical function often spare the macula due to this dual blood supply.
- Additionally, the macular region has the largest cortical representation, making it unlikely for a single lesion to affect all macular fibers. Because the optic radiations are widely distributed, a lesion must be large to affect half of the visual field. As a result, lesions in this area of radiating fibres more commonly produce **quadrantanopia**.

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.

Thalamus

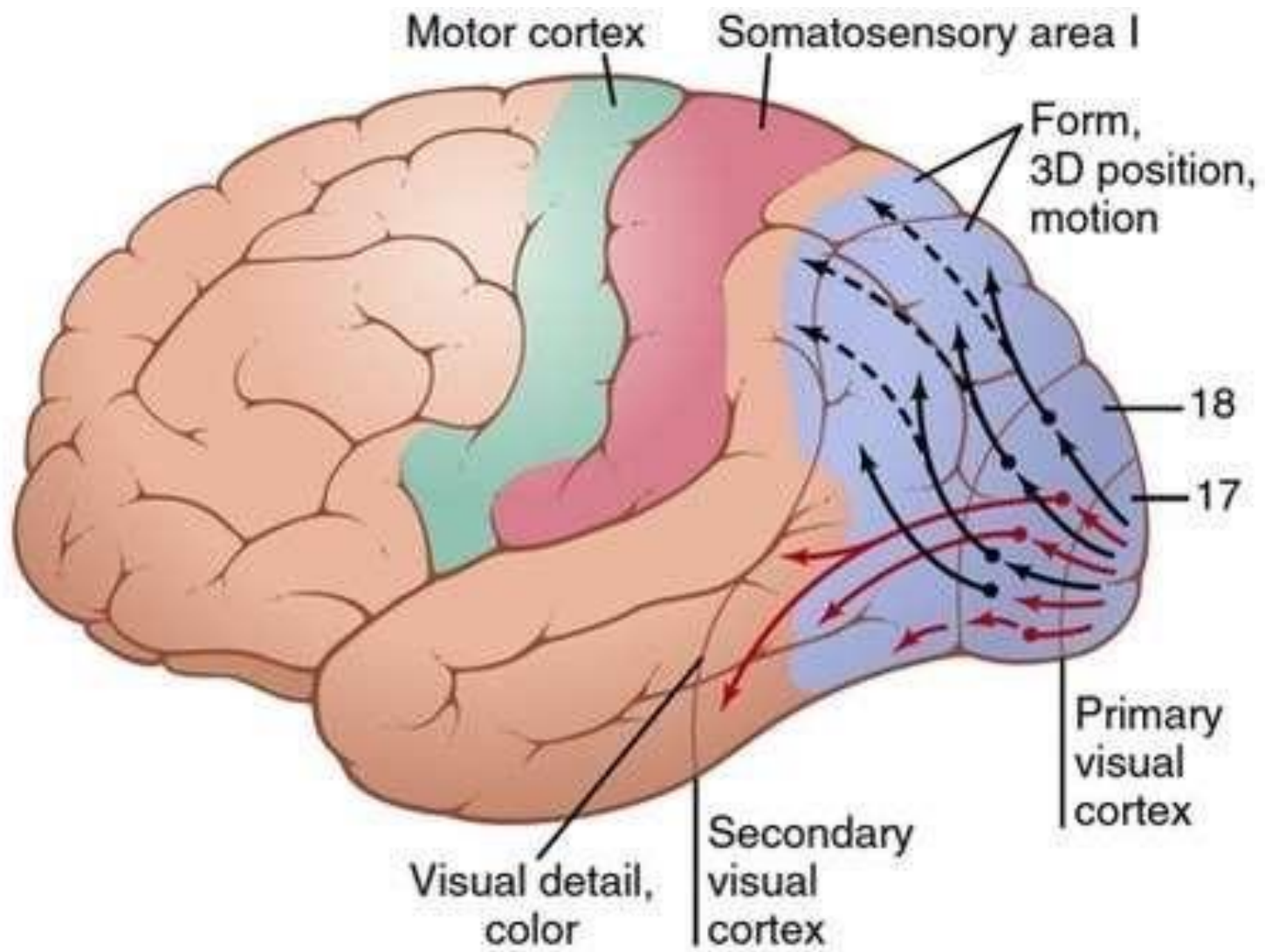
- After passing the optic chiasm, half the fibers in each optic tract are derived from one eye and half are derived from the other eye, representing corresponding points on the two retinas.
- However, the signals from the two eyes are kept apart in the dorsal lateral geniculate nucleus.
- This nucleus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

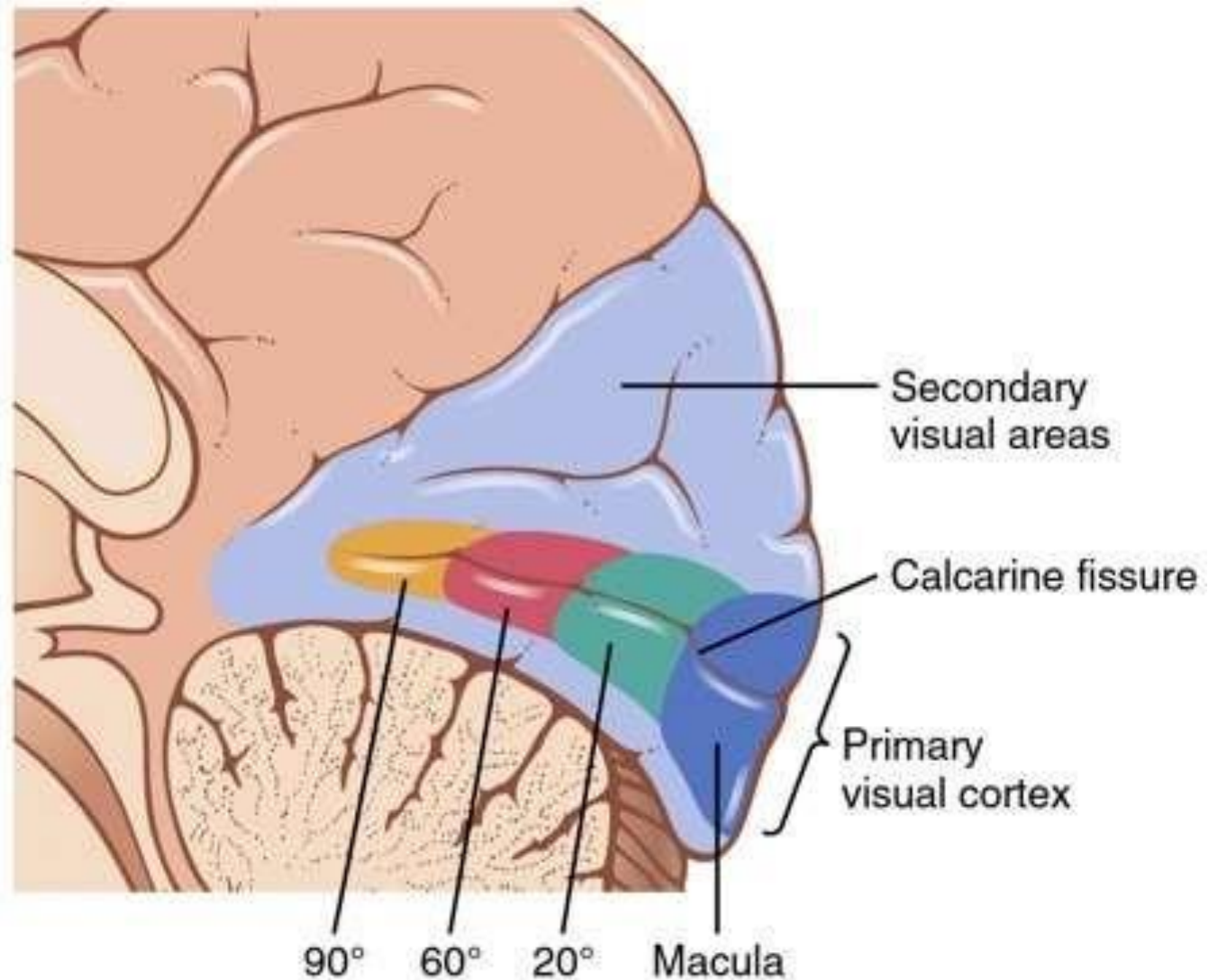


Primary visual cortex

- 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 optic fibers reach the occipital cortex, where the visual cortex is located. They first arrive at the primary visual cortex, which contains a topographic map of the retina, with the largest area devoted to the macula. Within the primary visual cortex, signals are processed by simple cells, complex cells, and hyper-complex cells. However, the primary function of the primary visual cortex overall is to detect lines and borders. To perceive the complete image, visual information must be sent to the secondary visual cortex and association areas. It is said that nearly half of the visual cortex is engaged in analyzing a single image.



Primary visual cortex

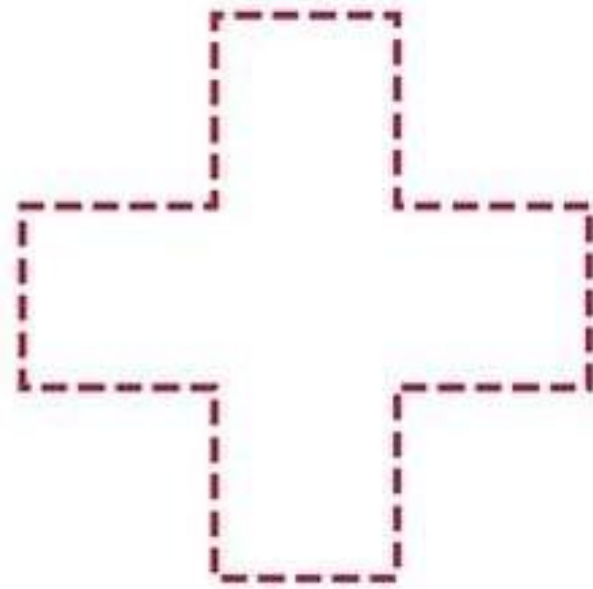
- The primary visual area detects borders, while other areas are responsible for processing color and three-dimensional form. Simple cells detect lines and their orientation. They are capable of recognizing the direction of a line. Retinal ganglion cells are the only cells in the visual pathway that generate action potentials. These cells are basally active, meaning they fire action potentials at a baseline frequency even in the absence of stimulation.
- When stimulation occurs, the firing frequency increases within a certain range; when inhibition occurs, the frequency decreases. These changes in frequency help encode the intensity of light and allow for the discrimination of different light intensities received by the retinal ganglion cells. Remember, the on-center, off-surround organization of retinal ganglion cells. Each cell has a characteristic firing frequency for the on-center and another for the off-surround, and these frequencies vary across different cells. The varying degrees of on-center and off-surround activation provide the basis for detecting lines in different orientations.
- Complex cells are more specialized for detecting angles. These signals then proceed to the secondary visual cortex and association areas, which process the 3-D shape and movement of the image.

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

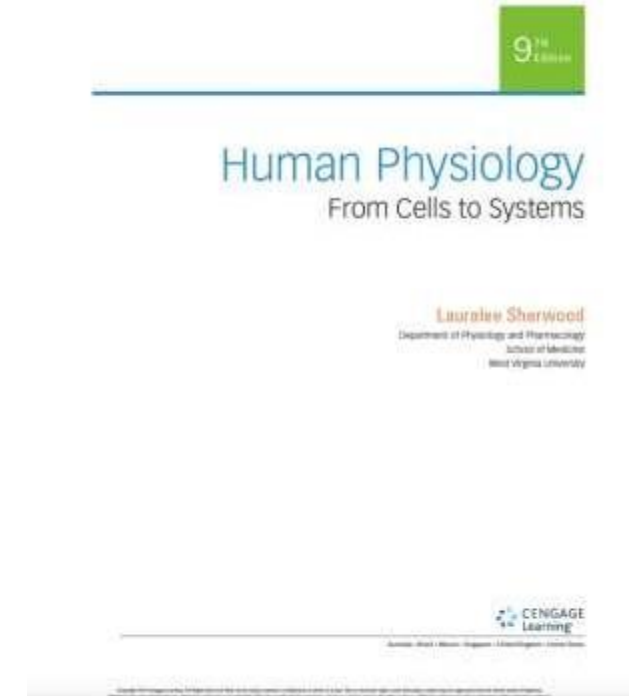
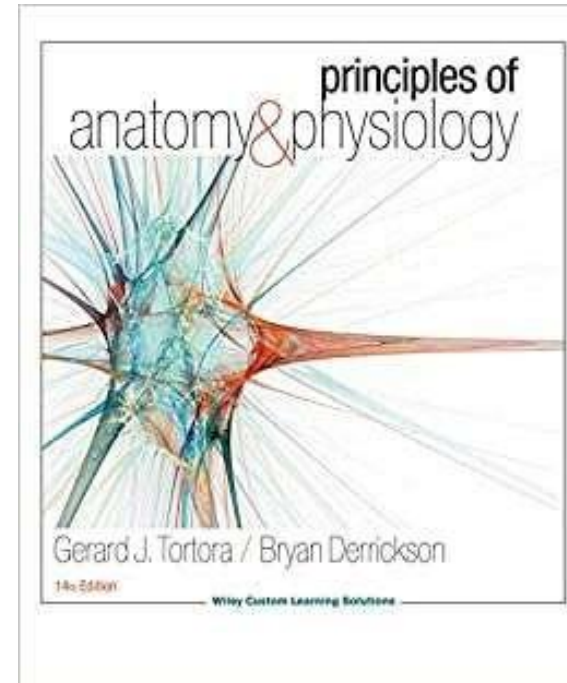
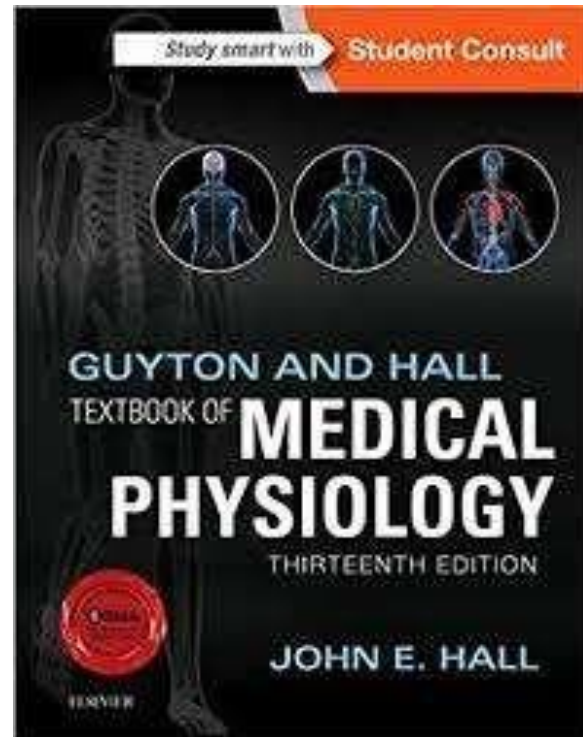
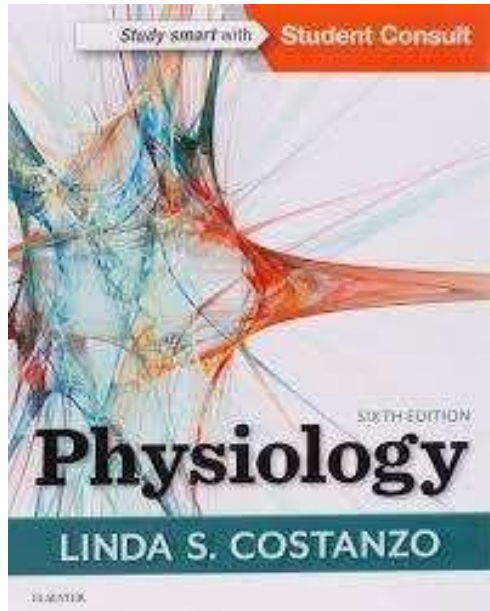
(Depth perception)

- Estimation of the distance of objects from us is an important function of binocular vision. This occurs when the two visual fields from both eyes are correlated in the visual cortex.
- In the visual fields, when an object is farther away, the images from the two eyes overlap more extensively, resulting in a greater number of corresponding points that register together.
- In contrast, when an object is near, less overlap occurs between the two images, leading to more non-corresponding points. In this way, the visual cortex calculates the number of corresponding and non-corresponding points to estimate the distance of the object from the viewer.
- The same mechanism also provides information about three-dimensional shape and depth.

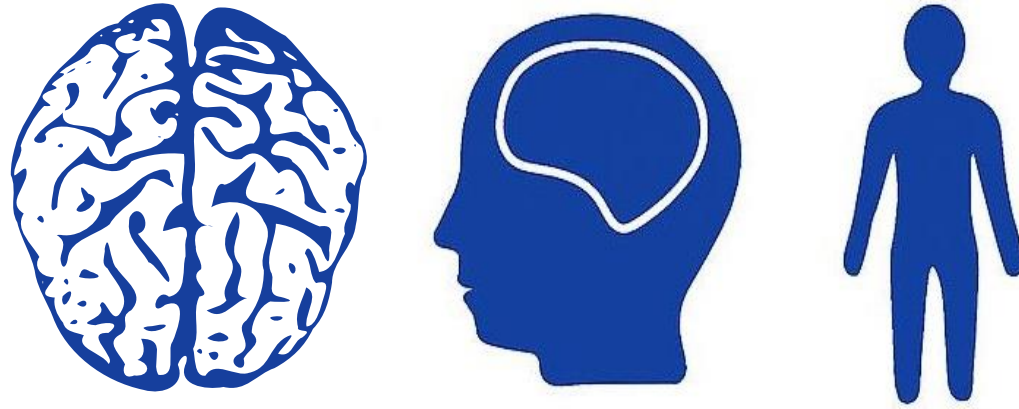
Stereopsis

- 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



Thank you



**PHYSIOLOGY
QUIZ
LECTURE 7**

اللهم إن عمر عطية في ذمتك وحبل جوارك، فقه من فتنة القبر وعذاب النار،
أنت أهل الوفاء والحق، فاغفر له وارحمه إنك أنت الغفور الرحيم.

على الهدى لمن استهدى أدلاءً
والجاهلون لأهل العلم أعداءً
فالناس مَوْتِي وأهل العلم أحياءُ
وكن له طالباً ما عشت مقتبساً

ما الفضلُ إلا لأهل العلمِ إنهمُ
وقيمةُ المرءِ ما قد كان يحسِنُهُ
فقم بعلمٍ ولا تطلبْ به بدلاً
العلمُ زينٌ فكن للعلمِ مكتسباً

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Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			