NERVOUS SYSTEM BLOCK

11th, 12th, 13th and 14th Lectures

Physiology of vision

PHYSIOLOGY TEAM – 430

This Lecture is done by:

Akeel Al-Mahdaly - Al-Waleed Al-Johar

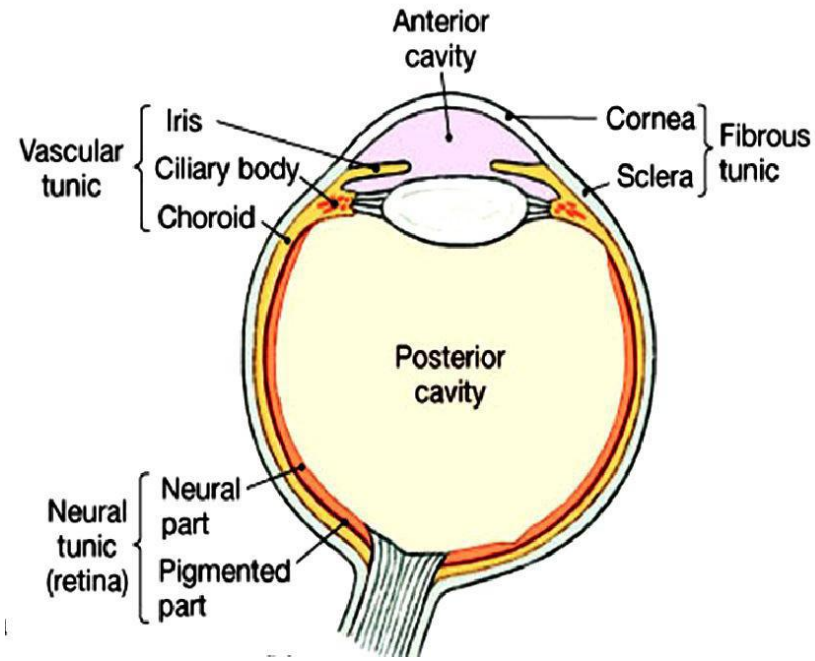
Faisal Al-Thuneyan - Talal Jawdat

Layan Akkeilah - Shahad Al-Muhanna

Hanan Al-Amer

Organized by: Al-Waleed Al-Johar

Anatomy of the eye



- **The eye consists of 3 layers:**

1. **Outer fibrous coat:**
   sclera
   cornea
2. **Middle vascular layer (Uvea):**
   iris
   cilliary body (muscle)
   choroid
3. **Inner neural layer:**
   retina (rods + cones)

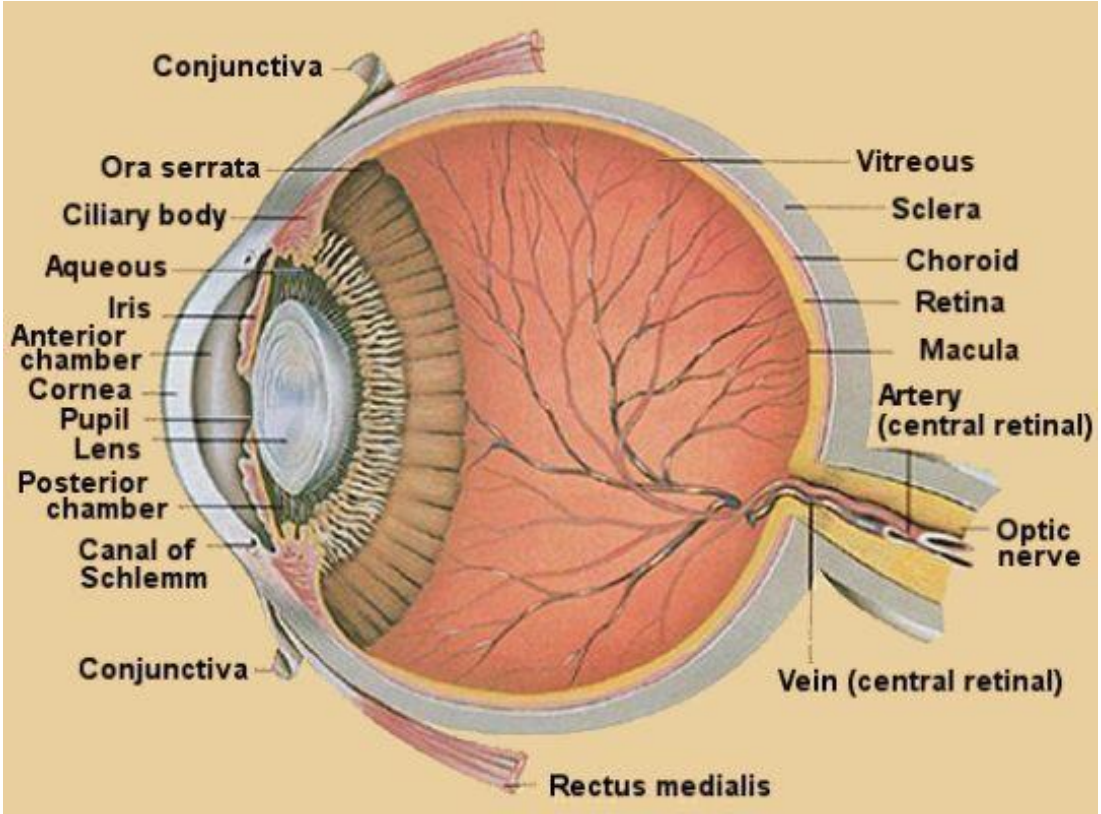
- **Anterior and posterior cavities:**

The Ciliary Body (and its suspensory ligament) and lens divides the eye into:

– **Anterior cavity:**
Which contains a fluid called Aqueous Humor
The iris divides the anterior cavity into:

1- **Anterior chamber:** between iris & cornea
2- **Posterior chamber:** between iris & cilliary muscles

– **Posterior cavity:**
Which contains fluid called Vitreous Humor



1. **Sclera:**

- **Function**: Protection – Maintains a Spherical appearance of the eye

2. **Choroid:**

- **Location**: Inside sclera
- **Function**: Blood supply to the retina

3. **Retina:**

- **Location**: posterior 2/3 of choroid and the innermost layer

4. **Cornea:**

- **Location**: Anterior 1/6 of sclera
- **Function**: To allow light to enter the eyes
- **Properties**: Transparent – Avascular – Diopteric power = 40-45 Dioptre

5. **Conjunctiva:**

Mucous membrane that lines the inner surface of eyelids

- **Location**: Anterior surface of eye, reflected on inner surface of eye lids
- **Function**: Protection, Wetness and Cleaning by thin film of tears

6. Iris:

It is the colored part of the eye

- **Function**:
  - Sympathetic → Radial Muscle → Dilation of pupil
  - Parasympathetic → Circular Muscles → Constriction of pupil

7. Pupil:

- **Location**: Behind center of cornea
- **Function**: To allow light to enter the eye

8. Cilliary Body (Muscles):

- **Location**: Anterior part of choroid and attached to suspensory ligaments (zonule)

9. Lens:

- **Location**: Attached to the cilliary body by suspensory ligaments (Zonules) and lies posterior to the pupil
- **Properties**: Transparent – Biconvex – Semisolid – Diopteric power = 15 – 20 Dioptre "Changeable"

Uvea = choroid + iris + cilliary muscles

Cataract:

A cataract is painless, cloudy area in the lens of the eye. A cataract blocks the passage of light from the lens to the nerves at the back of the eye, and it may cause vision problems. Changes in the lens of the eye are part of the aging process but normally do not develop into cataracts. However, cataracts are very common in older adults. Cataracts can also occur after an eye injury, as a result of eye disease, after the use of certain medications or as a result of medical conditions such as diabetes

Normal Vision

Cataract Vision

- **Refractive media of the eye:**

1. **Cornea:**

– 2/3 refractive power of eye
– Greatest refraction of light [40-45D]

2. **Aquous humour:**

– It is the fluid produced by cilliary body → to posterior chamber → to pupil→to anteriorchamber → to canal of schlemm at angle of ant chamber → to General circulation [veins]

- **Function of aqueous humour:**

– Provides nutrition for iris, lens, cilliarybody and the retina
– Causes intraocular pressure 10-20 mm Hg , which is NORMAL

3. **Lens:**

– 1/3 refractive power of eye
– Diopteric power [15-20D]

4. **Vitrous humour:**

- **Location:** between retina & lens
- **Functions:**

– Provides nutrition for retina
– Keep spheroid shape of the eye

- **External protection of the eye**

1) Bony orbit
2) Lids blinking keep cornea moist
3) Conjunctiva
4) Tears from lacrimal gland have antibacterial, lubricating effect, keep cornea moist & clear.)

Glaucoma:
Glaucoma is an eye condition that develops when too much fluid pressure (More than 20 mm Hg) builds up inside of the eye. The increased internal pressure can damage the optic nerve, which transmits images to the brain. Without treatment, glaucoma can cause blindness within a few years. Glaucoma is most often inherited, meaning it is passed from parents to children. Less common causes of glaucoma include a blunt or chemical injury to the eye, severe eye infection, blockage of blood vessels in the eye and inflammatory conditions of the eye. Glaucoma usually occurs in both eyes, but it may involve each eye to a different extent

Normal Vision

Glaucoma Vision

Retina

1. Photoreceptors (Rods + Cones)

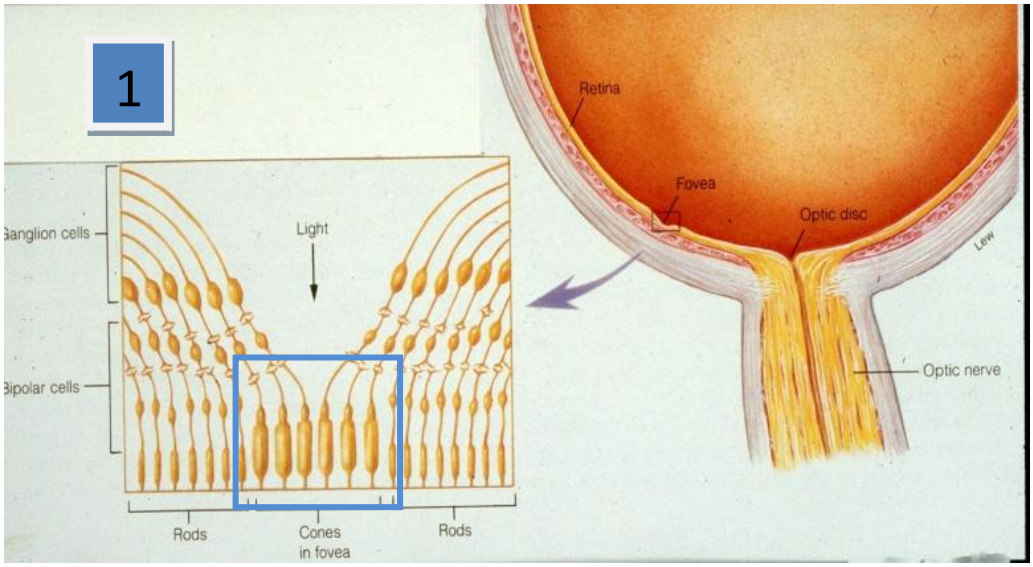
2. Optic Disc (blind spot):

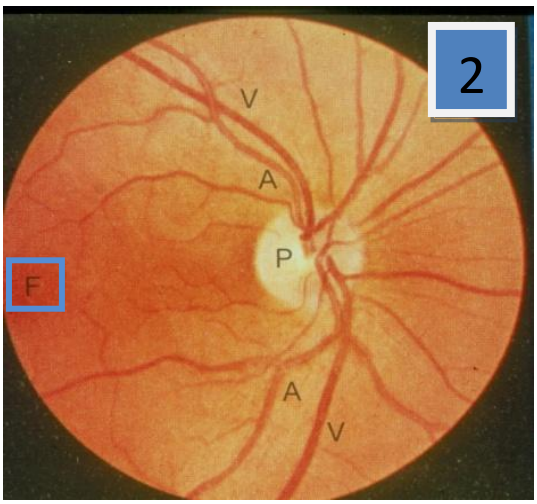
– **Location**: 3 mm medial & above post pole of eye
– While the optic nerve leaves, the blood vessels enter
– No photoreceptors (that is why it is called the blind spot)

3. Fovea Centralis:

– **Properties**:

1) Depression in macula lutea (yellow-pigmented spot at post pole of eye)
2) Contains cones only
3) High visual acuity
4) For colors vision & details detection
5) Not supplied by a direct artery (Avascular)





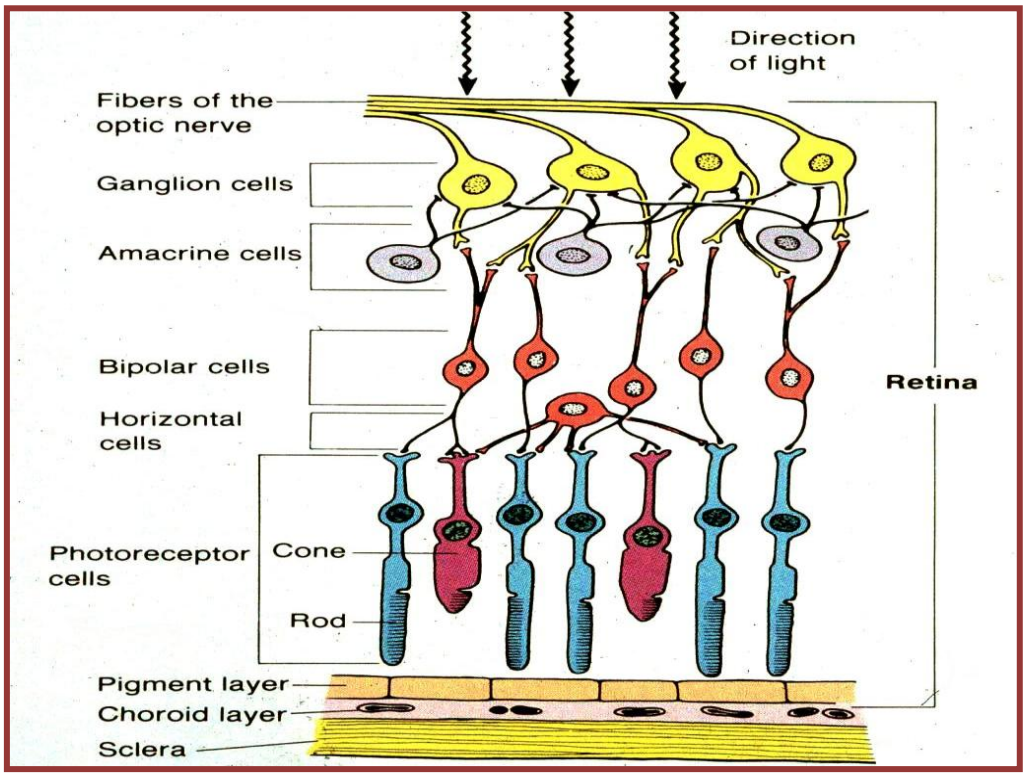
First picture:

Notice the presence of cones only

Second picture:

Notice the fovea centeralis area is avascular

- **Layers of retina (10 Layers), most important are:**



1- Pigment cell layer (Outermost layer):

– Supplied by vitamin A

– Absorbs light (because it contains melanin) & prevents its reflection back

2- Photoreceptors "Rods & Cons" (Inner Neural layer):

– Consists of outer and inner segments. (Without cell bodies)

– Rods = 120 millions

– Cons = 6 millions

3- Outer nuclear layer

– Consists of the cell bodies of the photoreceptors

4- Outer plexiform layer:

– Horizontal cells (synaptic connection with the receptors)

5- Inner nuclear layer:

– Bipolar cells

6- Inner plexiform layer:

– Amacrine cells (synaptic connections with the ganglion)

7- Ganglion cell layer:

– Their axons join to form the optic nerve

8- Optic nerve fibers:

– 1.2 million fibers

- **Binocular Vision for (The use of both eyes):**

1. **Large visual field:**
   Using both eyes gives you the ability to see wider

2. **Cancel the effect of blind spot:**
   While using both eyes, one eye will cancel the effect of the other eye's blind spot

3. **Stereoscopic vision:**
   Two images of the same object are blended into one

   Note: one eye lesion does not affect vision

Diabetic retinopathy:
Is an eye condition that affects people with diabetes who have high blood sugar over a prolonged period of time. Too much blood sugar can destroy the blood vessels in the back of the eye, causing damage to the retina. Without the retina, the eye cannot communicate with the brain, making vision impossible. In the early stages of diabetic retinopathy these blood vessels leak fluid and distort sight. In the more advanced stage of diabetic retinopathy fragile new blood vessels grow around the retina. If left untreated, these blood vessels may bleed, clouding vision or scar detaching the retina.

Normal Vision

Diabetic retinopathy Vision

Principles of optics

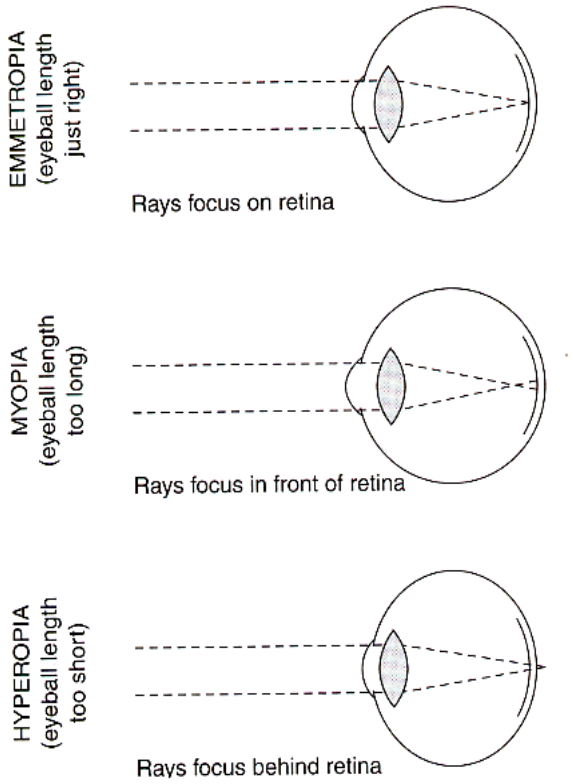
- Biconvex lens (converge) & biconcave lens (diverge)
- Diopter: (measure of refractive power = RF) = 1 / Principal focal distance in meters
- Example: if Principal focal distance of a lens is 25cm, so its R.P=1/ 0.25 meter = 4D
- Emmetropic eye: normal eye has image on retina,has diopteric power 60D
- Lens-retina distance =15mm
- The greater the curvature "convex" of the lens, the greater the refractive power of the eye.

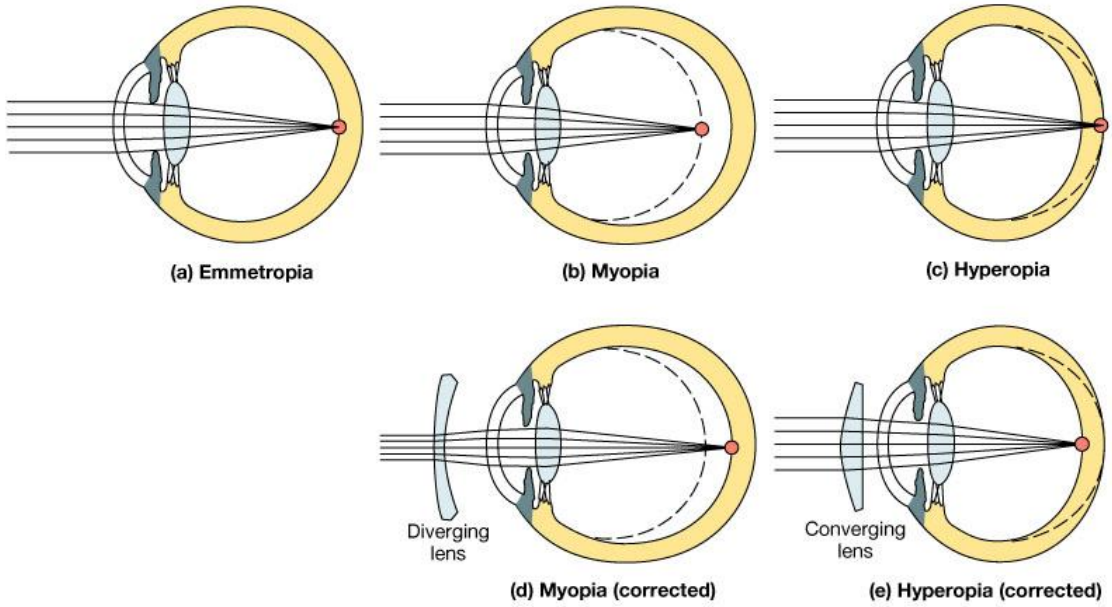
- **Image focusing and errors:**

- **Emmetropia:** Normal Vision

- **Myopia:** Long Antero-posterior diameter of Eyeball → Focus in front of retina → Short sight

- **Hyperopia:** Short Antero-posterior diameter of Eyeball → focus behind retina → long sight





- **Myopia** → Corrected by Divergence lens (Biconcave)
- **Hyperopia** → Corrected by Convergence lens (Biconvex)

- **Other Diseases:**

- **Presbyopia:**
- Loss of lens elasticity → lessening of accommodation
- Mainly caused by aging process
- Corrected by: biconvex

- **Astigmatism:**
- Uneven & ununiform corneal curvature → rays refracted to different focus → blurred vision
- Corrected by: Cylindrical lens

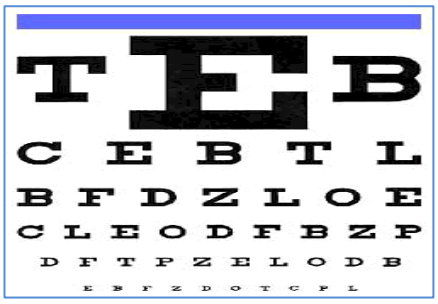
Visual Acuity

- It is the degree of which details of objects are perceived (sharpness, acuteness, clearness of vision)
- The fovea is the point of most distinct vision and has greater acuity

  (Because it has the greatest concentration of cones and because the light strikes the photoreceptors directly in that area)
- Visual threshold is the minimal amount of light that stimulate sensation of light
- To see two different lines or points , visual angle must be 1 minute between them

- **Snellens chart is a clinical method to measure visual acuity:**

  The chart for testing eyes usually consists of letters of different sizes and is placed 20 feet away from the person who is having the test.



Snellens Chart

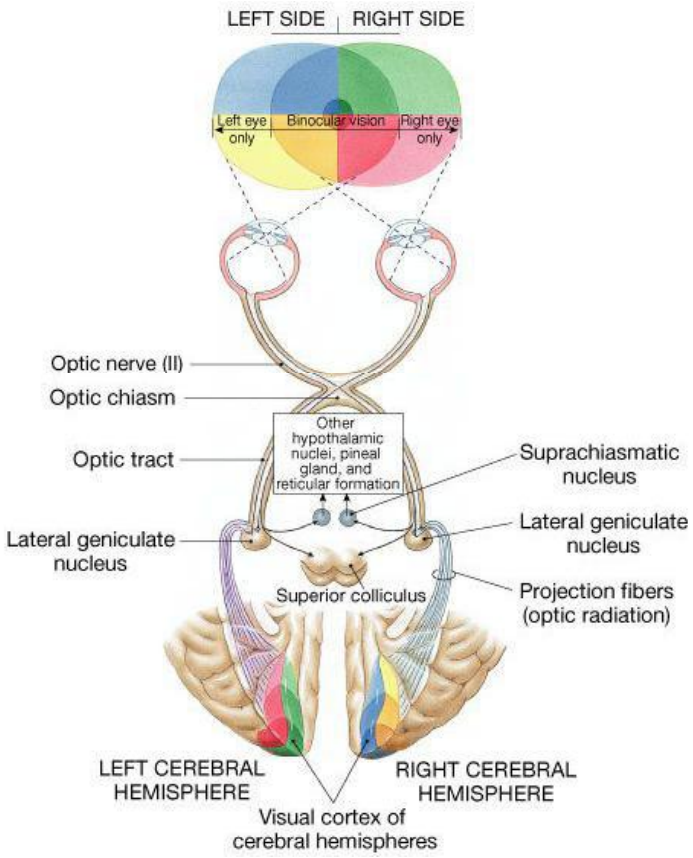
Normal acuity = d(patient's distance)/ D(normal distance) = 6/6 (normal vision acuity)

- A person of 12/6 has better vision than normal vision (not hyperopia)
- A person of 6/12 has less vision than normal vision

- **Duplicity theory of vision (2 kinds of vision under different conditions):**

Photopic Vision (bright light vision)	Scotopic Vision (night vision, dim light vision)
Served by Cones	Served by Rods
High visual acuity	Low visual acuity
Low sensitivity to light	High sensitivity to light
Needs high visual threshold	Low visual threshold

- **Visual Pathway and Fields:**



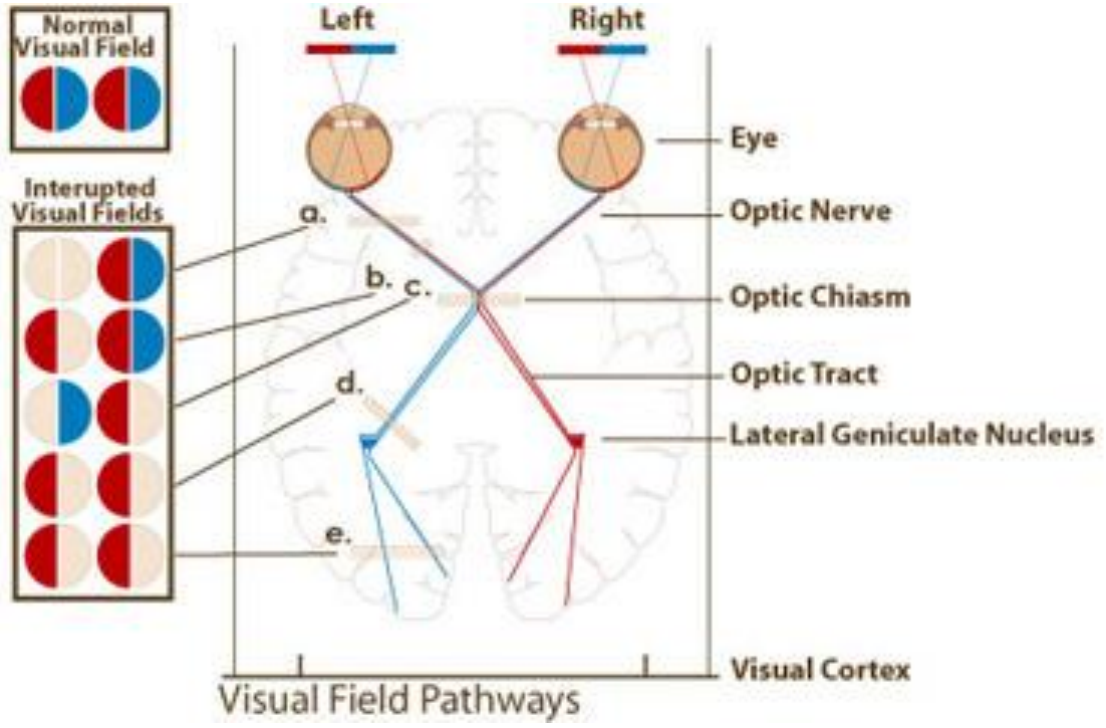
– **The main pathway :**

Light hits the photoreceptors (Cones & rods) → Bipolar cells → Ganglion cells → Optic nerve → Optic chiasma → Optic tract → lateral geniculate body in thalamus → Axons of cells form geniculocalcarine tract → Optic radiation → Visual cortex in occipital cortex (Broadmann area 17 on sides of calcarine fissure)

– **Three other pathways (continuation of the main pathways):**

1- some ganglion cells axons pass from optic tract to pretectal region of midbrain for papillary reflexes & eye movement
2- Some axons of ganglion cells from optic chiasma pass directly to hypothalamus for circadian rhythm (light-dark cycle)
3- Some axons from lateral geniculate body in thalamus to superior colliculus in midbrain for accommodation reflex & its miosis component

- **Visual fields:**



- It is the visual area seen by an eye at a given instant. The area seen at the nasal side is called the nasal field vision (close to the nose), the area seen to the lateral side is called temporal field vision.
- Each eye is supplied by temporal fibers and nasal fibers
- The nasal fibers convey the temporal side vision and the temporal fibers convey the nasal side of vision

- **Left optic tract consists of temporal fibers of the left retina and nasal fibers of right retina**

❖ Left optic tract → Left temporal fibers → Nasal visual field of the left eye
❖ Left optic tract → Right nasal fibers → Temporal visual field of the right eye

- **Right optic tract consists of temporal fibers of right retina and nasal fibers of left retina**

❖ Right optic tract → Right temporal fibers → Nasal visual field of the right eye
❖ Right optic tract → Left nasal fibers → Temporal visual field of the left eye

- The left optic tract corresponds to the right ½ of the visual field
- The right optic tract corresponds to the left½ of the visual field

Accommodation

- Is the ability to adjust the strength of the lens. It depends on the shape of the lens which is regulated by the cilliary muscles (Circular ring of smooth muscles attached to the lens by suspensory ligaments and it controls the lens shape)
- In the normal eyes (at rest) → Cilliary muscle relaxed → Taut (tense) suspensory ligaments → Flat lens (less convex) → Decrease diopteric power of the lens → Far objects focus on retina
- When you look at some object closely, the parallel rays focus behind retina therefore blurred vision will occur, so the solution is to increase curvature & refractive power of lens by accommodation to bring focus on retina.

- **Accommodation reflex:**

- Cilliary muscle contraction → Relaxation of the suspensory ligaments → Increase anterior surface curvature of lens (becomes more convex) → Increase diopteric power of the lens (+12 D) → Near object focused on the retina
- Both circular & longitudinal cilliary muscles contract to pull cilliary muscle forwards & inwards → cilliary muscles edges come close to each other.
- Test-sanson purkinje image

- **Near response (looking at close objects):**

1. **Convergence in the eye:**
   So that the picture would fall on the same level on both eyes

2. **Pupil constriction:**
   To protect the eye from exceed light

3. **Accommodation:**
   To increase lens thickness so that the RP increases

- **Notes:**
- The diopteric power of cornea is 40-45 D but the diopteric power of lens is 15 – 20 D
- The RP (refractive power) of cornea is stronger than lens but lens more important than cornea, because lens does the accommodation

- **Near point:**

– It is the nearest point to eye at which object can brought into focus on retina by accommodation.

– Near point increases as you get older

10 years → 9 cm

60 years → 80-100 cm (due to loss of lens elasticity & loss of accommodation)

Children have a closer and higher near point than adults

- **Pathway of accommodation reflex:-**

– Afferent: Light on eye → Retina → Optic nerve → Optic chiasma → Optic tract → Lateral geniculatebody in thalamus → Superior colliculusin midbrain → Edenger Westphal Nucleus → Cilliary ganglion to oculomotor nerve → Cilliary body contraction

– Efferent: Occuluomotor nucleus → Parasympathetic → Cilliary ganglion → cilliary muscle → Circular papillary muscle

– This pathway of near response is ventral to papillary light reflex

- **Lateral geniculatebody:**

– Thus left LGB(similar to left optic tract) has all layers receive from RIGHT ½ of visual field

– Right LGB(similar to right optic tract) has all layers receive from LEFT ½ of visual field.

- **Functions of LGB:**

1- Acts as a relay station for visual information from optic tract to cortex
2- It has point to point transmission (spatial fidelity)
3- Acts as gate controls signal transmission to visual cortex i.e control how much signals reach visual cortex
4- Color vision & detect shapes & texture

N.B: It is rapidly conducting to visual cortex.

- **Pupilary light reflex:**

– Cover one of your eyes with one hand and get a flash light and point it on the other eye's pupil, constriction of both pupils of both eyes will occur (direct miosis in the opened eye, indirect miosis in the covered eye)

– **Note:** Miosis (contraction of pupil)

- **Pathway of consensual Pupilary light reflex (indirect):**

– Light on eye → Retina → Optic nerve → Optic chiasma →Optic tract → Pass through superior colliculus to end in pretectal nucleus → Both occulomotor nerve nuclei (EWN) → Both ciliary ganglia → Supply both eyes by oculomotor nerves → Miosis in both eyes.
– Atropine drops: block parasympathetic supply of occulomotor nerve so mydriasis of the pupil will occur
– **Note:** Mydriasis (Dilation of pupil)
– Visual cortex has 6 layers

- **Primary visual cortex (braodmann area 17):**

– Perceive sensation of vision (movement + shapes + stereognosis + brightness)
– Have blobs for color detection

- **Association visual cortex(area 18 & 19):**

– Interpretation of visual stimuli

- **Argyll Robertson pupil:**

– Occurs in syphilis tabes dorsalis which destroy pretectal nucleus
– Light reflex is lost & accommodation reflex remains
– Because lesion is in pretectal nucleus only, away from superior colliculus & fibers of accommodation

Color vision

- Color vision is the ability to discriminate between different colors.
- Cones provide color vision. Rods provide vision in shades of gray. There are 4 different photopigments , one in the rods (gray shades) and one in each of three types of cones (red , blue , green).
- There are 3 primary colors (blue-red-green) sensed by Cones in fovea centralis & appreciated within photopic vision (bright light vision).

Fovea centralis: is a depression in the center of the macula of the retina, the area of the most acute vision, where only cones are present and where blood vessels are lacking.

Photopigment: is any pigment, such as the visual pigment found in the photoreceptors of the retina, which is altered by the absorption of light energy. Each photopigemnt has the same retinal (an aldehyde precursor of vitamin A produced by the enzymatic dehydration of retinol. It is the active form of the vitamin necessary for night, day, and color vision) but different opsin (a protein that binds to the retinal to form a visual pigments) . Retinal and opsin bind together in different ways, therefore each of the four photopigments absorb different wavelengths of light.

- **Color vision theory (Young-Helmholtz theory):**

- **Sensation of any color determined by:**

1. Wavelength of light
2. Amount of light absorbed by each type of cones
3. Frequency of impulses from each cone system to ganglion cells which is determined by wavelength of light.

- **Color vision is coded by different responses in ganglion cells that depends upon :**

1. The wavelength of stimulus which determine frequency of impulses in ganglion cells
2. The color perception in the brain depends on the amount of activity in each of the 3 cone systems
3. We have 3 kinds of cones each has a specific photopigment (rhodopsin) & is sensitive to one of the 3 primary colors :

Blue cone system	Green cone system	Red cone system
(S) pigment (blue sensation pigment)	(M) pigment (green sensation pigment)	(L) pigment (red sensation pigment)
Respond to short wavelength	Middle wavelength	Large wavelength
440 nm senses the blue color	535 nm senses the green color and less to yellow and absorb light at green portion	At or > 535 nm so senses the red & yellow color & absorb light at the red portion

- Each cone system respond to its color at a lower threshold than needed to sense other colors (red cones respond to red or yellow color at a lower threshold than to green color – needs a very high visual threshold)

- **Perception of colors:**
  Sensation of extra spectral colors as white, yellow, orange, purple, can be produced by mixing properties of the blue &red & green in different combinations

Black	Absence of light (not darkness because in dark we do not see black)
White	Due to equal stimulation of blue & red & green cones There is no wave length corresponds to white, white is a combination of all wave lengths
Orange	Due to stimulation of 99% of red cones & 42% of green cones & 0% of blue cones(so ratio is 99:42: 0)
Yellow	Is due to stimulation of 50% of red cones & 50% of green cones & 0% of blue cones (so ratio is 50:50: 0)
Blue	Is due to stimulation of 0% of red cones & 0% of green cones & 97% of blue cones (so ratio is 0:0: 97)

- **Color Blindness:**

– There is gene for rhodopsin on chromosome (3)
– There is gene for blue sensitive cone pigment on chromosome (7)
– There is gene for red & green sensitive cone pigment on x chromosome.
– When a single group of color receptive cones is absent (due to absence of their gene), the person can't see or distinguish some colors from others

- **Red–green blindness:**

– Green & red cones see different colors between wavelength 525-675 nm & distinguish them.
– If either of these cones are absent, the person cannot distinguish 4 colors (red – green – yellow - orange) & he cannot distinguish red from green (primary colors)
– It is x-linked disease transmitted from females to their male sons, rarely occurs in females as they have 2 x chromosomes
– Males have one x & one y chromosome so if this one x chromosome miss the gene for color vision , he will get red-green color blindness
– Females show the disease only if both x chromosomes lack the gene
– Females from color blind fathers are carriers transmit the disease to ½ of their sons

❖ **Trichromats:**
Have 3 cone pigments (normal or have slight weakness in detecting one of the primary colors)

❖ **Dichromats:**
Have only 2 cone pigments (completely blind to one of the primary colors)

❖ **Monochromats:**
have only one cone system or loss of all (see white, black or grey or have no color perception)

	Prot (Red)	Deuter (Green)	Trit (Blue)
Nopia (Blindness)	Protanopia	Deuteranopia	Tritanopia
Nomaly (Weakness)	Protanamoly	Deuteranamoly	Tritanamoly

Phototransduction of light (mechanism of vision)

- **Light:**
  "Electromagnetic" radiation that is capable of exciting the human eyes (Extremely fast)

- **Visible light Spectrum:**

– Extends from 397 to 723 nm
– Eye functions under two 2 conditions of illumination:
❖ Bright light (Photopic vision) by: **Cones**
❖ Dim light (Scotopic vision) by: **Rods**

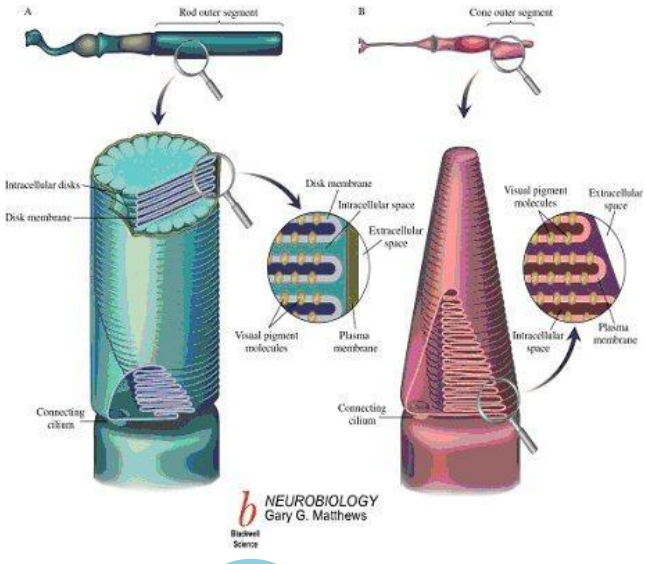
➔ **Leads to Duplicity theory of vision:**
– Photopic visibility curve peaks at 505nm
– Scotopic visibility curve peaks at 550nm

- **Vision receptors:**
  Cones and Rods there structure is divided into outer segment and inner segment.

– **Outer segment:** (modified cilia) have disks full of photosensitive pigment react with light to initiate action potential.
❖ **Cones outer segment:** conical, small and contain 3 types of rhodopsin
❖ **Rods outer segment:** rode like, big and contain one type of rhodopsin

– **Inner segment:** full of mitochondrion (important energy source for Na-K pump) the inner segment in cones thicker than the ones in rods.

Na/K pump:
(3 NA) out
(2 K) in



- **Convergence of cones and rods:**

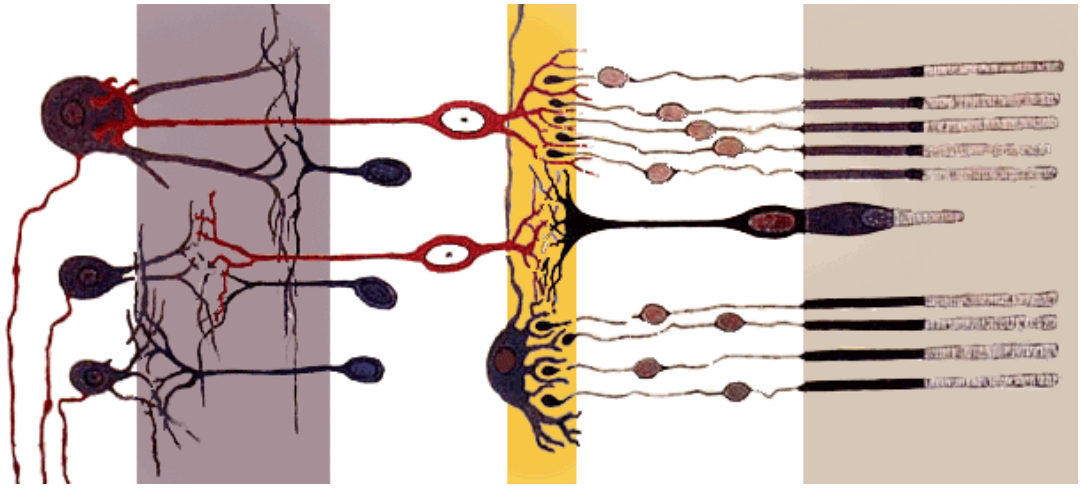
	Rods	Cones
Level of convergence	High convergence	Low convergence
Function	Decreases visual acuity	Increases visual acuity
Result	Increases sensitivity to light (dim light) Need low threshold to stimulate them	Decreases sensitivity to light Needs high threshold to stimulate them

- **Low convergence (cones):** each foveal cone → one bipolar cell → one ganglion cell → single optic nerve fiber

- Properties of low convergence:
  Increases visual acuity (the ability to detect and recognize small objects visually) because the integrated information are from small area of retina, decreases sensitivity to light i.e. need high threshold to stimulate them.

- **High convergence (rods):** several rods about 300 synapse with one bipolar cell and one ganglion cell

- Properties of high convergence: decrease visual acuity because the integrated information are from small large of retina, increase sensitivity to light i.e. low threshold to stimulate them.



There are 120 million rode, 6 million cone and 1.2 million optic nerve fibers, so convergence is 105 receptor: 1 fiber.

- **Comparison between rods and cones:**

Rods	Cones
Used for scotopic vision (vision under low light conditions)	Used for photopic vision (vision under high light conditions)
Low visual acuity	High visual acuity
Not present in fovea	Concentrated in fovea (center)
Have more pigment than cones, so can detect lower light levels	Have less pigment than rods, require more light to detect images
One type of photosensitive pigment	Three types of photosensitive pigment in humans
Confer achromatic vision (black white and shades of gray)	Confer color vision

- **Genesis of photoreceptor potential:**

- Rods and cones potentials are graded, local potential (generator potential) propagated as action potential in ganglion cells
- Ganglion cell action potential (all or none action potential) transmitted to optic nerve
- Rods, cones, horizontal cells and bipolar cell responses are depolarization at dark and hyperpolarization at light

- Cones respond to high levels of light intensity (illumination)
- Rods respond to levels of light intensity (illumination) below threshold levels for cones, from that we know that rods are more sensitive to light

- **Photosensitive compounds:**

– **In cones rhodopsin formed of:**

❖ Opsin protein + retinene1 (retinal = aldhyde form of Vit A).
❖ There are 3 types of rhodopsinin in 3 types of cones each respond to a certain wavelength of light

– **In Rods rhodopsin formed of:**

❖ scotopsinprotein + retinene1
❖ It is stored in rods disks at outer segment it forms (90% of its protein)

At dark Rhodopsin is in 11-cisretinal form (inactive form light sensitive form that increases sensitivity of rods to light)

- **Retinal photoreceptors mechanism:**

  Light → absorption by photosensitive substance → structural change in photosensitive substance → phototransduction → action potential in the optic nerve

- **Electric recording in Retinal cells:**

– **Rods & Cones:** Hyperpolarization
– **Bipolar cells:** Hyper- & Depolarization
– **Horizental cells:** Hyperpolarization
– **Amacrine cells:** Depolarizing potential
– **Ganglion cells:** Depolarizing potential

	Rods	Cones
Light Environment	Dim light - scotopic	Bright light - photopic
Spectral sensitivity	1 pigment	3 pigments
Color discrimination	No	Yes
Absolute sensitivity	High	Low
Speed of response	Slow	Fast
Rate of dark adaptation	Fast	Slow

- **Phototransduction:**

  Is a process by which light is converted into electrical signals in the rod cells, cone cells and photosensitive ganglion cells of the retina of the eye.

- To understand the photoreceptor's behaviour to light intensities, it is necessary to understand the roles of different currents.
- There is an ongoing outward potassium current through nongated K+-selective channels. This outward current tends to hyperpolarize the photoreceptor at around -70 mV (the equilibrium potential for K+).
- There is also an inward sodium current carried by cGMP-gated sodium channels. This so-called 'dark current' depolarizes the cell to around -40 mV.

- **At Dark (scotopic vision, dimlight vision):**

❖ Rhodopsin in 11-cisretinal (inactive form)
❖ (5 –GMP) in the c-GMP form
❖ Na channels open

– In the dark, cGMP levels are high and keep cGMP-gated sodium channels open allowing a steady inward current, called the dark current. This dark current keeps the cell depolarized at about -40 mV.
– The depolarization of the cell membrane opens voltage-gated calcium channels. An increased intracellular concentration of Ca2+ causes vesicles containing special chemicals, called neurotransmitters, to merge with the cell membrane, therefore releasing the neurotransmitter into the synaptic cleft, The neurotransmitter continuously (steadily) released is (mainly glutamate, Ach, dopamine, GABA) this release of neurotransmitters will cause (depolarization) in bipolar cells → Generator potential in ganglion cells (depolarization) → action potential → optic nerve → optic pathway

- **Notes:**

1- At dark, rhodopsin is inactive (cis-retinal needs light for its activation)
- inactive rhodopsin is essential for depolarization.
- Its inactivation keeps Na channels open & Na current occurs,this is the causative factor for depolarization.

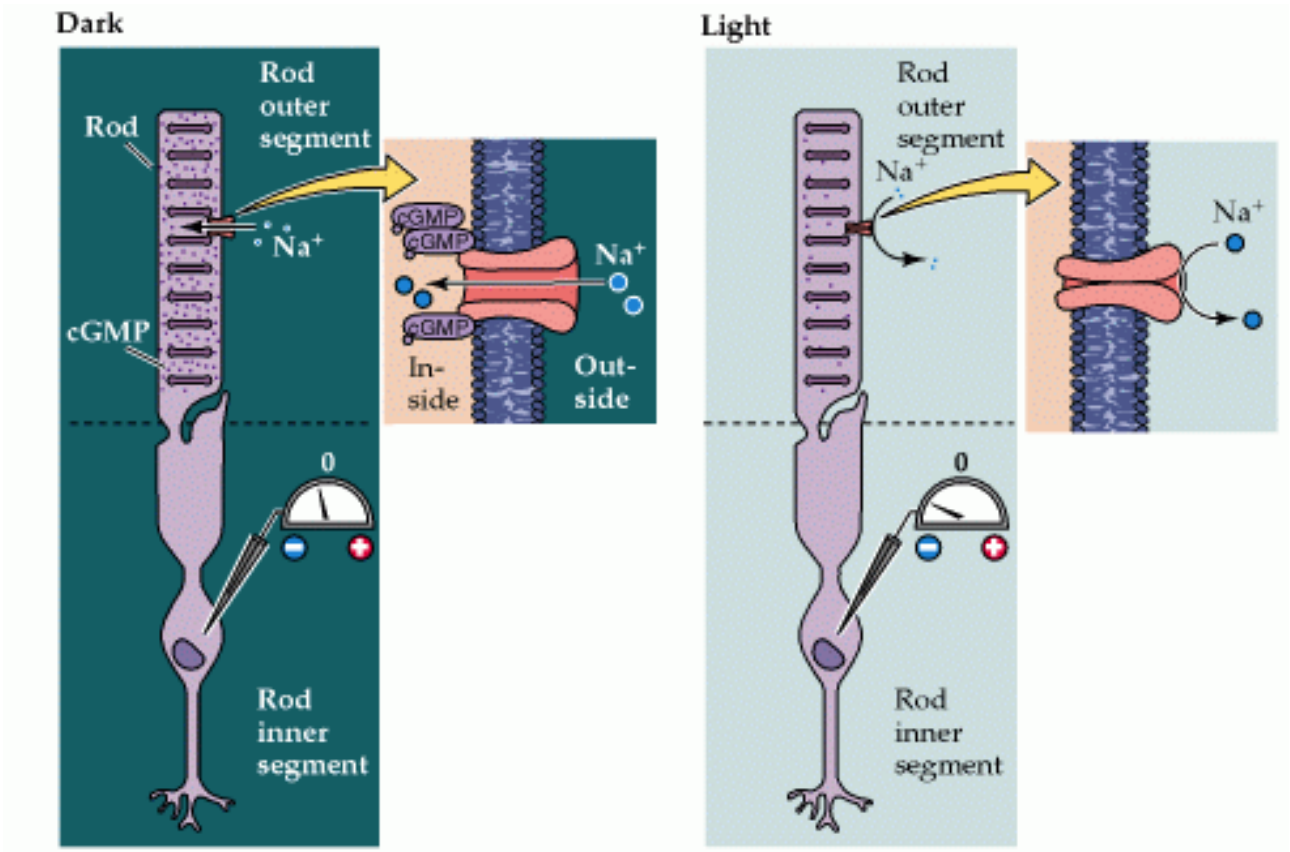
2- At dark rhodopsin is regenerated from retinine + scotopsin

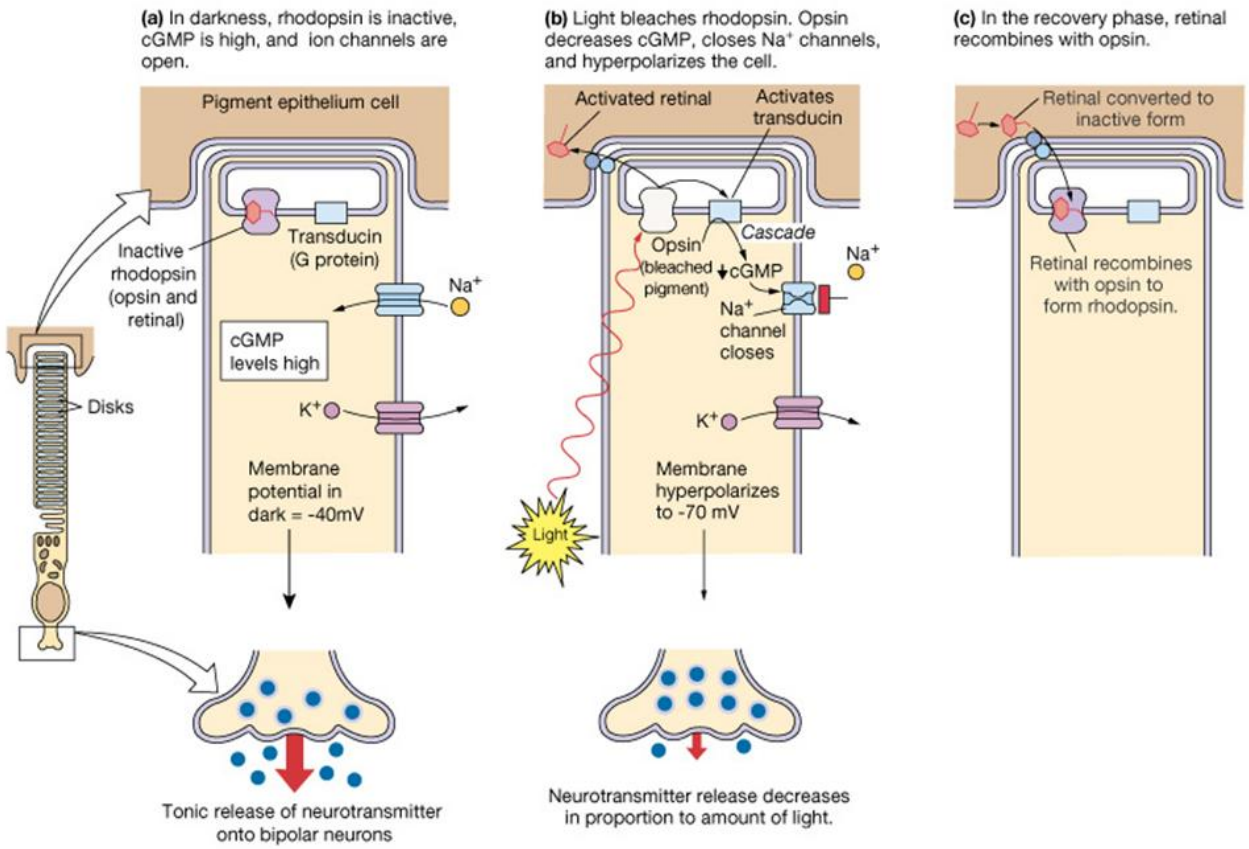
- **Incident light (photopic vision):**

❖ Rhodopsin in metarhodopsin II form (active form)
❖ (5 –GMP)
❖ Na channels close

1) A light photon interacts with the retinal in a photoreceptor cell. The retinal undergoes isomerisation, changing from the 11-cis to all-trans configuration.
2) Retinal no longer fits into the opsin binding site.
3) Opsin therefore undergoes a conformational change to metarhodopsin II.
4) Metarhodopsin II is unstable and splits, yielding opsin and all-transretinal.
5) The opsin activates the regulatory- protein transducin. This causes transducin to dissociate from its bound GDP, and bind GTP, then the alpha subunit of transducin dissociates from the beta and gamma subunits, with the GTP still bound to the alpha subunit.
6) The alpha subunit-GTP complex activates phosphodiesterase.
7) Phosphodiesterase breaks down cGMP to 5'-GMP. This lowers the concentration of cGMP and therefore the sodium channels close.
8) Closure of the sodium channels causes hyperpolarization of the cell due to the ongoing potassium current.
9) Hyperpolarization of the cell causes voltage-gated calcium channels to close.
10) As the calcium level in the photoreceptor cell drops, the amount of the neurotransmitter glutamate that is released by the cell also drops. This is because calcium is required for the glutamate-containing vesicles to fuse with cell membrane and release their contents.
11) A decrease in the amount of glutamate released by the photoreceptorscauses (hyperpolarization) in bipolar cells (this cause decreased release of inhibitory synaptic transmitter) → Generator potential in amakrinecells and ganglion cells (depolarization) → action potential → optic nerve → optic pathway

- These reactions occur in both rods and cones but in rods occur at low illumination as in dimlight and in cones at high illumination.
- In cones 4 times faster


Dark
Rod
Rod outer segment
Na+
cGMP
cGMP
cGMP
Na+
In-side
Out-side
0
Rod inner segment
Light
Rod outer segment
Na+
Na+
0
Rod inner segment


(a) In darkness, rhodopsin is inactive, cGMP is high, and ion channels are open.
(b) Light bleaches rhodopsin. Opsin decreases cGMP, closes Na+ channels, and hyperpolarizes the cell.
(c) In the recovery phase, retinal recombines with opsin.
Pigment epithelium cell
Inactive rhodopsin (opsin and retinal)
Transducin (G protein)
Na+
cGMP levels high
Disks
K+
Membrane potential in dark = -40mV
Activated retinal
Activates transducin
Opsin (bleached pigment)
Cascade
cGMP
Na+
Na+ channel closes
K+
Membrane hyperpolarizes to -70 mV
Light
Retinal converted to inactive form
Retinal recombines with opsin to form rhodopsin.
Tonic release of neurotransmitter onto bipolar neurons
Neurotransmitter release decreases in proportion to amount of light.

- **Dark adaptation:**

- Adaptation is the ability of the eye to adjust to various levels of darkness and light.
- The eye takes approximately 20–30 minutes to fully adapt from bright sunlight to complete darkness and become ten thousand to one million times more sensitive than at full daylight. In this process, the eye's perception of color changes as well. However, it takes approximately five minutes for the eye to adapt to bright sunlight from darkness. This is due to cones obtaining more sensitivity when first entering the dark for the first five minutes but the rods take over after five or more minutes.
- Changes in the sensitivity of rods and cones in the eye are the major contributors to dark adaptation.

- **Dark adaptation has 2 components:**

1. Rapid (about 5 minutes) drop in visual threshold, Fast dark adaptation of cones, only in fovea sensitivity of cones to light increase to see at that time.
2. Less rapid (till 20 min) drop in visual threshold, dark adaptation of rods in the peripheral retina sensitivity of rods to light increase, in 1 min increase 10 folds.

- Rods increase their sensitivity to light by convergence 300:1 ganglion cell, so summation at ganglion cells potential will increase sensitivity of rods to light.
- 20 mins for dark adaptation are for regeneration of rhodopsin → increase sensitivity of rods to light → a drop in visual threshold.

Q- Why radiologists & aircraft pilots wear red goggles in bright light?
A- Because red light stimulates rhodopsin (in rods) less, i.e. less rhodopsin is bleached; less time is needed for the eye to become dark-adapted.

Q- In vitamin A deficiency, What happens to Dark adaptation?
A- Night blindness (Nyctalopia)

- **Light adaptation:**

- When light switched on again, the rods are knocked out of action (they stop sending AP at high levels of light) and cones start to function to adjust and adapt to the level of brightness in 5 minutes