10 The eye & refraction

CNS

Sources:-
-females slides.
-males slides
-Neuroanatomy chapter 15
-Linada p 78

(تنبيه)

- سيتم إيضاح مصادر السلايدات في بداية كل محاضرة
- لن تكون هناك أسئلة نهاية كل محاضرة بل سيتم وضع أسئلة للمراجعة شامل قبل كل اختبار
- ينصح بمتابعة محاضرات الدكتور نجيب لهذا البلوك

http://www.ksums.net/files/2nd/Archive/01%20CNS%20BLOCK/Female/Physiology/Dr.%20Najeeb%20lectures/

•OBJECTIVES:-

- different components of the eye and function of each and the eye protection media.
- the refraction of light as it passes through the eye to the retina, the refractive media of the eye.
- glocuma and binocular vision.
- layers of retina, blind spot, and fovea centralis.
- the different light sensitivities of the fovea, peripheral retina and optic disk.
- principles of optics and errors of refraction.

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Anatomy of the eye

sclera*
-Spherical appearance
-For protection

Cornea*
-Modified Anterior **1/6** of sclera.
-Transparent, avascular to allow light to enter the retina.
-Refractive or diopteric power **40-45 D** at its anterior surface.

Conjunctiva *
-Transparent membrane cover anterior surface of eye.
-reflected on inner surface of eye lids.
-Covered with thin film of **tears** for **protection, wetness, cleaning**.

choroid *
-Inside sclera.
-Contain blood vessels to supply retina.
-Posterior **2/3** of choroid has retina innermost layer.

ciliary muscles (body) *
-thick anterior part of choroid to which attached **suspensory ligaments** (zonule).

Iris*
-colored part
-**radial muscle** dilates (mydriasis) the pupil by **sympathetic supply.**
-**circular muscles** constrict (miosis) the pupil by **parasympathetic supply.**

Lens
transparent, biconvex, semisolid, diopteric power (**15-20) D**, held in place by **zonules** (lens ligament= suspensory ligament)

Pupil
behind center of cornea, allow light to enter the eye.

Uvea
choroid + iris + cilliary muscles.

Continue

Retina *

The functional portion of the eye **except** blind spot:

1-Photoreceptors:

(RODS + CONES).

2-optic disc(blind spot):

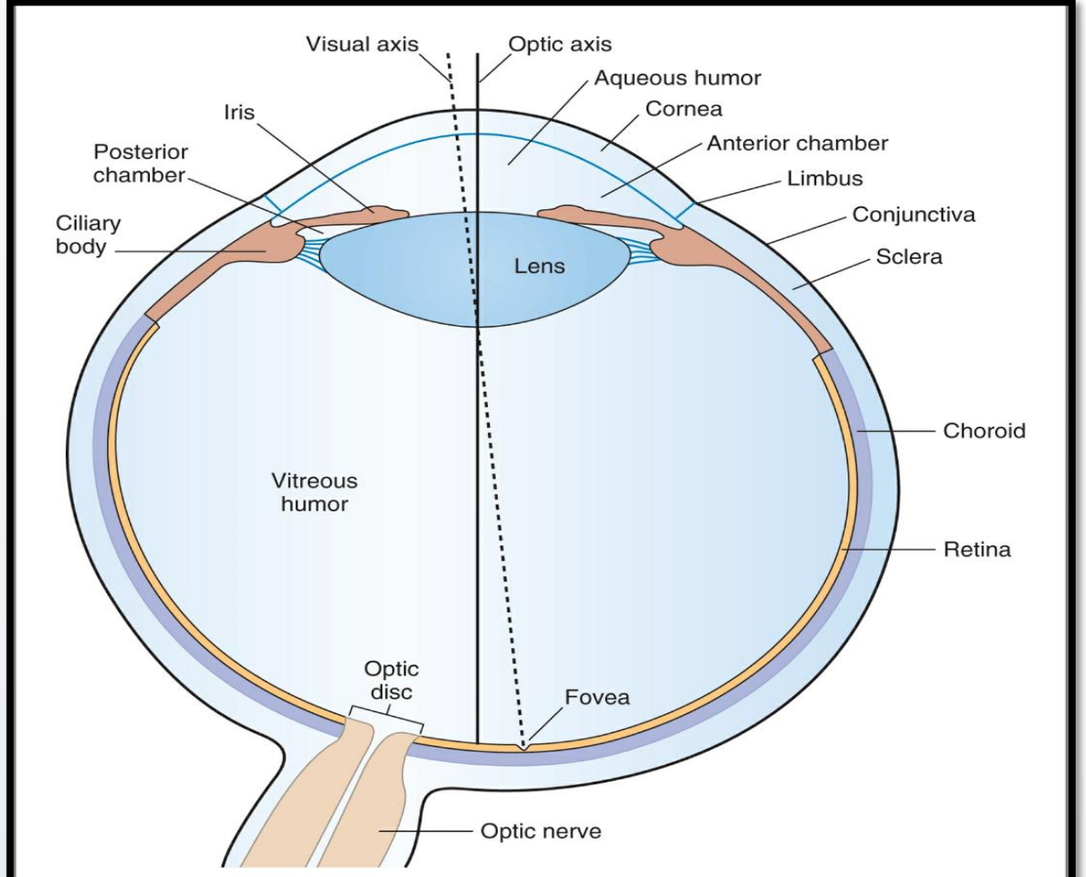
- **3** mm medial & above post pole of eye -optic nerve leave & retinal blood vessels enter + no photoreceptors, **so it is blind.**

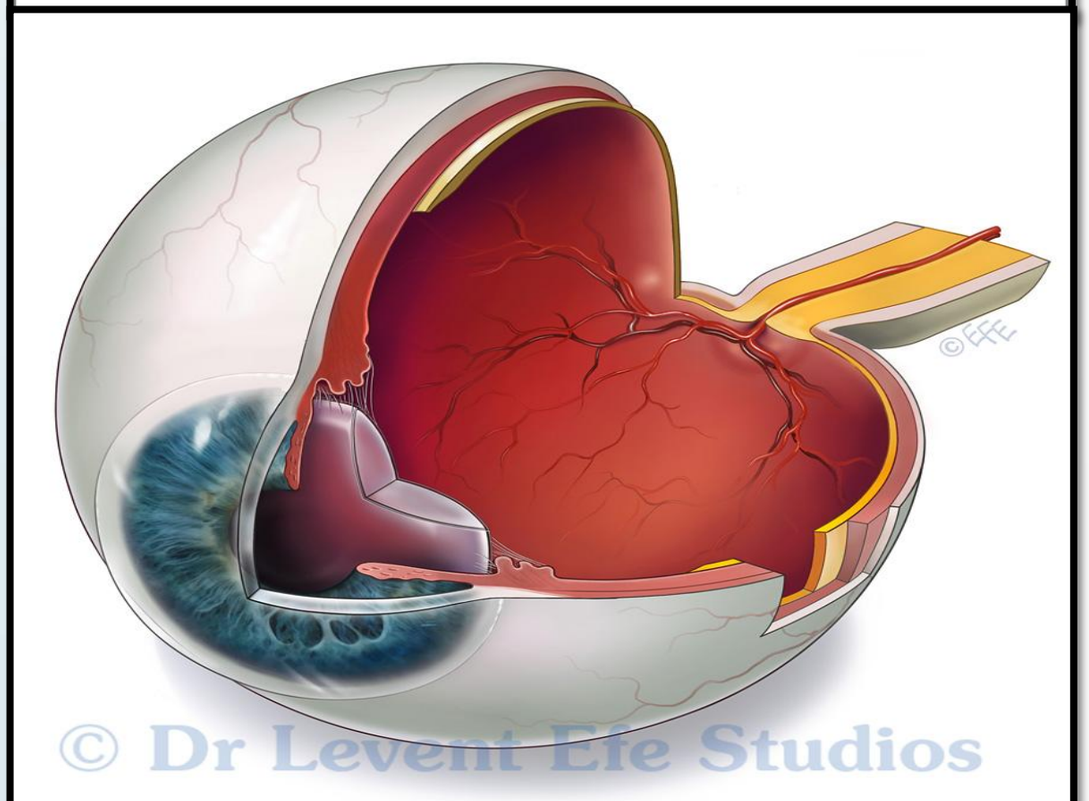
3-fovea centralis:

-depression in **macula lutea**.

- yellow pigmented spot at post. pole of eye + only cones + high visual acuity + for colors vision & details detection.

* Outer layer (fibrous)
* Middle layer (vascular)
* Inner layer (neural)





Chambers of the eye

- Are filled with aqueous humor and nurishes cornea and iris as they are avascular.

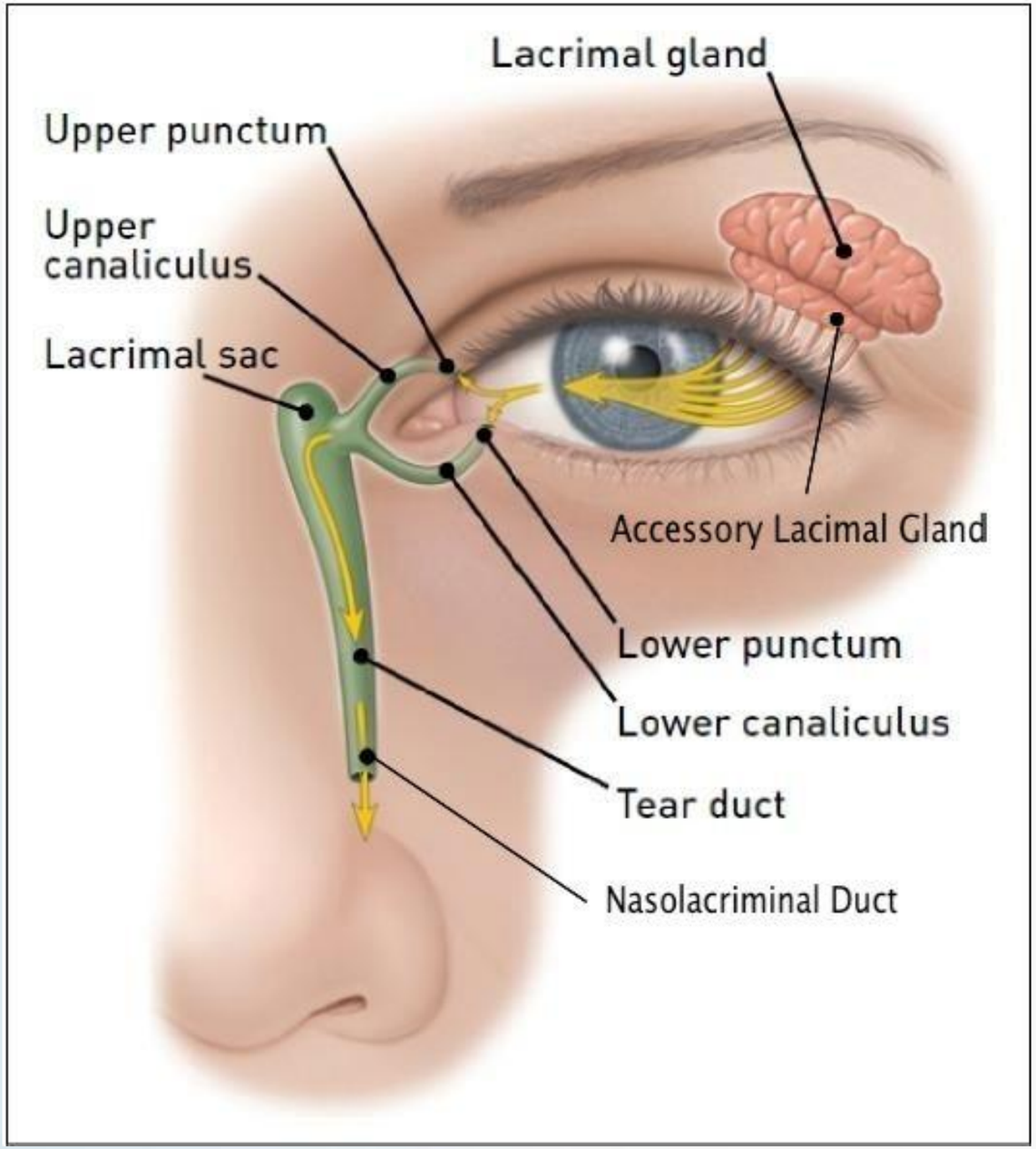
1- anterior champer of the eye:

Between iris and cornea.

2- posterior champer of the eye:

Between iris and cilliary muscle.

-- so **iris** between both.



External protection of the eye

1- bony orbit.

2- lids blinking keep cornea moist.

3- conjunctiva.

4- tears from lacrimal gland has (***antibacterial, lubricating effect ,keep cornea moist & clear***).

Refractive media of eye

1- cornea:

-**2/3** of refractive power.
-Its diopteric power is **40-45** diopter at its anterior surface.

2- aqueous humor:

-**nourishes** the cornea and iris ➡ it is produced in the ciliary body ➡ posterior chamber ➡ to pupil ➡ ant. chamber drained into **canal of Schlemm** in anterior ➡ chamber angle, **[**which is a venous channel at the junction between the iris and the cornea (anterior chamber angle)**]**.
-It causes intra-ocular pressure **10-20** mmHg.
-Obstruction of this outlet leads to **increased intraocular pressure (***a critical risk factor for glaucoma***)**.

3- lens:

-**1/3** of refractive power.
-diopteric power **15-20** D
But more important than cornea's refractive power, **because (***in reponse to nervous signals from the brain, its curvature can be increased markedly to provide "**accommodation**"***)*** up to **14** D.

4- vitrous humor:

-between retina & lens for nourishing retina.
-**keep** spheroid shape of the eye.

-Diopter (s) = 1 / Focal length (m)
Diopteric power of the eye:
Cornea .....40-45 D (max refraction)
Lens ..... 15-20 D
Accommodation by lens .... +12 D

Cataract and glocuma

- Cataract المياه البيضاء

-Common in older people.

-A cloudy or opaque areas in the lens.

-in early stage, the proteins in some of the lens fibers become denatured.

-Later, these same proteins coagulate to form opaque areas of the normal transparent protein fibers.

-Can be corrected by surgical removal and replaced by artificial lens.

Extracapsular cataract extraction → removal of lens without lens capsule

Intracapsular cataract extraction → removal of lens with lens capsule

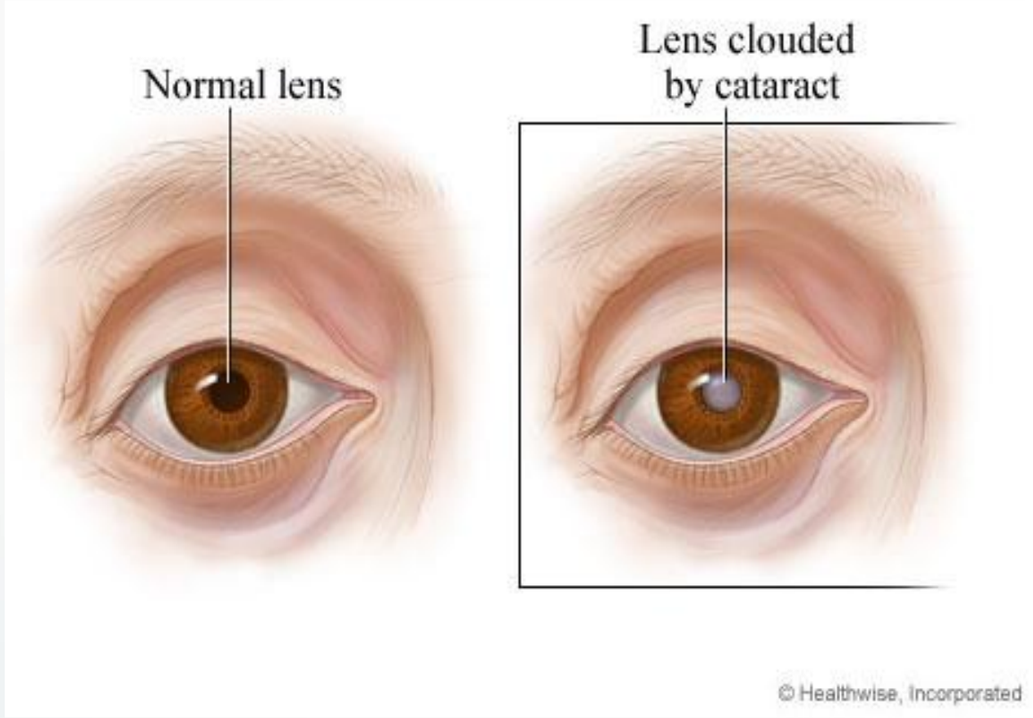
- Glocuma المياه الزرقاء

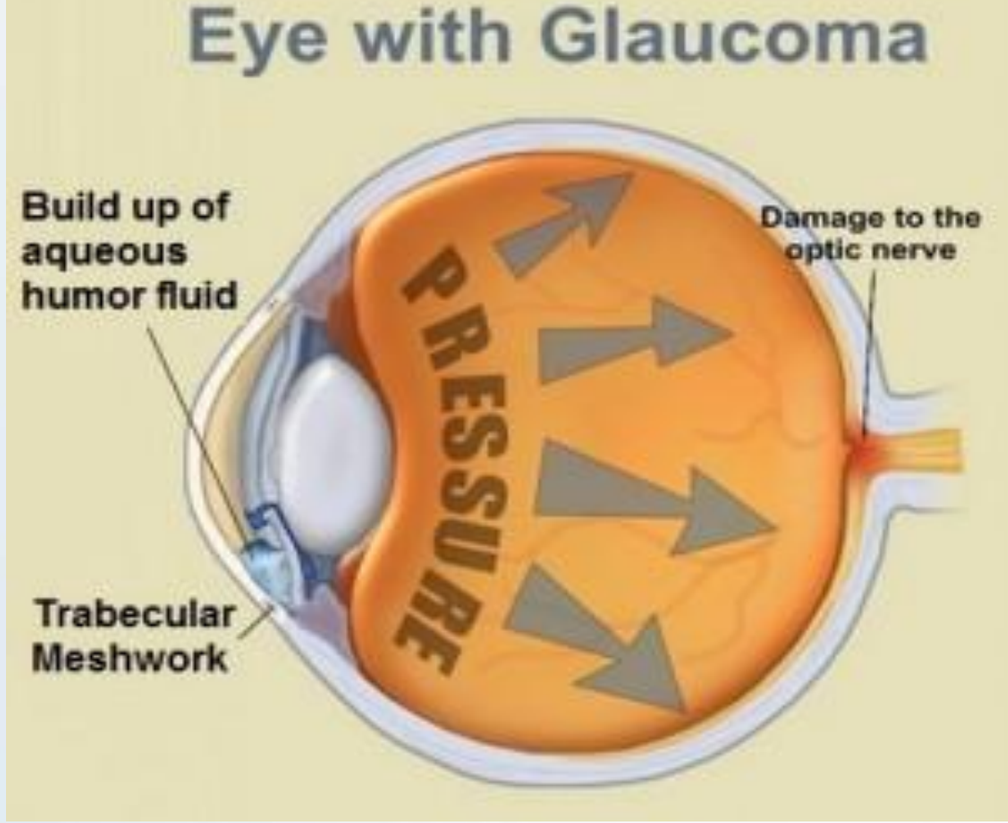
-Most common cause of blindness.

-It is a disease of the eye which the intraocular pressure become pathologically high, pressure above 25-30 mmhg.

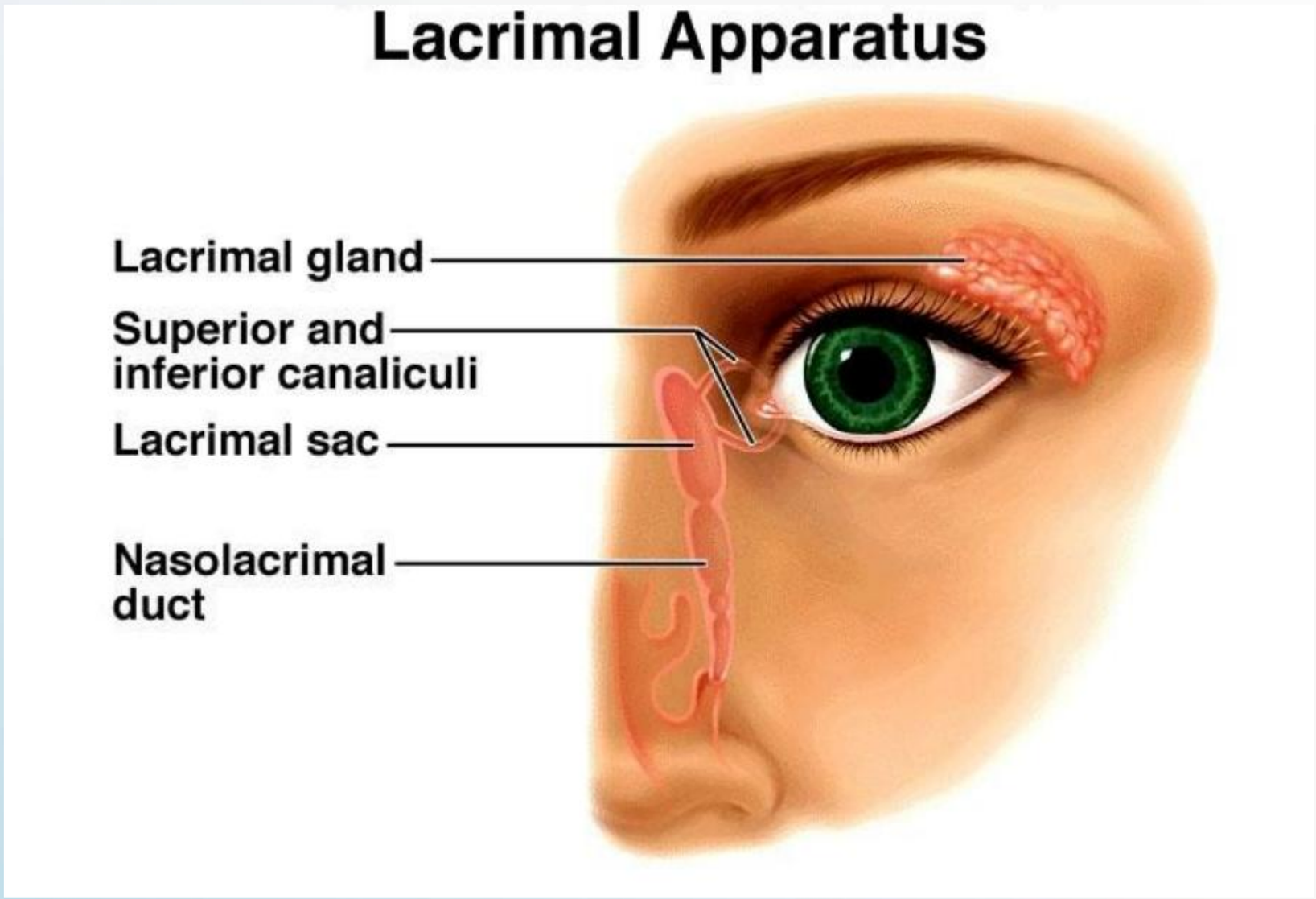
-As the pressure rises, the axons of the optic nerve are compressed. This compression believed to block axonal flow of cytoplasm from the retinal neuronal cell bodies into the optic nerve fibers to the brain. The result is lack of appropriate nutrition of the fibers which eventually cause death of the involved fibers.

-Can be treated by drops which reduces the secretion or increase the absorption of the aqueous humor.





Lacrimal Apparatus



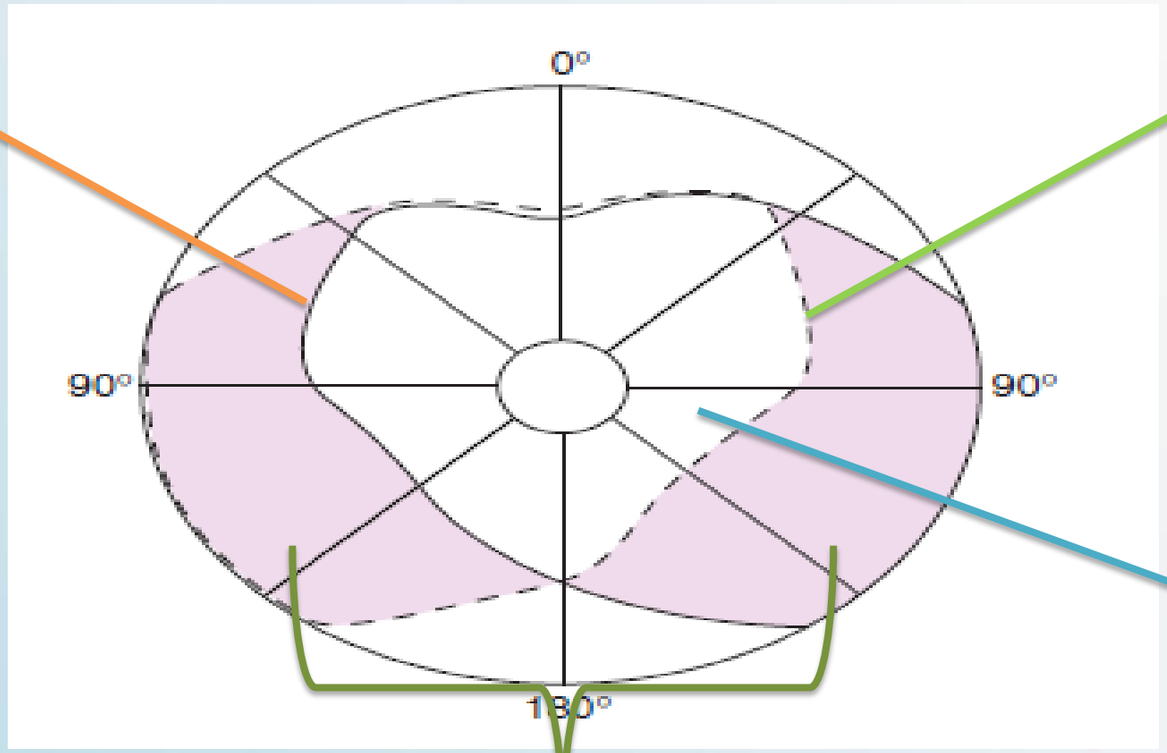
Lacrimal gland → Superior and inferior canaliculi → Lacrimal sac → Nasolacrimal duct

Binoclular Vision for :

- Large visual flied
- Cancel of the effect of blind spot
- Stereoscopic vision (3D vision)
- One eye lesion does not affect vision

Monocular Binoclular Visual flieds :

This solid line encloses the visual flied of the left eye



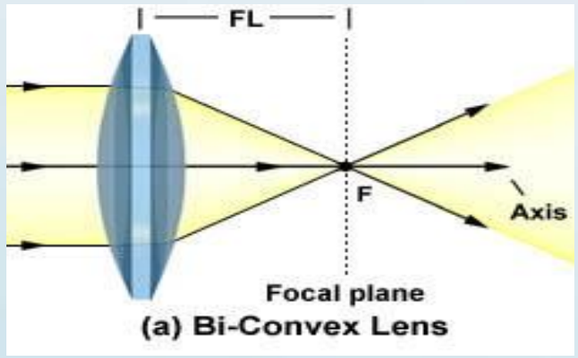
This solid line encloses the visual flied of the right eye

This heart-shaped is viewed with the binocular vision

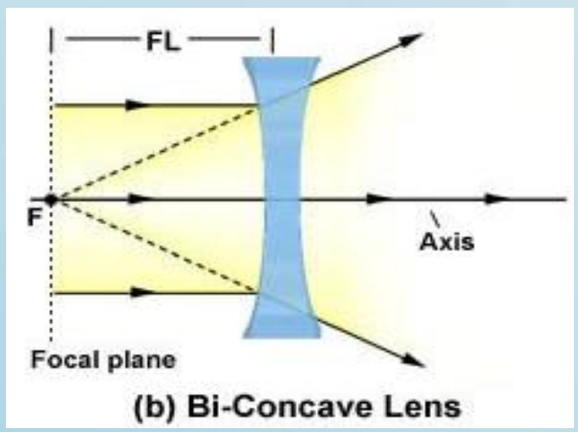
Those two colored areas are viewed with monocular vision

Principales of optic :

Biconvex lens (converge)



Biconcave lens (diverge)



Diopter (mesure of the refractive power = RF)

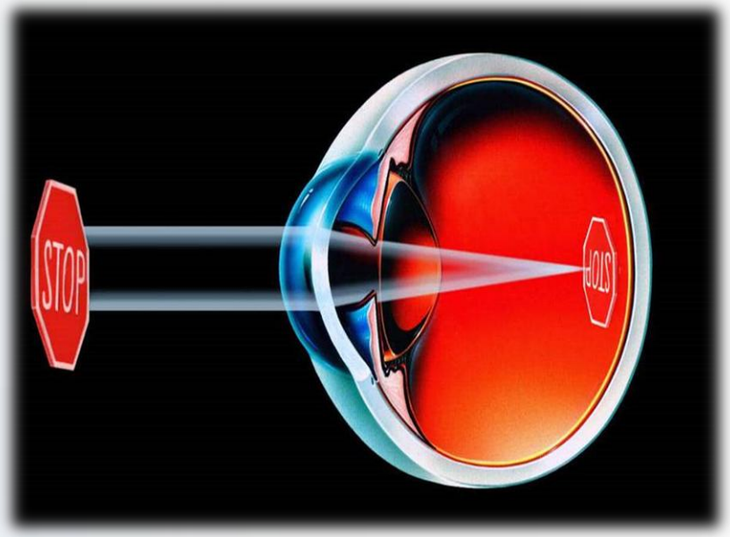
$$\left(\begin{array}{c}\text{Refractive}\\ \text{power of a lens}\end{array}\right) = \frac{1}{f\,(\text{in meters})}$$

$$P\begin{cases} +: \text{converging lens} \\ -: \text{diverging lens} \\ 0: \text{flat sheet (no power)} \end{cases}$$

Exp/ if Principal focal distance of a lens is 25cm, so its R.P=1/ 0.25 meter = 4D

The greater curvature of the lens , the greater the RF of the eye .

Emmetropic eye: normal eye has image on retina, has diopteric power 60D

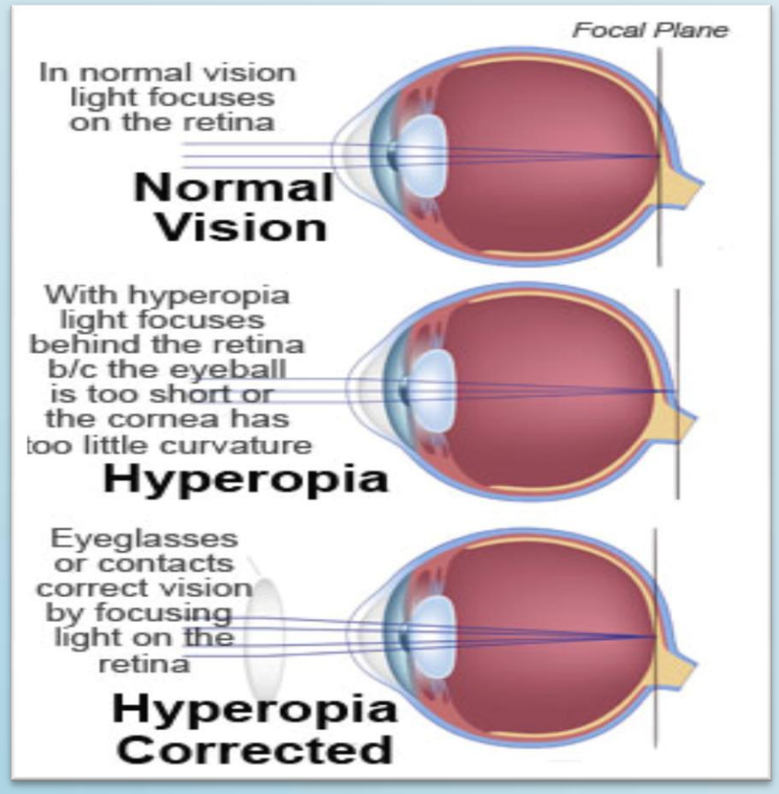


Errors of refraction :

Hypermetropia (hyperopia = farsightedness) :
It is usually do to either an eye ball that is too short or a lens system that is too weak
Focus behind the retina

Continuous Accomodation → To bring the image on the retina → Muscular effort → Cause headache , blurred vision

prolonged convergence by accommodation → Squint (in children)

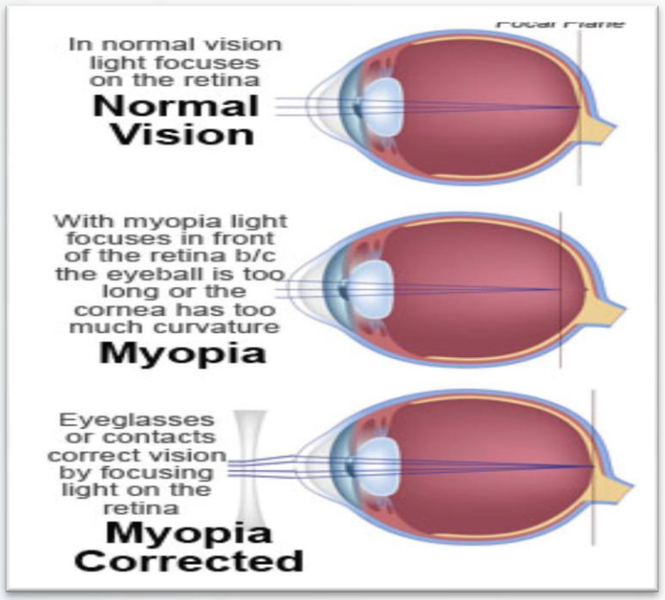


Correction by biconvex lens

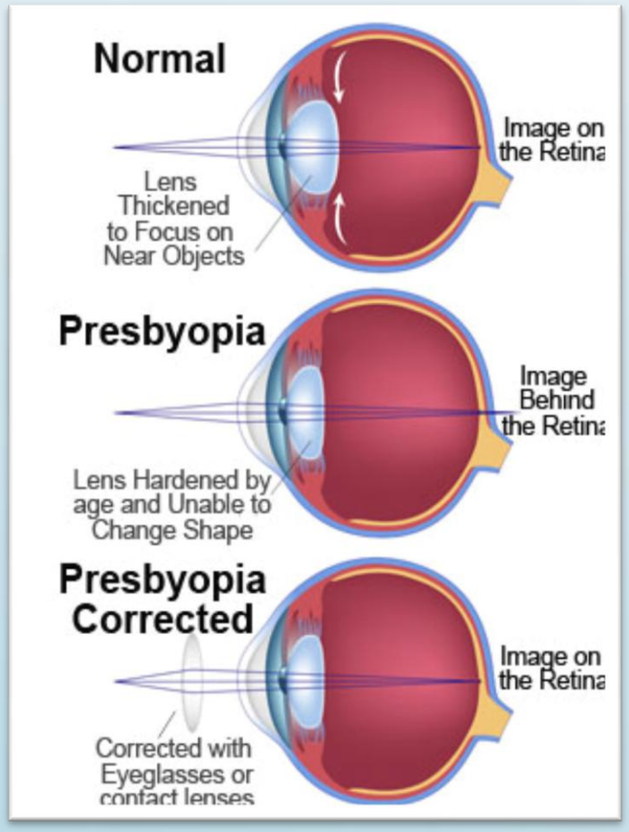
Myopia (nearsightedness) :
This is usually duo to too long an eye ball , genatic , long antero-posterior diameter , extensive work as in studying or it can result from too much refractive power in the lens system of the eye .
Focus in front of the retina

The ciliary muscle is completely relaxed → The light rays coming from distant objects are focused in front of the retina

Correction by biconcave lens



Presbyopia :
Eye near point recedes by age due to loss of accomodation .

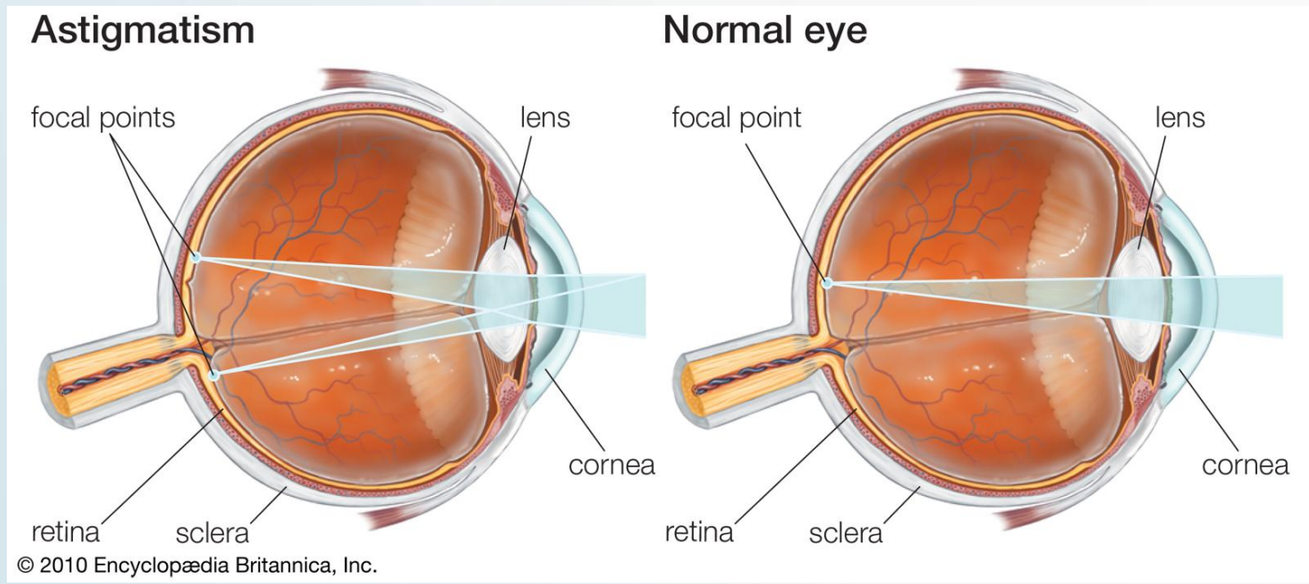


Correction by biconvex lens

Astigmatism (uneven & ununiform corneal cuvature) :
It is a refractive error of the eye causes the visual image in one plane to focus at different distance from the plane at right angle . This often result from too great curvature of cornea in one plane of the eye .

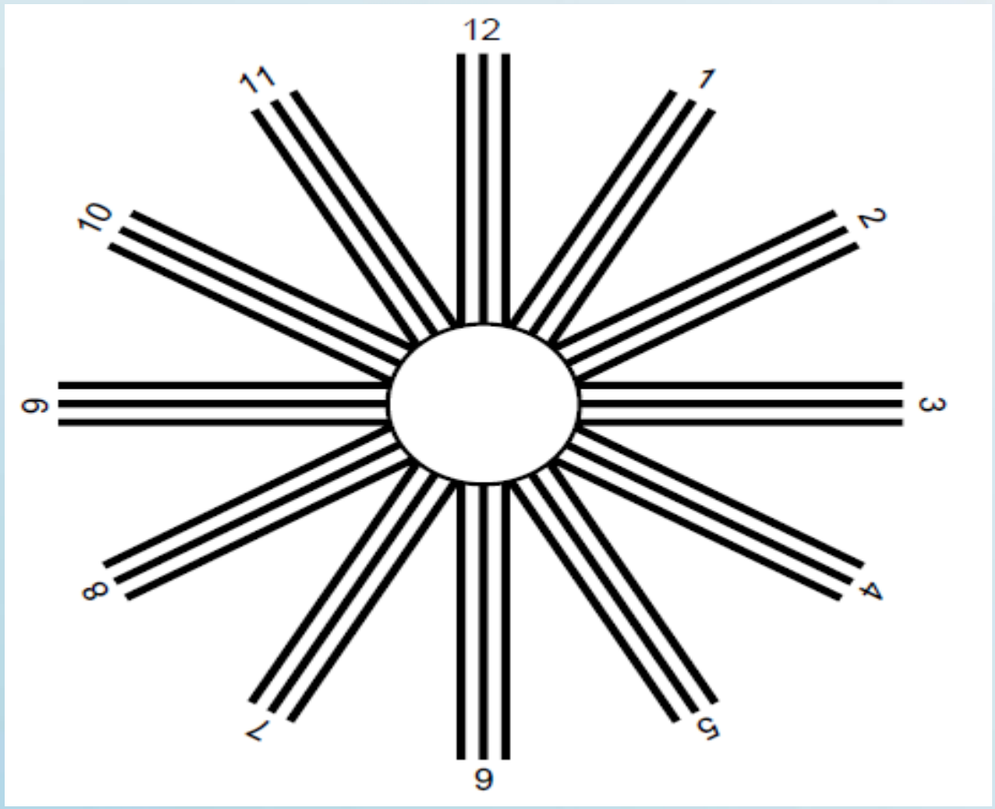
Correction by cylindrical lens

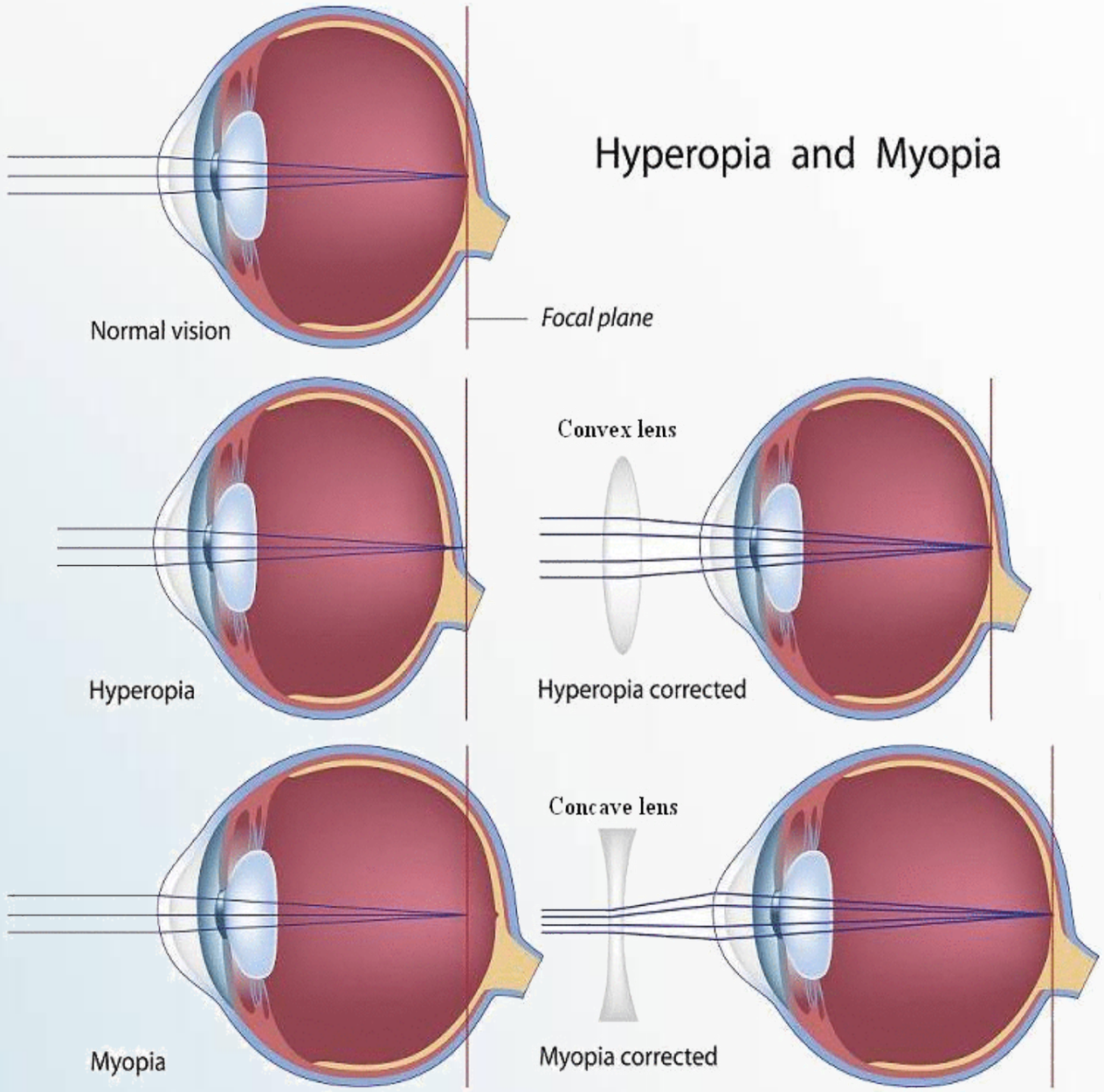
Rays refracted to different foci → Blurred vision



http://youtu.be/X7RptqdvBWE
http://youtu.be/edYnfWFPUIw

There are methods for determining the axis of the abnormal cylindrical components of the lens system of an eye . One of these methods is based on the use of parallel black bars as shown in the figure .





Layers of Retina : (10 layers)

1. pigment cell layer

- storage of vit A
- outermost layer
- absorb light & prevent its reflection back

2.Photorecepter (rods & cones)

- consist of cell body , outer segment and an inner segment .
- *rods 120 million
- *cones 6 million

3.Outer nuclear layer

- Contains the nuclei of photoreceptors

4.Outer plexiform layer

- Horizontal cells (make synaptic connections with receptors)

5.Inner nuclear layer

- Bipolar cells

6.Inner plexiform layer

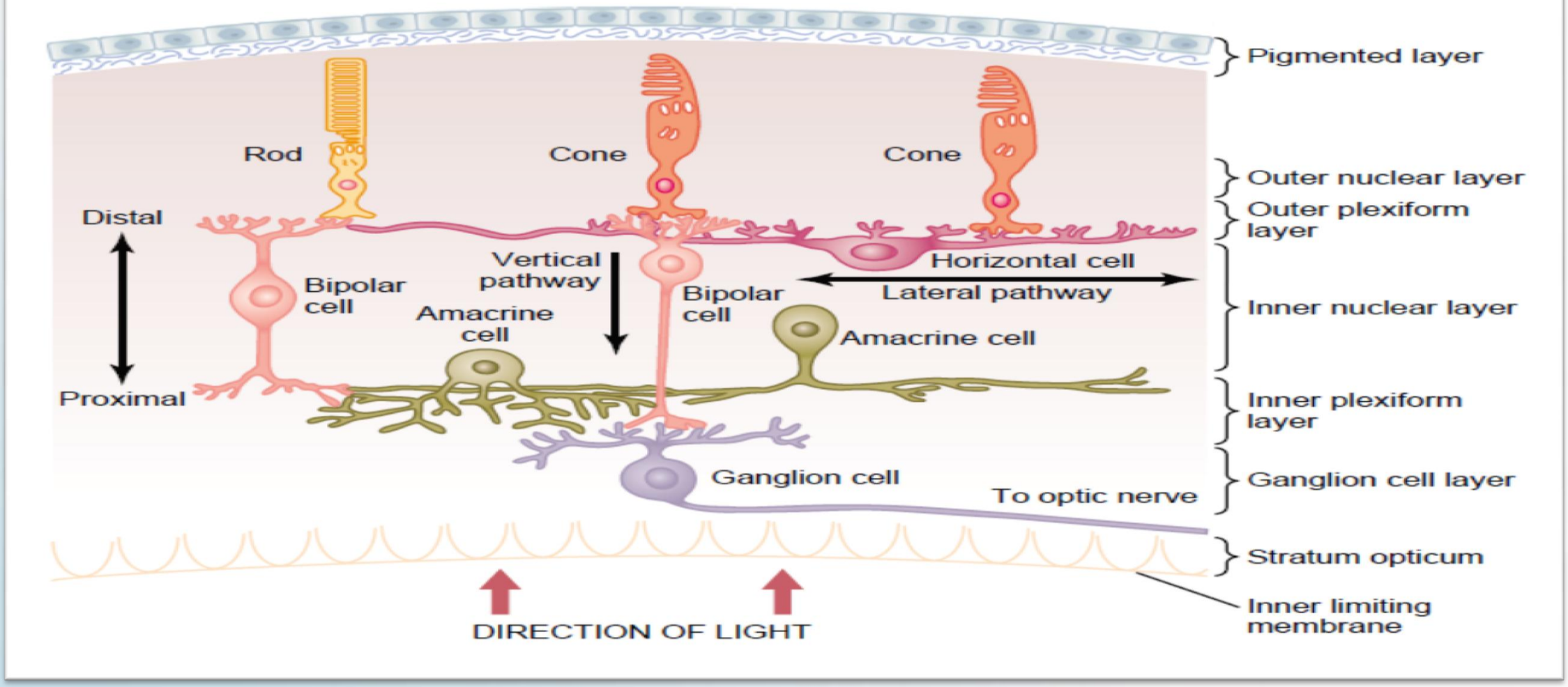
- Amacrine cells (make synaptic connections with ganglion cells)

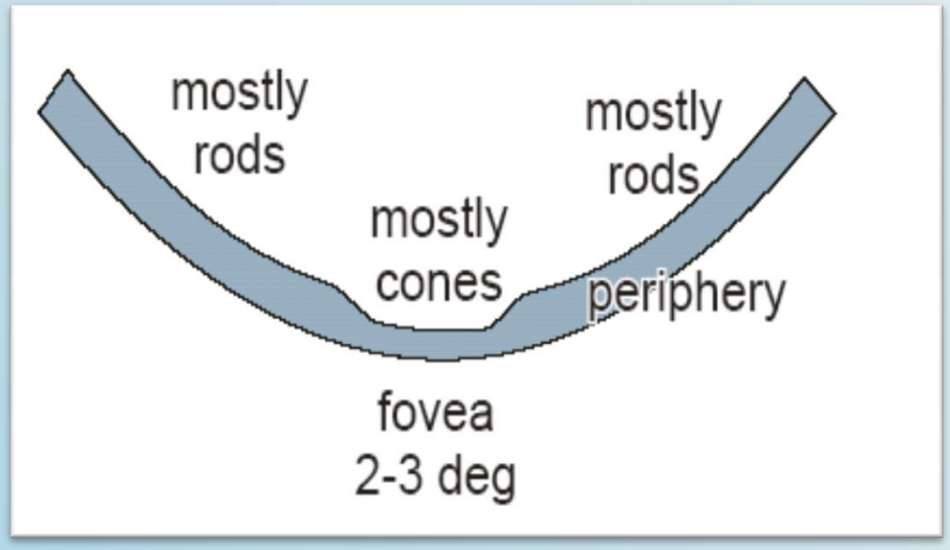
7.Ganglion cell layer

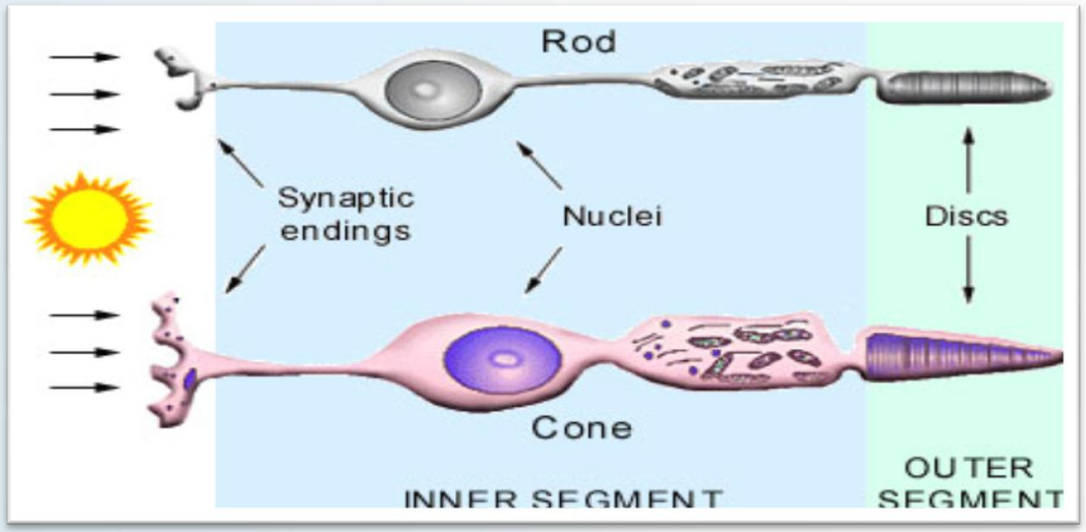
- Contains cell bodies of ganglion cells , which are the output if the retina .

8.Optic nerve layer

- Axons of retinal ganglion cells from the optic nerve layer. These axons pass through the retina (avoiding macula) , enter the optic disc , and leave the eye in the optic nerve


Pigmented layer
Rod
Cone
Cone
Outer nuclear layer
Outer plexiform layer
Distal
Vertical pathway
Horizontal cell
Bipolar cell
Amacrine cell
Bipolar cell
Lateral pathway
Inner nuclear layer
Amacrine cell
Proximal
Inner plexiform layer
Ganglion cell
To optic nerve
Ganglion cell layer
Stratum opticum
Inner limiting membrane
DIRECTION OF LIGHT


mostly rods
mostly cones
mostly rods
periphery
fovea
2-3 deg


Rod
Synaptic endings
Nuclei
Discs
Cone
INNER SEGMENT
OUTER SEGMENT

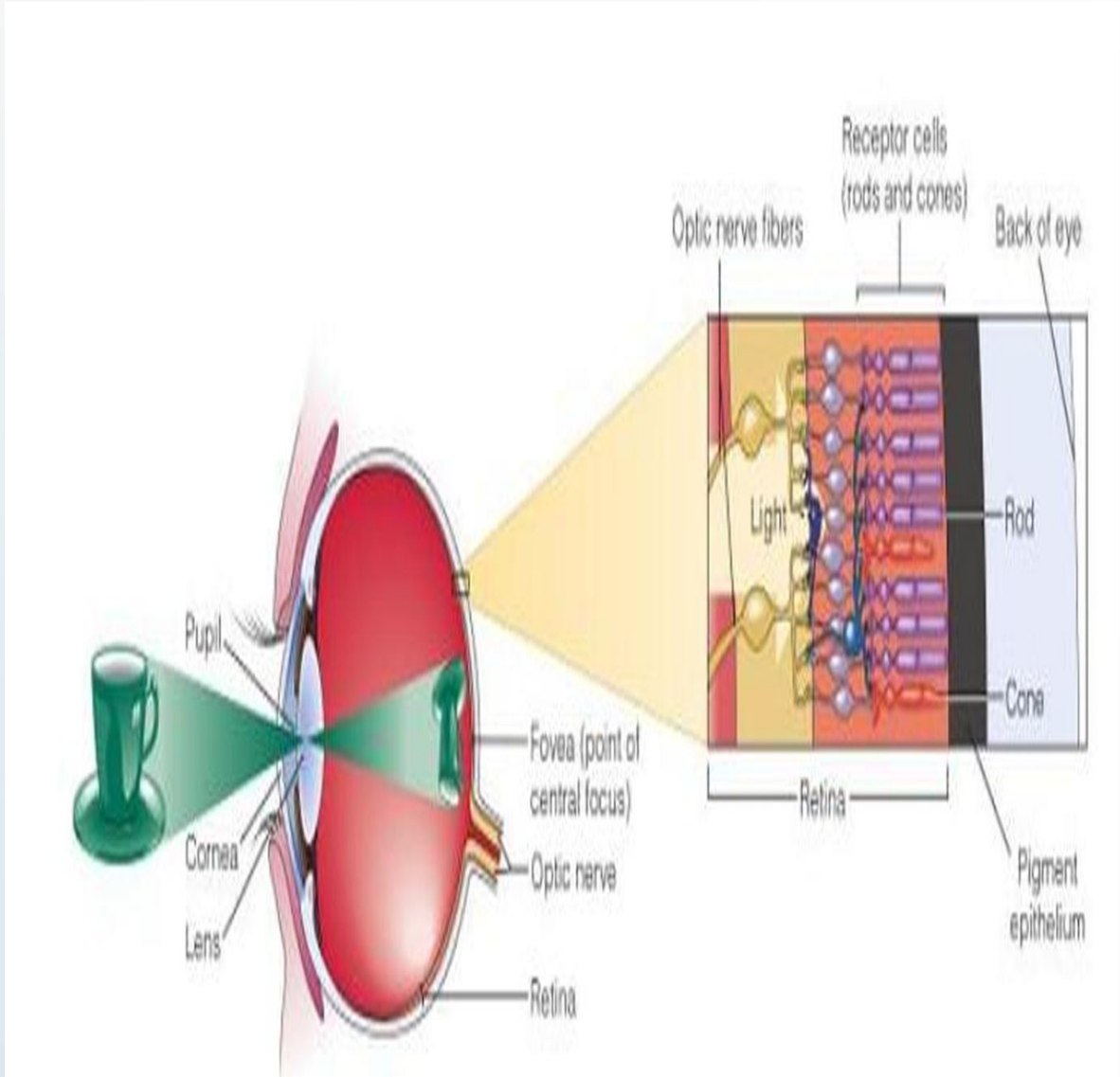
Light pathway in the eye :

Light absorbed by pigment layer that contain melanin pigment

Optic nerve

Impulses pass from rods & cones to rest of layers

Ganglion cell layerv



11

Accommodation & pupillary light reflex

CNS

Surces :
-Female Slides
-Male Slides
- Guyton chapter (49+50)

)تنبيه(

- سيتم إيضاح مصادر السلايدات في بداية كل محاضرة
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Objectives:

1-Describe visual acuity

2-Contrast photopic and scotopic vision

3-To know visual pathway and field of vision

4-Describe the process of accommodation reflex and its pathway, contrasting the refraction of light by the lens in near vision and in far vision

5-Identify and describe pupillary light reflex and its pathway and -relate these to clinical situations as argyl Robertson pupil

6-Identify the lateral geniculate body and visual cortex

Surces :
-Female Slides
-Male Slides
- Guyton chapter (49+50)

VISUAL ACUITY (حدة الإبصار)

Definition :-

- The degree to which the **details** and contours of objects are **perceived**,
- and it is usually defined in terms of the shortest distance by which two lines can be separated and still be seen as 2 lines

Visual threshold :-

is minimal amount of light that elicit sensation of light

Snellen s chart :-

- It is used to measure visual acuity

- Normal acuity = (d/D = distance of Patient / distance of normal person = 6/6)

- A person of / 6/12 has less vision than normal vision (This mean, normal person see the object from 12m distance while this patient can't see it until the distance decrease to 6m) .

Visual Acuity in 5 min :
http://www.youtube.com/watch?v=ovuyPrffiqg

DUPLICITY THEORY OF VISION

DUPLICITY THEORY OF VISION : (2 kinds of vision under different conditions)

		
	PHOTOPIC VISION	**SCOTOPIC VISION**
Condition of vision	(bright light vision)	(night vision, dim light vision)
Photoreceptor	served by **cones**	served by **rodes**
Visual acuity	high visual acuity = colors & details	low visual acuity = no colors or details
Visual threshold (sensitivity to light)	low sensitivity to light = needs high visual threshold to be stimulated	great sensitivity to light =low visual threshold

VISUAL PATHWAY

Cones & rods

↓

bipolar cells

↓

ganglion cells

↓

optic nerve (axons of ganglion cells)

↓

Optic chiasma

↓

Optic tract

↓

lateral geniculate body in thalamus

↓

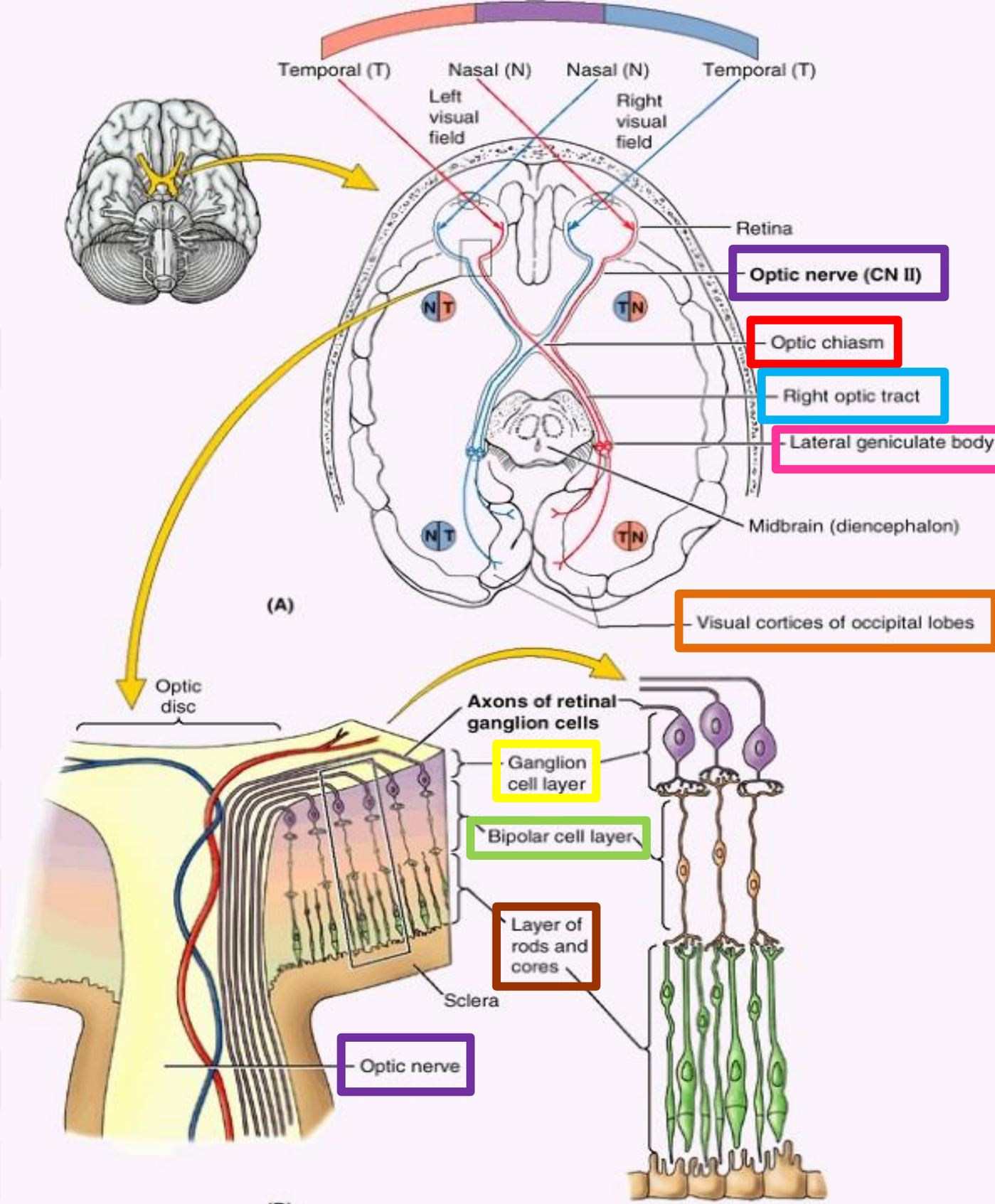
axons of cells form geniculocalcarine tract

↓

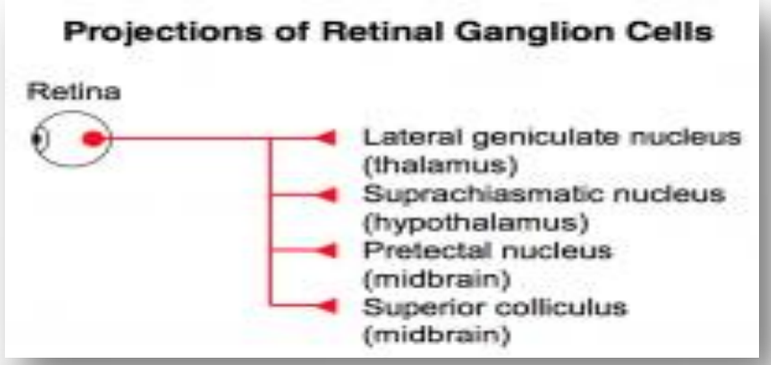
Optic radiation

↓

visual cortex in occipital cortex (Broadmann area 17)

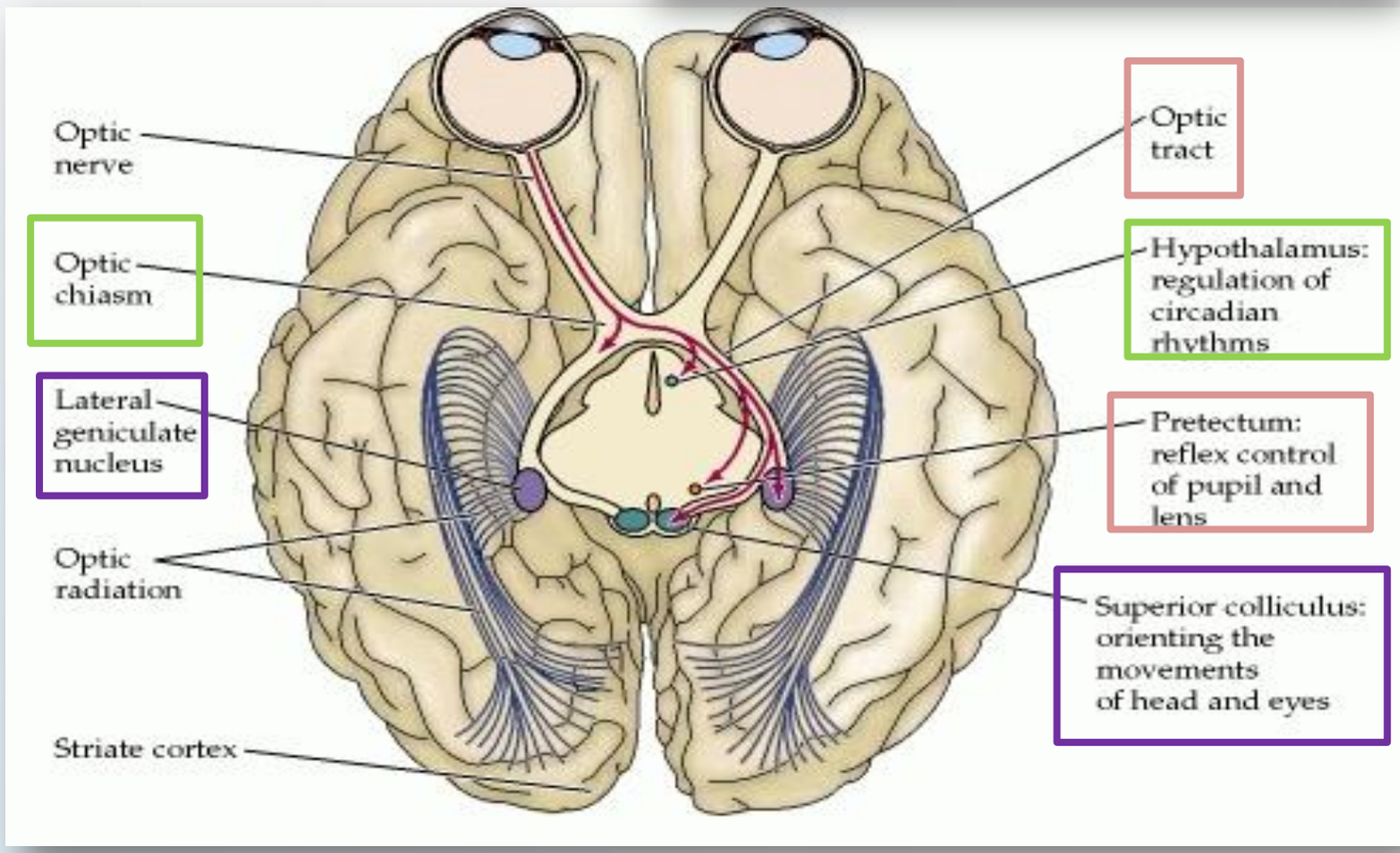


1- some ganglion cells axons pass:
From: optic tract
To: pretectal region of midbrain
For: 1- pupillary reflexes &
2- eye movement (nuclei of extraocular muscles).



2- Some axons of ganglion cells:
From: optic chiasma pass directly
To: hypothalamus
For: circadian rhythm (light-dark cycle) =
الساعة البيولوجية نصحى بالنهار و ننام بالليل

3-Some axons:
From: lateral geniculate body in thalamus
To: superior colliculus in midbrain
For: accomodation. R & its miosis component



•**N.B/-**70% to 80% of the axons from the retina pass to the lateral geniculate bodies ->This geniculostriate system .
•-20% to 30%of the fibers from the retina, -> superior colliculus of the midbrain (also called the optic tectum).Axons from the superior colliculus activate motor pathways .
•leading to eye and body movements.

VISUAL FIELD

-VISUAL PATHWAY & FIELD :-

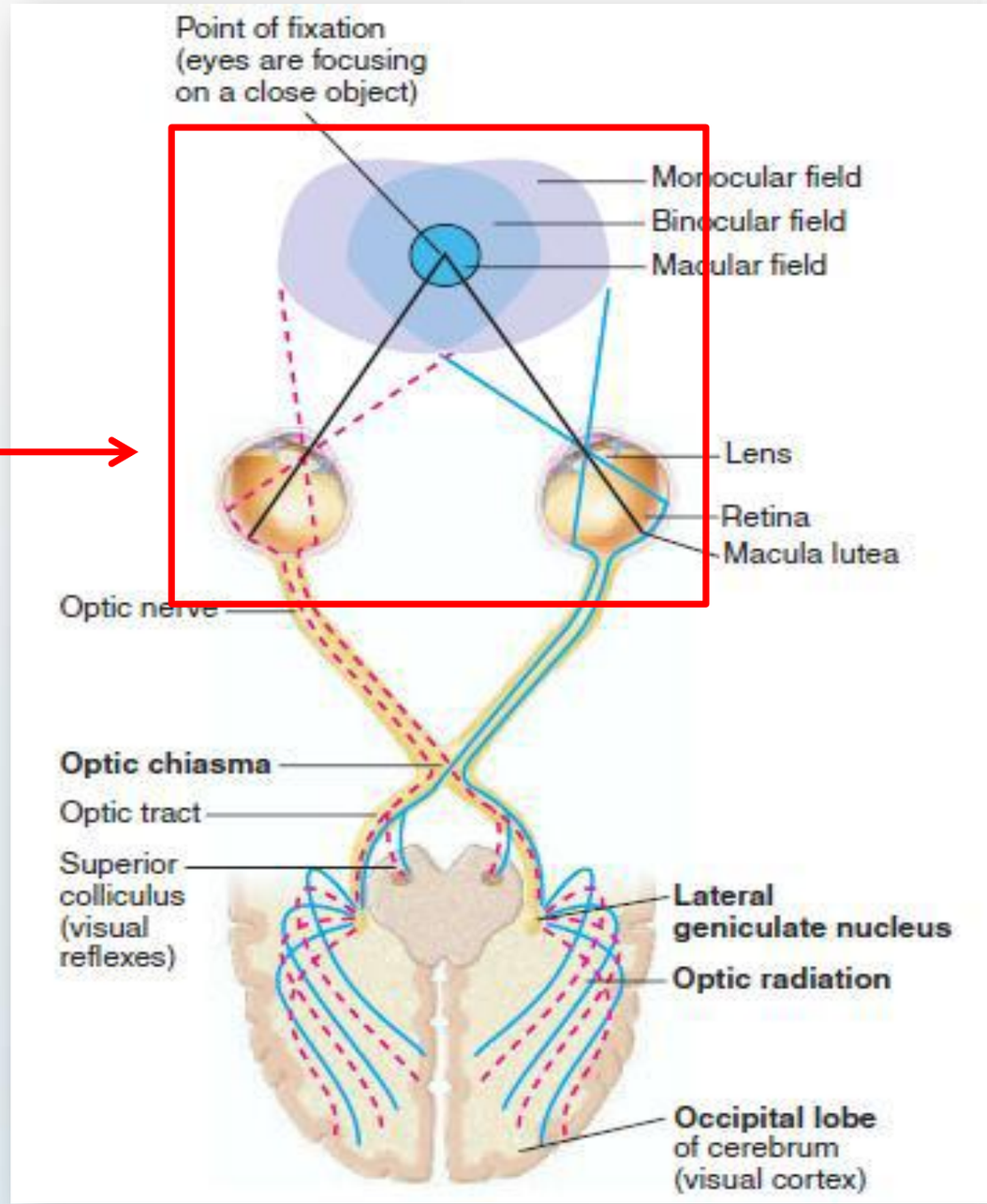
- -The **nasal fibers** (medial) **cross** to opposite side through optic chiasma.
- - The **temporal fibers** (lateral) **do not cross**
- **-Nasal fibers** conveys **temporal field** (outer)of vision
- **-Temporal fibers** conveys **nasal field** (inner)of vision

•OPTIC TRACT :-

- includes temporal fibers of the same side i.e nasal field of same eye (inner)+ nasal fibers of the opposite side i.e temporal field of other eye(outer)

Vision: Visual Field Processing
http://www.youtube.com/watch?v=aobWzlXIooQ
duration/ 4:9

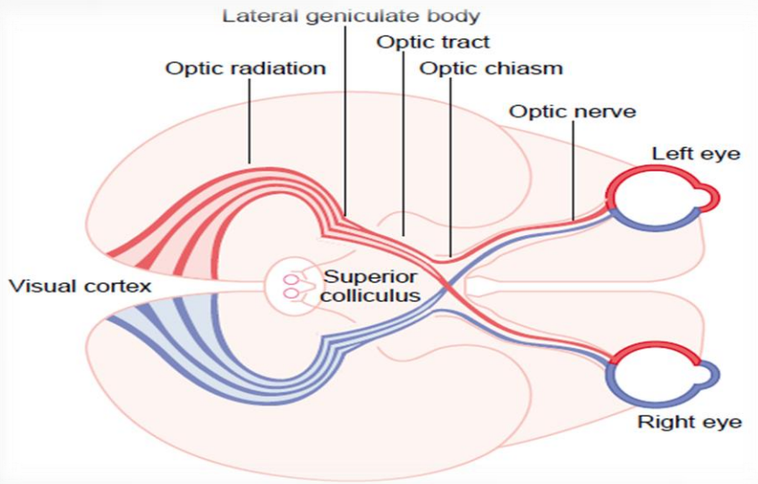
Visual Nerve Pathways
http://www.youtube.com/watch?v=QALdBU670Ro
duration/ 7:36



VISUAL FIELD

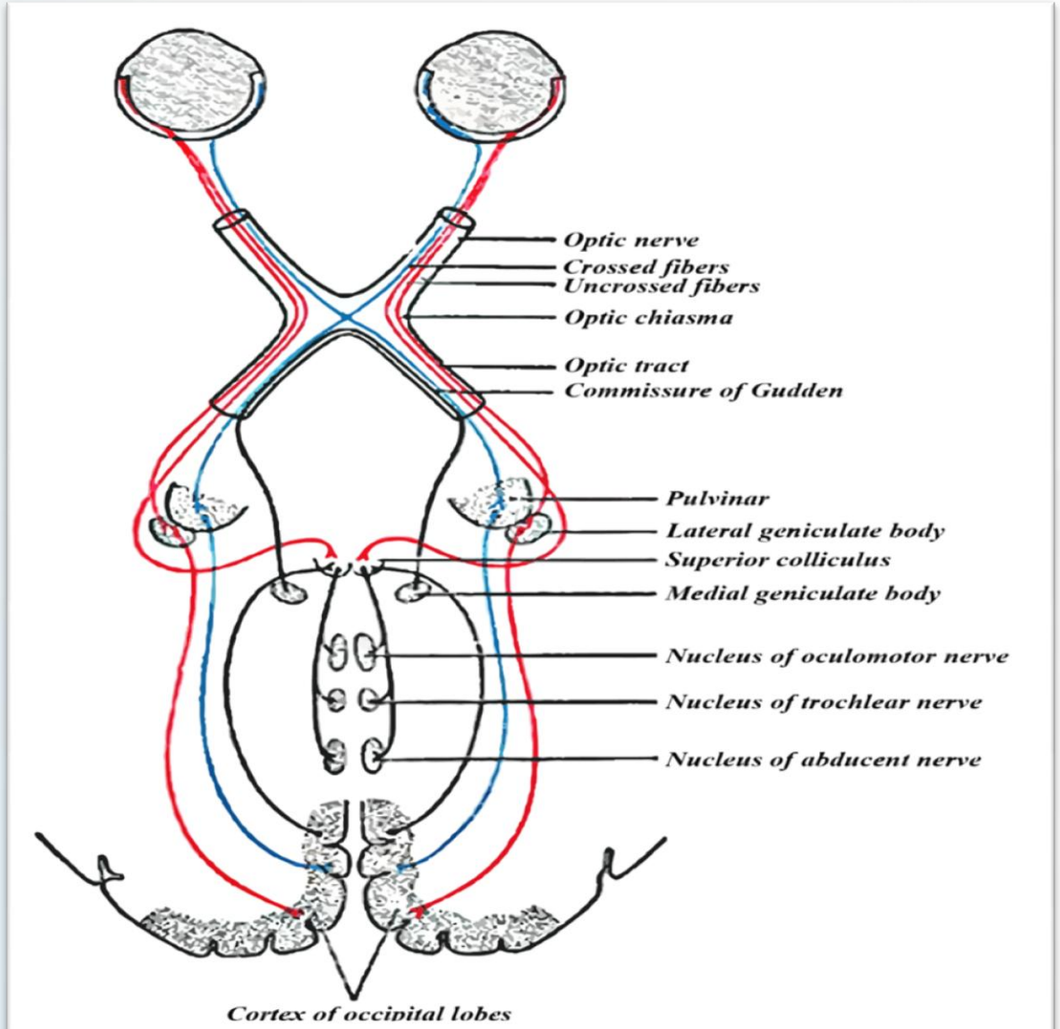
exp//LEFT OPTIC TRACT:-

Conveys temporal fibers of the left eye + nasal fibers of the right eye =(half of visual field of left eye+ half of visual field of right eye),
both form right half of visual field of both eyes.



N.B –

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



In other words :

-**Right optic nerve:** It has Nasal and temporal fibers from the same eye (Right eye).

-**Left optic nerve:** It has Nasal and temporal fibers from the same eye (Left eye).

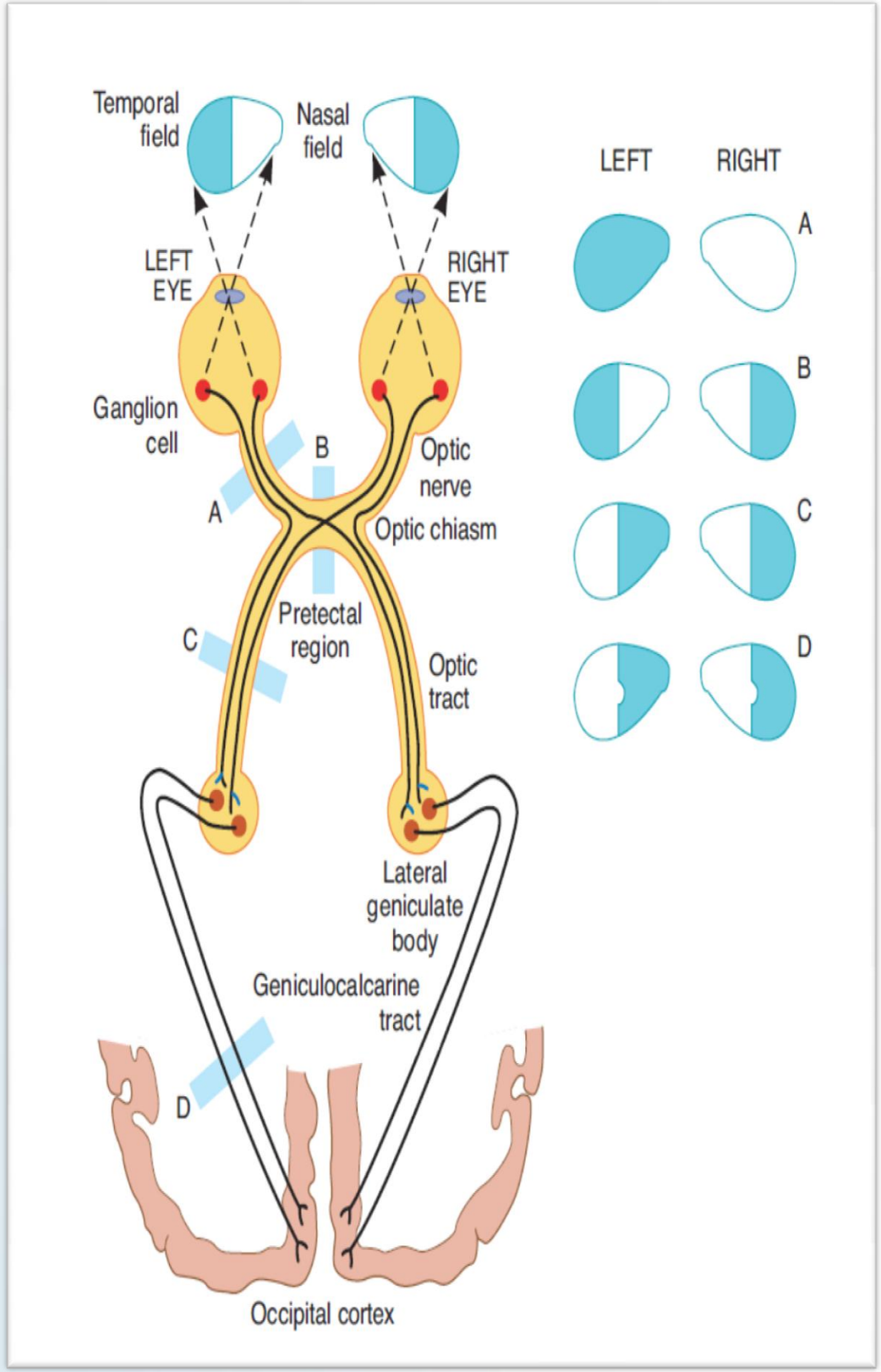
-**Right optic tract:** It has temporal fiber from one eye(Right eye) and nasal fiber from anther eye (Left eye).

-**Left optic tract:** It has temporal fiber from one eye(Left eye) and nasal fiber from anther eye (Right eye).

-**Right optic tract :** see the left half of the filed.

-**Left optic tract :** see the right half of the filed.

- **Right optic tract + Left optic tract :** see the complete field .



Visual pathways,

Transection of the pathways :

at the locations indicated by the letters causes the visual field defects shown in the diagrams on the right.

Very helpful video

http://www.youtube.com/watch?v=eiRVqsXfhGc

duration/ 6:58

Accomodation(focusing)

Is an active process for modification of the refractive power of the eye to view a nearby object by increasing the curvature of lens

Normally what happen without accommodation is the following:

- **At rest (looking at far objects):-**

Cillary muscle don't contract → Tense ligaments → No change of the lens curvature (flat) → *Picture behind retina (blurred vision)

- **looking at near objects:-**

Ciliary muscles are relaxed → taut (tense) ligaments → Flat lens → Picture in retina

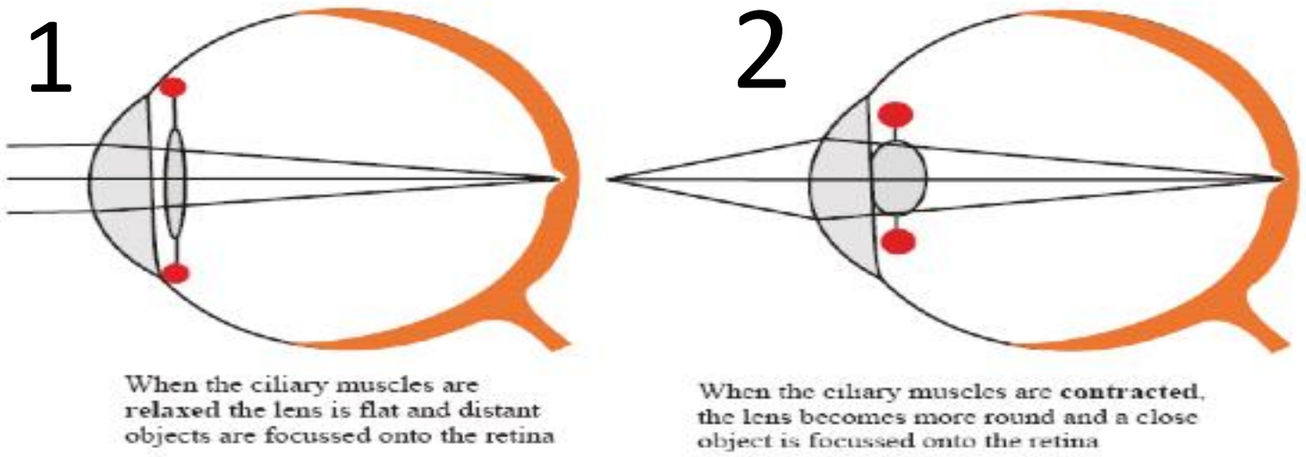
***Solution is to increase curvature & refractive power of lens by accomodation to bring focus on retina.**

Accomodation reflex

What happen if you look at a near object to you ?

Focusing at near object lead to increase anterior surface curvature of lens by contraction circular & longitudinal ciliary muscles(muscle become tall) , slack = relaxed ligaments, increased anterior surface curvature of lens . why?

To change the shape of the lens.	and add 12D to refractive power of lens.



1- The lens is flattened for distant objects

2-The lens is rounded for near objects

(near response)

3 things happen when you look to something near (near response):

a- convergence of both visua axis.
When an object is near to the eyes ,both eyes will look to nose. Because the picture should be in the retina of both eyes

b- pupil constriction. To decrease the amont of light That intered the eye (to protect retina from damaging).

C-Accomodation. To increase the refractive power and make the picture in the retina

Near point:-

Nearest point to eye at which object can brought into focus on retina by ACCOMODATION

-10 years-----9 cm (the nearst point for a child)
-At 60 years-----80-100 cm, due to hardness of lens & loss of accomodation (sometimes if you put an object too near you can not see it)

Near point and amplitude of accomodation

age	Near point (cm)	Amplitude of Accomodation
10	9	11
20	10	10
30	12.5	8
40	18	5.5
60	83	1.2
70	100	1

To test accomdation reflex by (sanson purkinje image)
***not used any more**

Mechanism of "Accommodation"

(For more illustration)

- When the lens is in a relaxed state with no tension on its capsule, it assumes an almost spherical shape.

suspensory ligaments attach radially around the lens, pulling the lens edges toward the outer circle of the eyeball. These ligaments are constantly tensed by their attachments at the anterior border of the choroid and retina. The tension on the ligaments causes the lens to remain relatively flat under normal conditions of the eye.

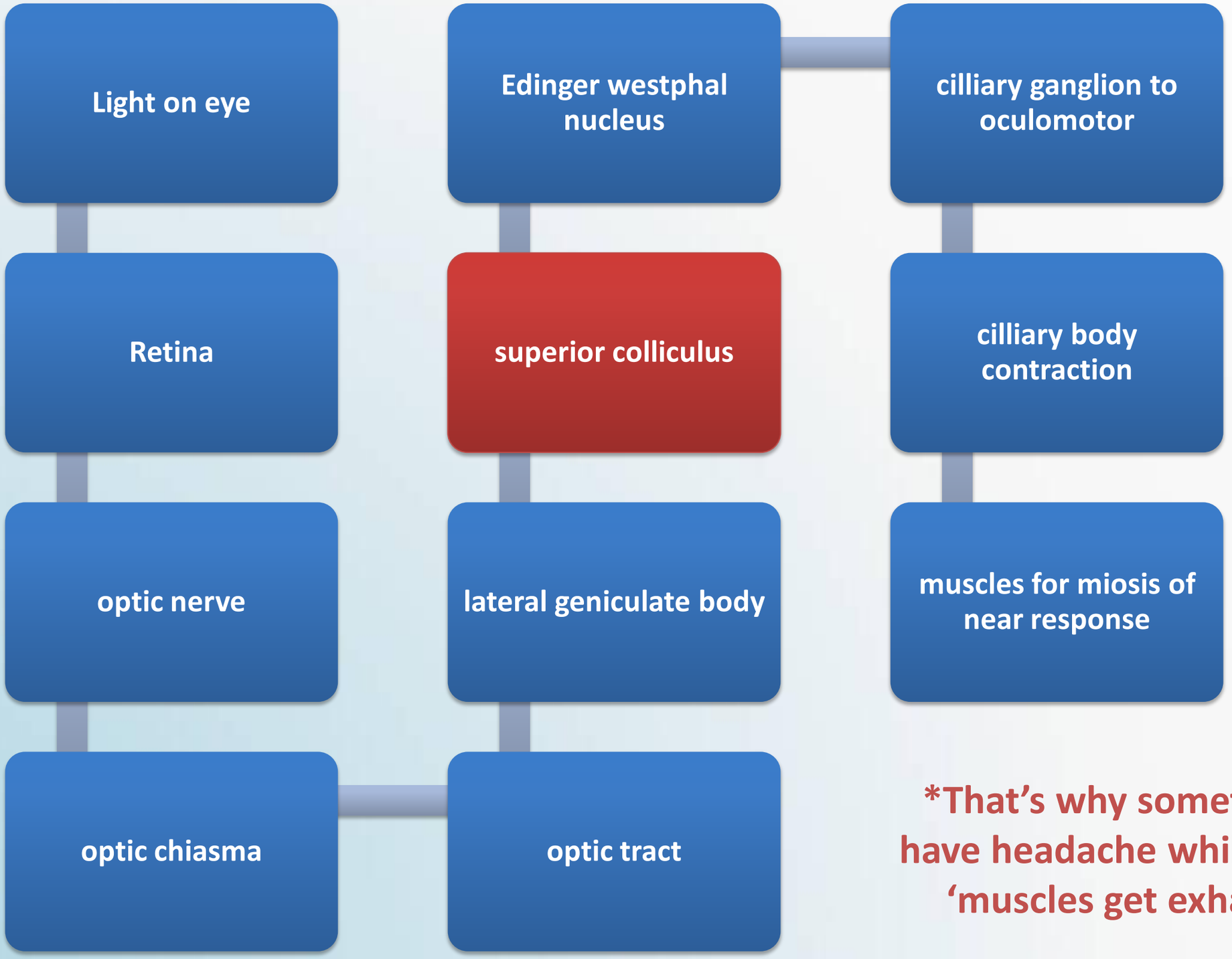
- Thus, contraction of either set of smooth muscle fibers in the ciliary muscle relaxes the ligaments to the lens capsule, and the lens assumes a more spherical shape, like that of a balloon, because of the natural elasticity of the lens capsule.

Accommodation Is Controlled by Parasympathetic Nerves.

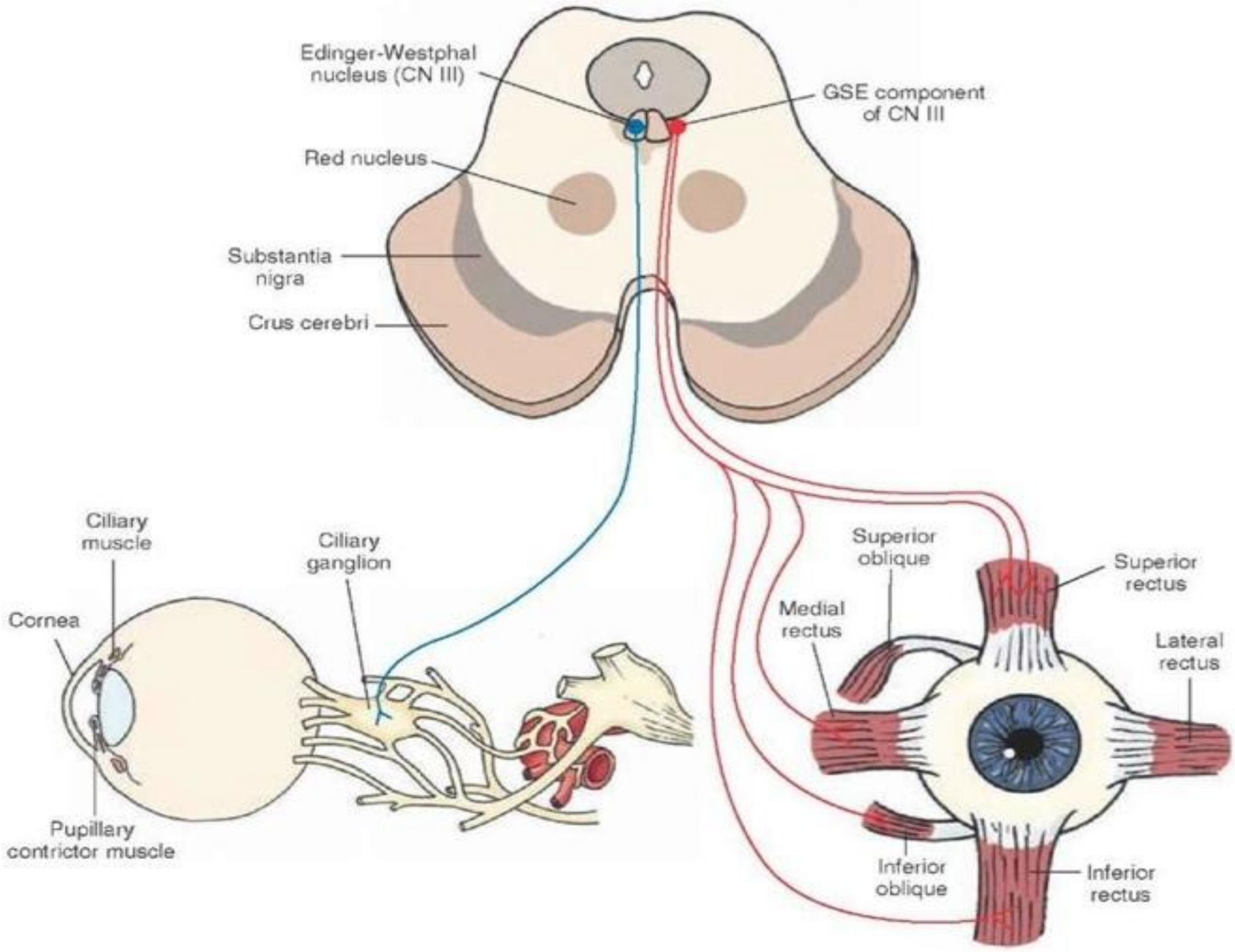
- The ciliary muscle is controlled almost entirely by parasympathetic nerve signals transmitted to the eye through the third cranial nerve.

- Sympathetic stimulation has an additional effect in relaxing the ciliary muscle, but this effect is so weak that it plays almost no role in the normal accommodation mechanism

Pathway of accomodation



*That’s why sometimes you have headache while you read ‘muscles get exhausted’

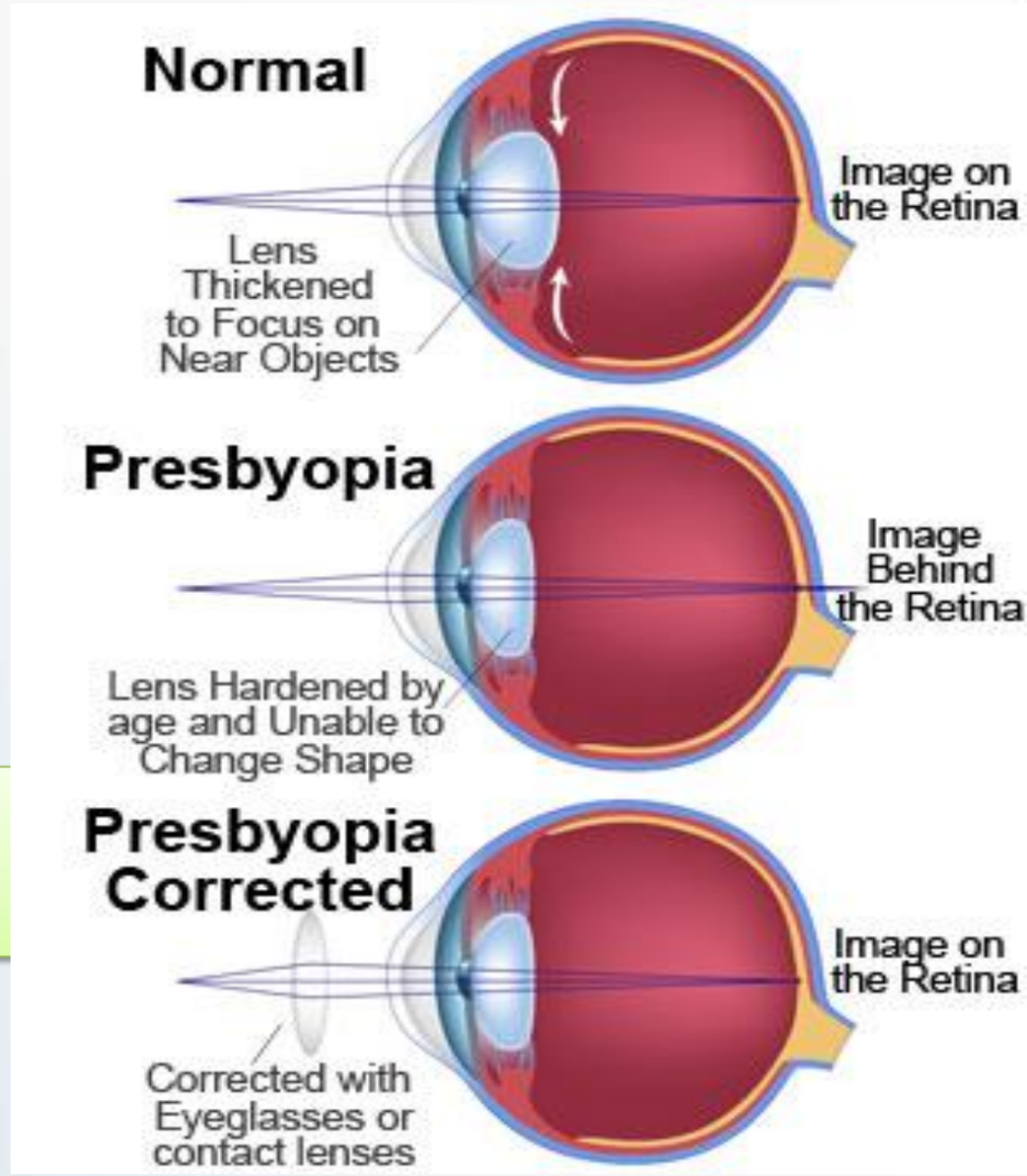

Edinger-Westphal nucleus (CN III)
GSE component of CN III
Red nucleus
Substantia nigra
Crus cerebri
Ciliary muscle
Ciliary ganglion
Cornea
Pupillary contrictor muscle
Superior oblique
Superior rectus
Medial rectus
Lateral rectus
Inferior oblique
Inferior rectus

presbyopia:(triade)

Loss of Accommodation by the Lens

As a person grows older, the lens grows larger and thicker and becomes far less elastic, partly because of progressive denaturation of the lens proteins. The ability of the lens to change shape decreases with age. The power of accommodation decreases from about 14 diopters in a child to less than 2 diopters Thereafter, the lens remains almost totally nonaccommodating, a condition known as "presbyopia."

It charstraised by following :



1-loss of accomodation

2-loss of lens elasticity

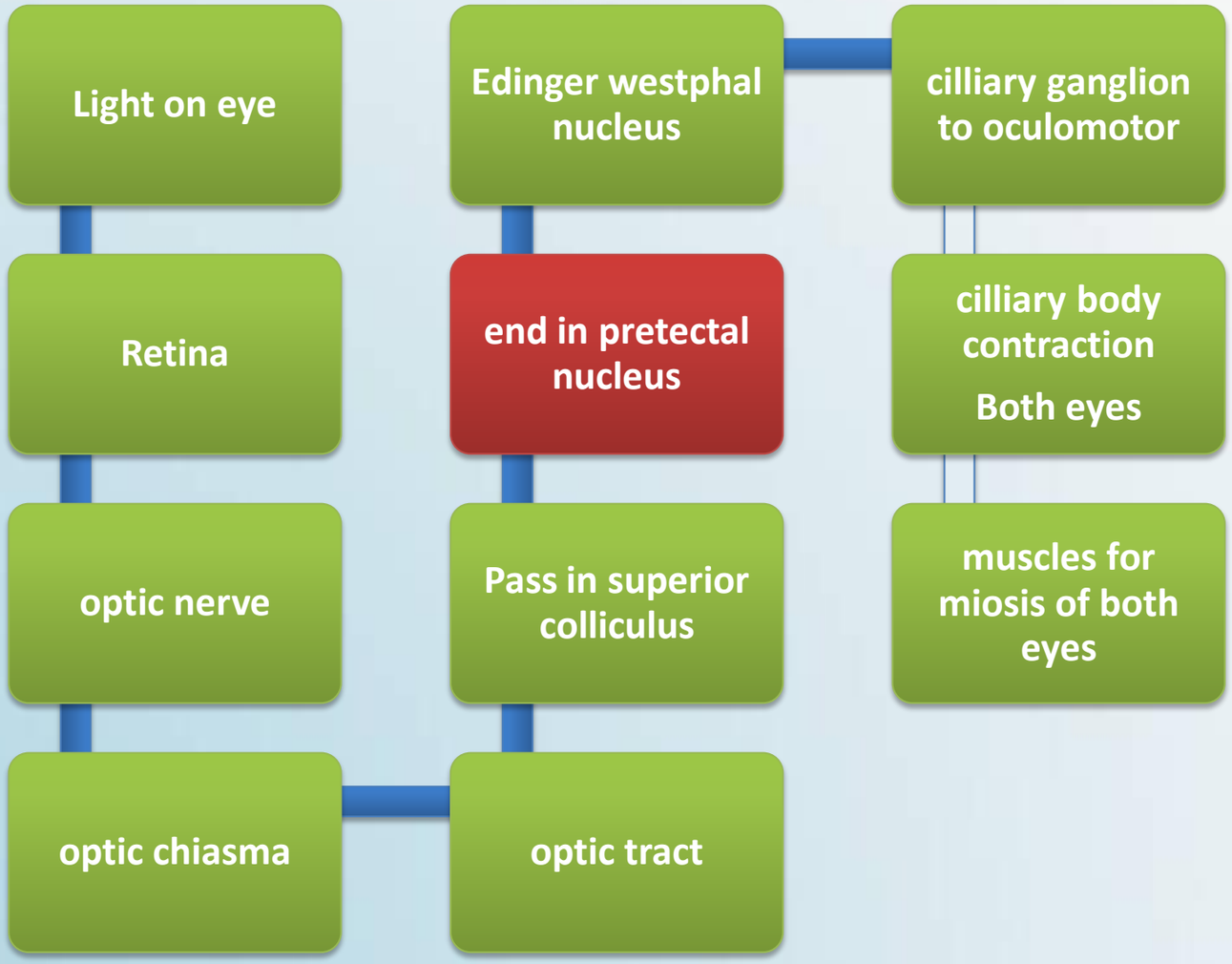
3- near point recede

correction by biconvex lens

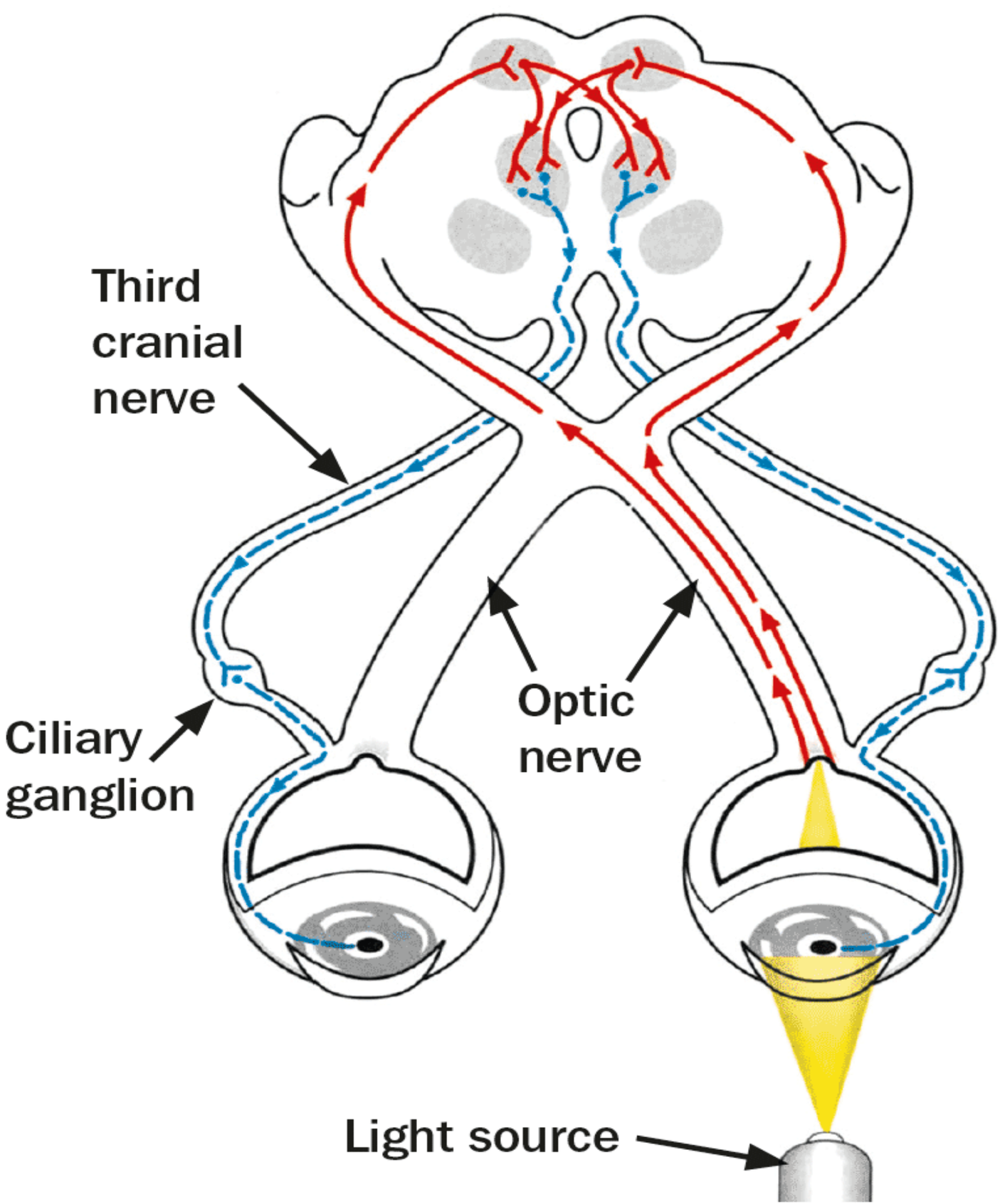
Pupilary light reflex

<u>Light on one eye pupil lead constiction of this pupil (direct) & the other pupil (indirect)</u>
Ex: you are in a dark room , opening one eye and lighting a candle lead to constriction of pupil in both eyes

Pathway of consensual Pupilary light reflex (indirect)



Note: Blindness with preservation of the pupillary light reflex is usually due to bilateral lesions caudal to the optic tract.



***-<u>Atropine drops</u>:- block parasympathetic supply of oculomotor lead to mydriasis.**

Used to examine the eye

Q. Argyll Robertson pupil?

In syphilis tabes dorsalis which destroy <u>pretectal nucleus</u>

-light reflex is lost & accomodation reflex remains

because lesion is in pretectal nucleus only, away from superior colliculus & fibers of accomodation.

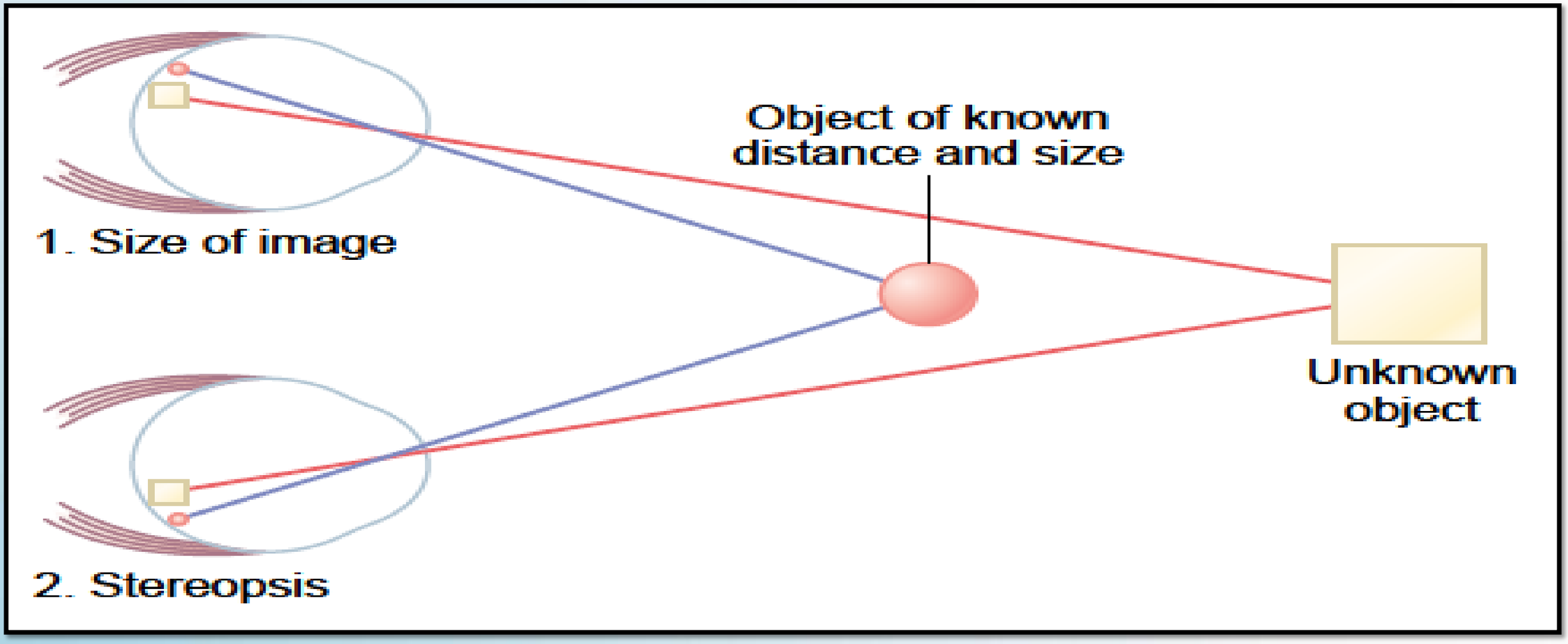
Depth Perception

-Depth Perception: Ability to determine Distance of an Object from the Eye

-**Stereopsis** is Use both eyes to perceive depth – **"depth perception"**

-Each visual cortex (R &L) receives information from both eyes so it can compare what each eye sees.

Note: Depth Perception = Stereoscopic vision = stereopsis



Lateral geniculate body (LGB)

Lateral geniculate body (6 layers):-

- **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.**

- **FUNCTION OF LGB:-**

1-acts as a relay station for visual information from optic tract to cortex.

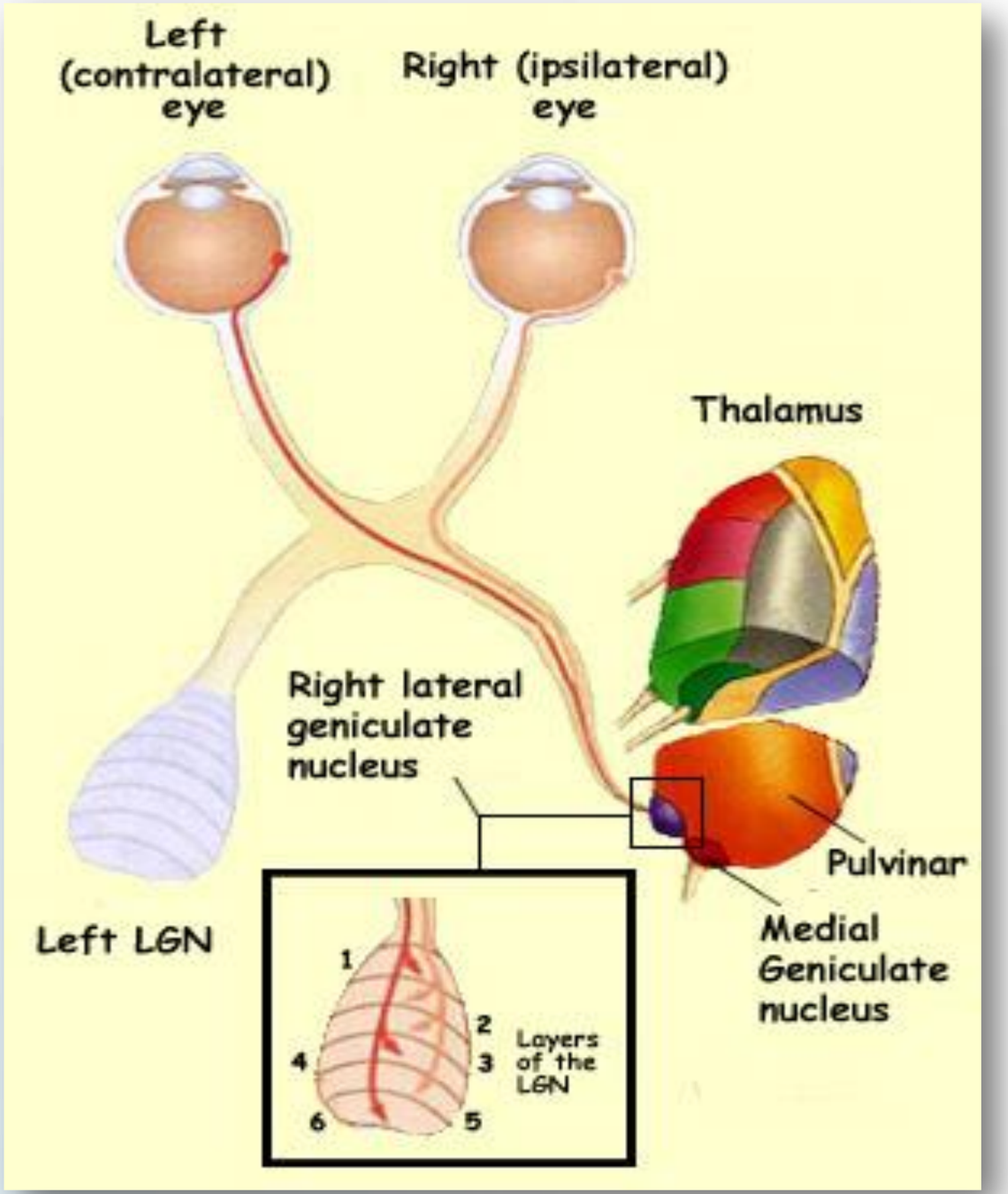
2-It has point to point transmission(spatial fidelity) = space exactness.

3-Acts as gate controls signal transmission to visual cortex i.e control how much signals reach visual cortex .((يعمل تثبيط للاشارات لو كان عددها كبير

4-color vision & detect shapes & texture

(texture: سطح رأى اذا الشخص يعرف مثلاً الأشياء ملمس بمعنى الخامة خشن أنه خشن بمجرد الرؤية)

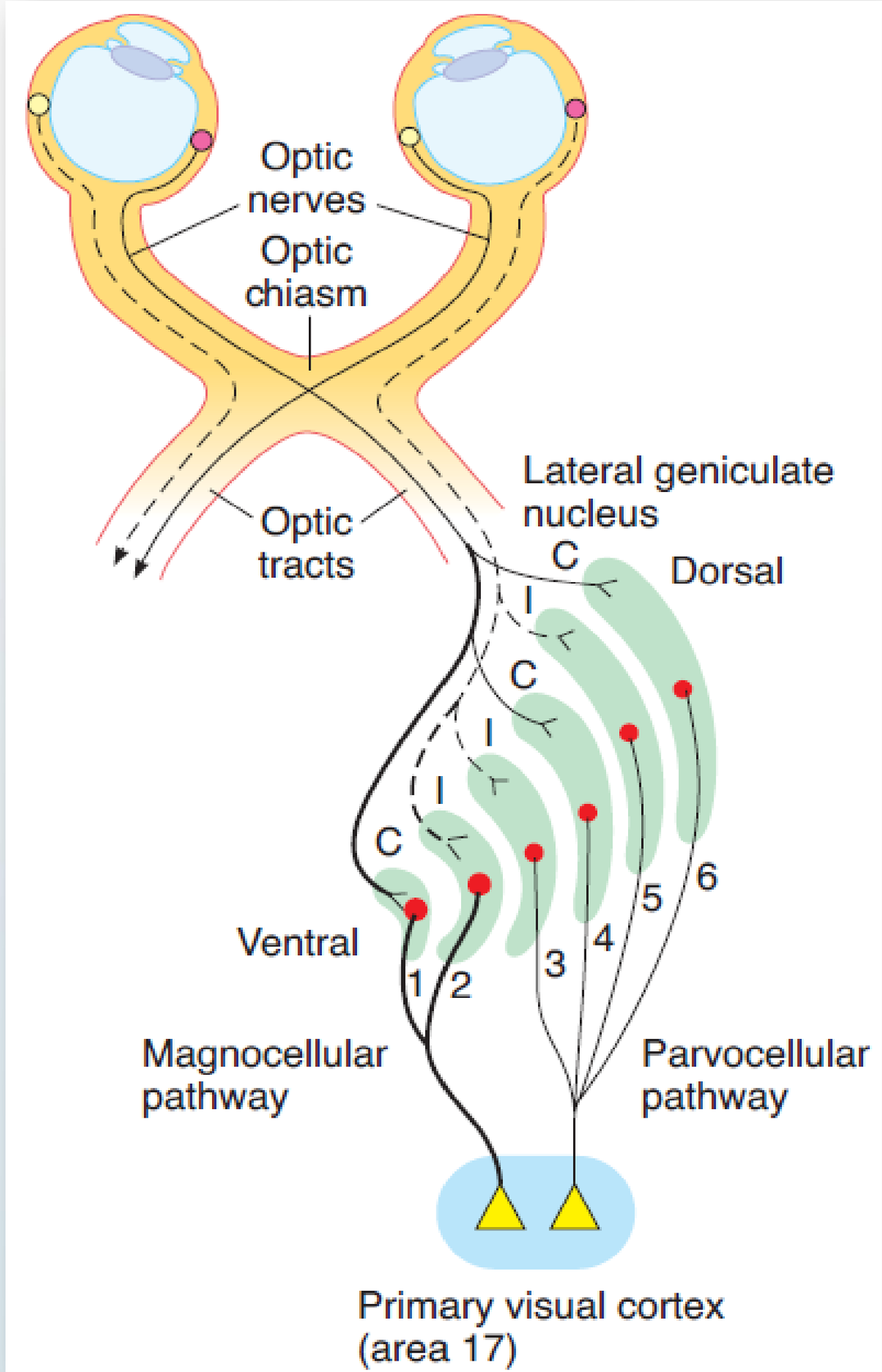
NB/ it is rapidly conducting to visual cortex.



	The magnocellular pathway	The parvocellular pathway
layers	from layers 1 and 2	from layers 3–6
cells	have large cells and are called magnocellular	have small cells and are called parvocellular
Functions	carries signals for detection of movement, depth, and flicker. =flicker)ومضات(	carries signals for color vision, texture, shape, and fine detail.

On each side, layers 1, 4, and 6 receive input from the contralateral eye, whereas layers 2, 3, and 5 receive input from the ipsilateral eye

http://www.youtube.com/watch?v=63D03ArzYjI
duration/ 4:30



Visual cortex :

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

percieve **sensation of vision** (movement + shapes+ stereoscopic vision + brightness) &has blobs for color detection

(يشوف ويحس بالأشياء لكن بدون تمييز؛بمعنى مايفهم ايش فاعد يشوف)

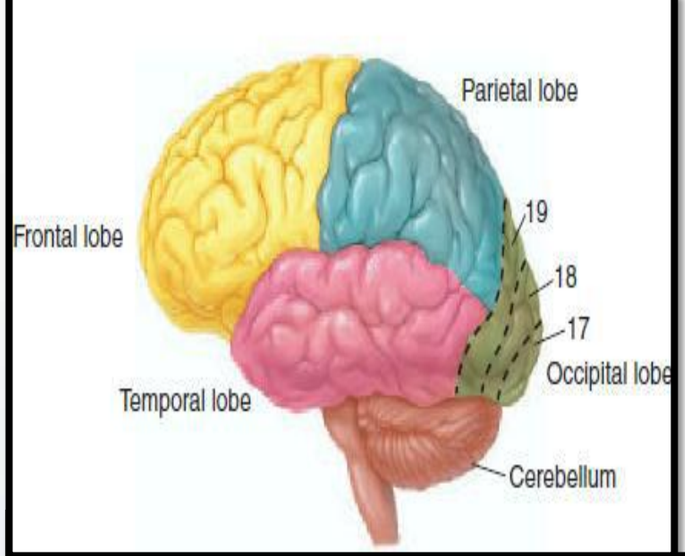
2-Association visual cortex(area 18&19):-

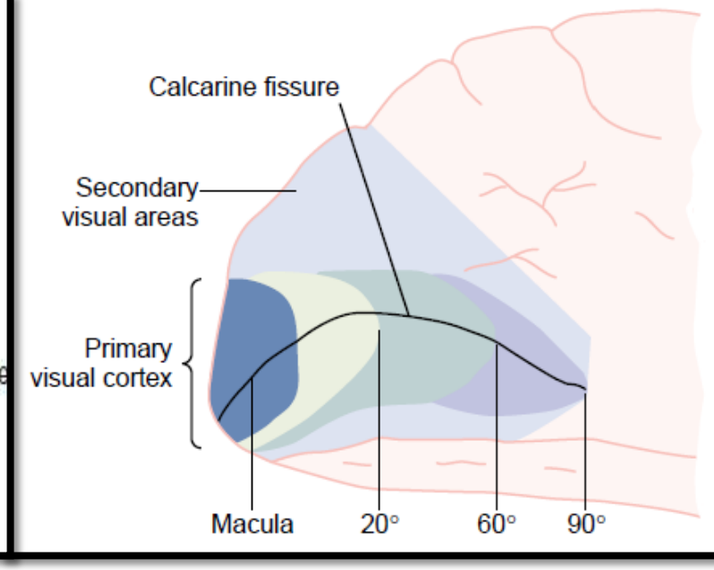
interpretation (تفسير) of visual stimuli

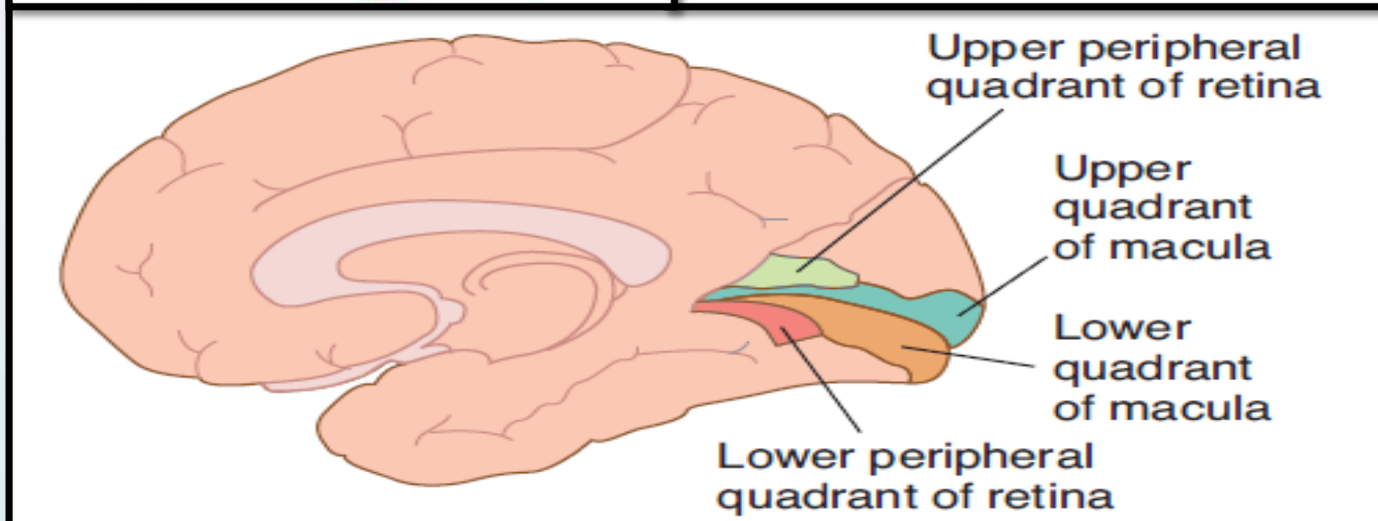
(إذاً ممكن يكون الشخص أعمى لو كان عنده مشكلة في الـ Association visual cortex
لأنه لازم يكون فاهم ايش قاعد يشوف)

- **visual cortex has 6 layers**
- -**Blobs** are clusters of cells responsible for <u>color detection</u>
- -**Simple cells** detect bars of <u>light, lines and edges</u>
- -**Complex cells** detect <u>linear movements</u> of a stimulus

Macular sparing, that is, loss of peripheral vision with intact macular vision, is also common with occipital lesions because the macular representation is separate from that of the peripheral fields and very large relative to that of the peripheral fields.







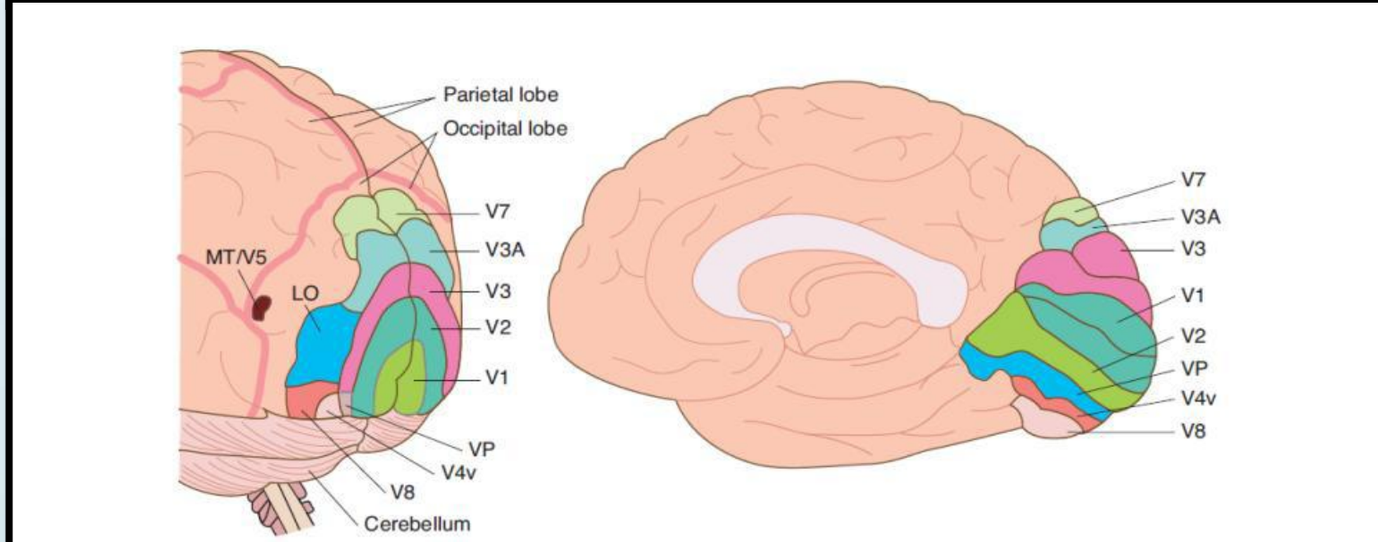


FIGURE 12–19 Some of the main areas to which the primary visual cortex (V1) projects in the human brain. Lateral and medial views. See also Table 8–1. (Modified from Logothetis N: Vision: A window on consciousness. Sci Am [Nov] 1999;281:99.)

Summary

1.What is visual acuity and how to measure it ?

visual acuity is degree to which details of objects are perceived, and we measure visual acuity by using Snellen chart .

2.Differntiate between photopic & scotopic vision ?

- **photopic vision served by cones while scotopic by rods.**
- **photopic vision have high visual acuity while scotopic have low visual acuity .**
- **photopic vision have low sensitivity to light while scotopic have great sensitivity to light.**

3.What do you know about visual pathway & field of vision?

Visual pathway : Cones & rods-→bipolar cells → ganglion cells- → optic nerve → optic chiasma → optic tract →lateral geniculate body → axons of cells form geniculocalcarine tract----- optic radiation → visual cortex in occipital cortex (Broadmann area 17) .

Field of vision : -Nasal fibers conveys temporal field (outer)of vision
-Temporal fibers conveys nasal field (inner)of vision .
-The left optic tract corresponds to the right ½ of the visual field .
-The right optic tract corresponds to the left ½ of the visual field.

4.What is the difference between optic nerve and optic tract ?

Optic nerve has the nasal and temporal fibers from the same eye while optic tract has nasal fiber from one eye and temporal fiber from the another eye .

5.What is the test using for accommodation reflex ?

Sanson purkinje image .

6. How is accommodation reflex happen ? (short answer without details)

accommodation reflex depends on ciliary muscles contraction & curvature of lens (refractive power); the stimulus is near object.

Summary

7. How is Pupillary light reflex happen ? (short answer without details)

Pupillary light reflex depends on circular muscles of iris; the stimulus is light toward the pupil.

8. Why Pupillary light reflex occurs to both eyes (not only the stimulated eye) ?

due to oculomotor nerve supply to both eyes.

9.Why near point becomes farther by aging ?

due to loss of lens elasticity & accommodation leading to presbyopia.

10.What are functions of LGB ?

1. Relay station for visual information. 2. spatial fidelity. 3. gate controls signal transmission to visual cortex . 4.Color vision & detect shapes & texture.

11.What do you know about visual cortex ?

-Visual Cortex has 6 layers.

-There are:

1.Primary visual cortex(Broadmann area 17) : sensation of vision

2. Association visual cortex(area 18&19): interpretation

12 Photo transduction in Light & Dark

CNS

- Lecture slides
- Guyton
- Linda
- http://www.webmd.com/eye-health/night-blindness
- http://neuroscience.uth.tmc.edu/s2/index.htm
- http://youtu.be/NLQCYflVV3M
- http://youtu.be/CqN-XIPhMpo

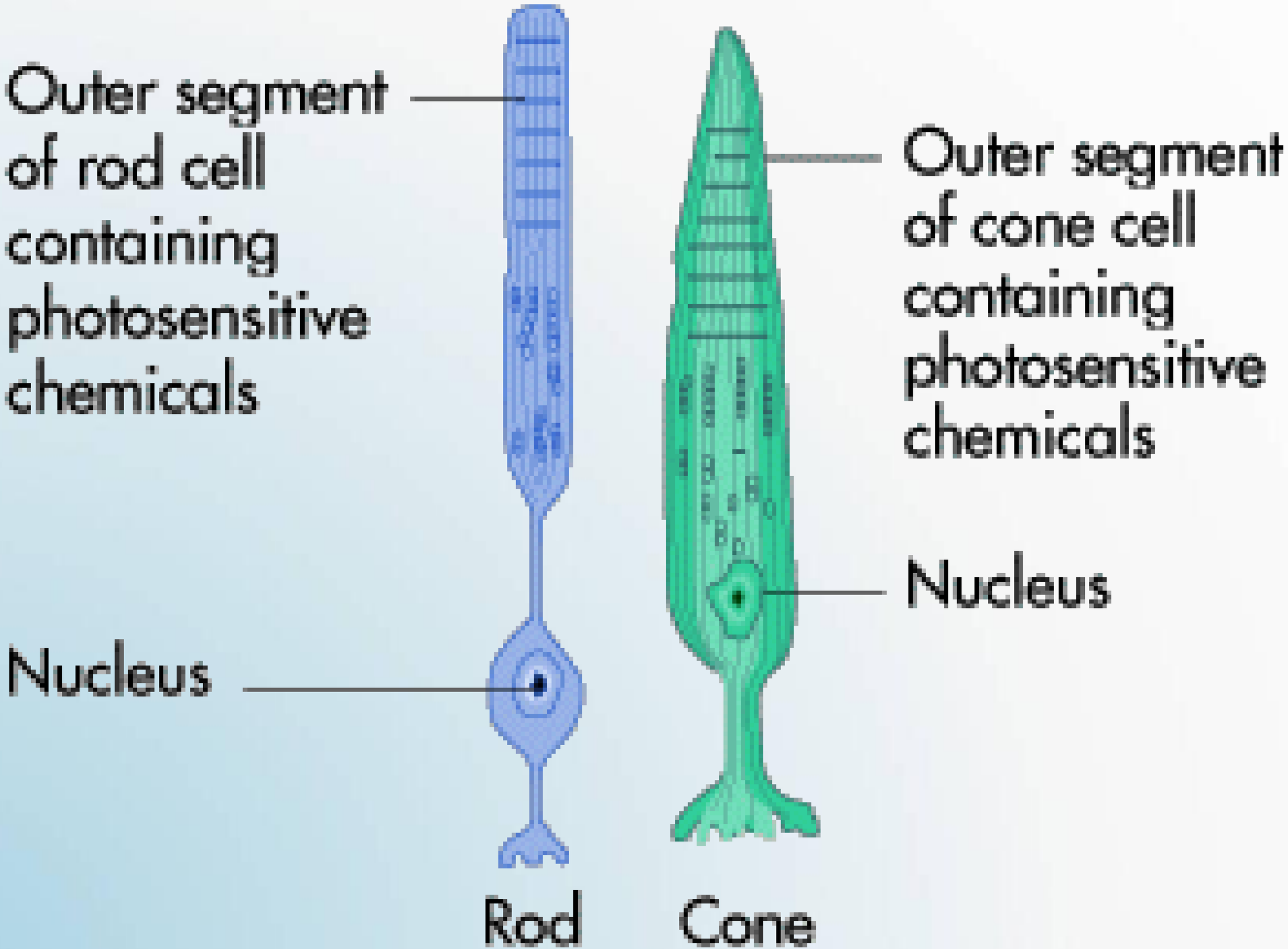
• Lecture objectives :

- List and compare functional properties of rods and cones in Scotopic and photopic vision
- To know the convergence and its value
- To know the photosensitive compounds
- Contrast the photo-transduction process for rods and cones in light and dark and the ionic basis of these responses
- To know the synaptic mediators at retina
- To know the process of rhodopsine regeneration
- To know the meaning of nyctalopia
- Contrast the dark and light adaptation
- To know the visual cycle and rhodopsine regeneration

Light intensity
= illumination.

❖ Guyton ❖ Linda ❖ Explanation ❖ slides

	Rods	Cones
Sensitivity To Light	Low threshold, sensitive to Low-intensity Light	High threshold, Sensitive to High-intensity Light
Acuity	Low acuity	High
Adaptation	Adapt Late (take 20 min)	Adapt Early (take 5min)
Color Vision	see black/white and shades of gray	See All the colors
Night Vision \ Day Vision	Night Vision	Day Vision
Convergence	Have High Convergence (the reason for their low acuity and one of the reasons for their high sensitivity for light)	Have Low Convergence (the reason for their high acuity + one of the reasons for their low sensitivity for Light)
Amount & Types Of Photopigments	**High Amount of Rhodopsin** (the second reason for their high sensitivity for Light)	**Low amount of rhodopsin and high amount of Cone pigments or Color pigments** . (the second reason for their low sensitivity for Light) and have three types .
Presence On Fovea	Not Present On Fovea, but abundant in the periphery of the retina. About 120 million.	Present in & around fovea About 6 million.


Outer segment of rod cell containing photosensitive chemicals
Nucleus
Rod
Outer segment of cone cell containing photosensitive chemicals
Nucleus
Cone

Convergence and It's Value

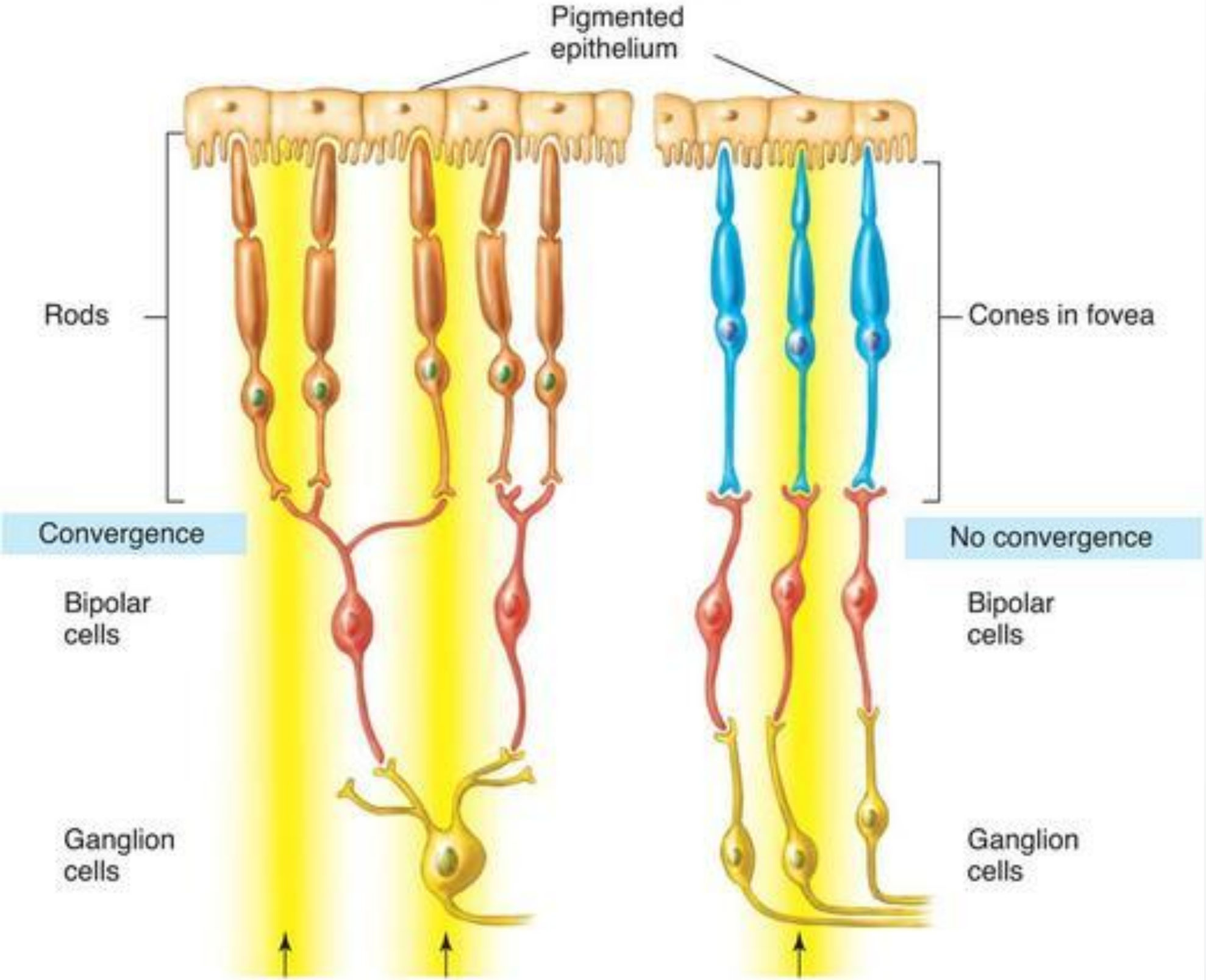
- Convergence happens when many **presynaptic neurons** synapses on a **single postsynaptic neuron**.
- Convergence has an **Inverse proportion** (علاقة عكسية) with <u>the acuity</u> and a **Direct proportion** (علاقة طردية)with the <u>sensitivity for light.</u>

Convergence and Sensitivity for Light

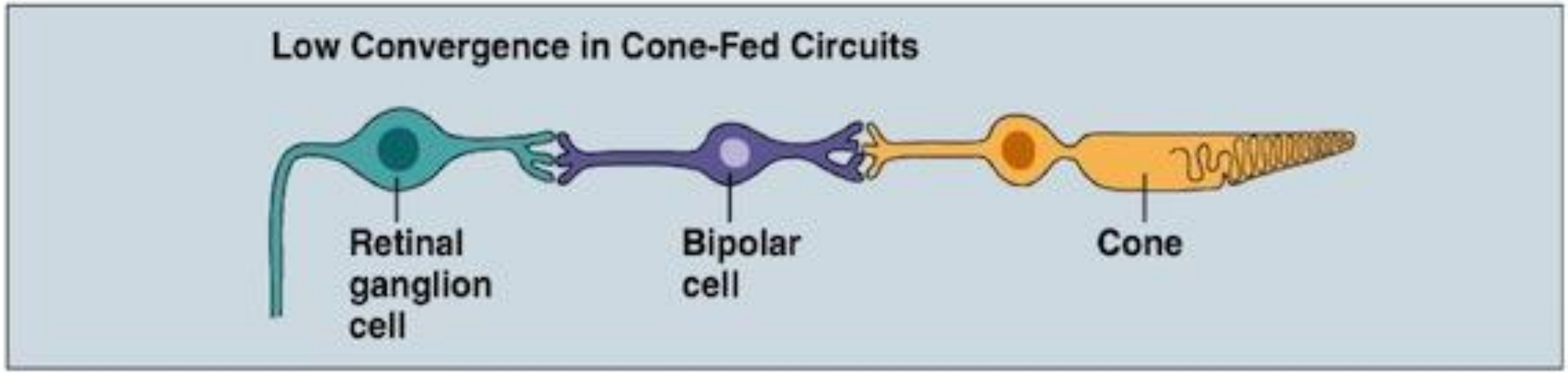
- **In Rods** there is a <u>high convergence</u> happening, which mean there is many rods synapses on a single bipolar cell, that's mean when the light strike any one of the rods it will activate the bipolar cell even if it didn't strike the other rods (it take very little amount of light to activate the bipolar cell attached to the rods).

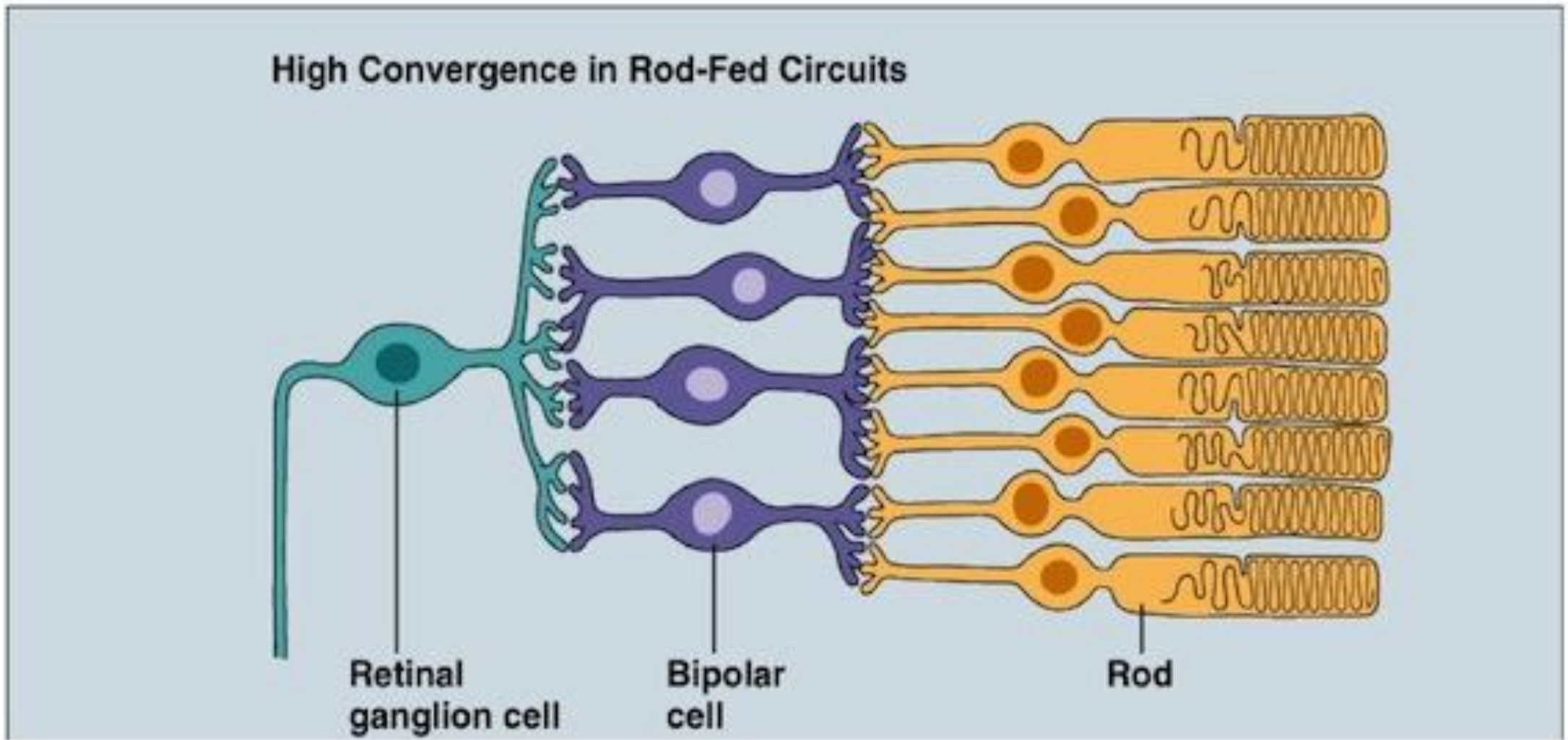
Convergence and Acuity

- **Cones** have <u>low convergence</u> specially in the **fovea** whereas every single cone synapses on a single bipolar cell which synapses on a single ganglion cell, so they have **High acuity** unlike rods.
- It's like the Pixels in the picture the more pixel you have the more your picture will be HD. (imagine that the bipolar cell is pixels and the photoreceptors " rods and cones " are the Cm , no matter if your picture is big and has many CM it will be unclear if it has low pixels).
- So The low convergence in Cones increases their visual acuity.
- And High convergence in Rods (almost 300 rods to one bipolar cell) decreases their visual acuity.


Pigmented epithelium
Rods
Cones in fovea
Convergence
No convergence
Bipolar cells
Bipolar cells
Ganglion cells
Ganglion cells
(a)
Light
(b)
Light

▶ Convergence of Cones and Rods





Photosensitive Compounds

- What does photosensitive compound means?

a photo-sensitive compound decomposes or changes its energy state when exposed to light “react to light”. Ex : **Rhodopsin**.

- Rhodopsin in **Cones** is formed of : **Photopsin + Retinal**
- There are 3 types of Cone pigments “color pigments” in 3 types of cones each respond to a certain wave length of light (certain color).
- As each cone receptor contains only one of the three types of cone photopigments , there are **three types of cones**; **red**, **green** or **blue**. Each cone responds best to a specific color of light.

- In **Rods** rhodopsin is formed of : **Scotopsin protein + Retinal.**
- Rhodopsin of the rods most strongly absorbs **green**-**blue** light and, therefore, appears reddish-**purple** “that’s why they call it visual purple”.
- At dark rhodopsin in Rods is in 11-cis retinal form (inactive) but light sensitive form which increase sensitivity of rods to light.

Photoreception

** Generally what happening is :

When the light strikes the photoreceptors , Rhodopsin is chemically transformed in a process called “Photoisomerizatoin” , which begins the transduction process

Photo transduction

“The process in rods & cones that converts light energy into electrical energy”

Dark

“Scotopic vision, Dimlight vision”

Depolarization

Depolarize Photoreceptor membrane

↓

Depolarize Bipolar cell

↓

Generator Potential

↓

A-P in Ganglion cells

11-cis Retinal

isomerase — light

11-trans Retinal

↓

c GMP

5’ GMP

↓

open — Na^+ channels — close

Light

Photopic vision

Hyperpolarization

Hyperpolarize Photoreceptor membrane

↓

Hyperpolarize Bipolar cell

↓

Gradual Depolarize amacrin cell

↓

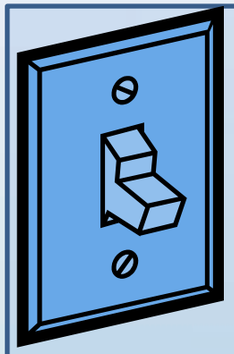
Generator Potential

↓

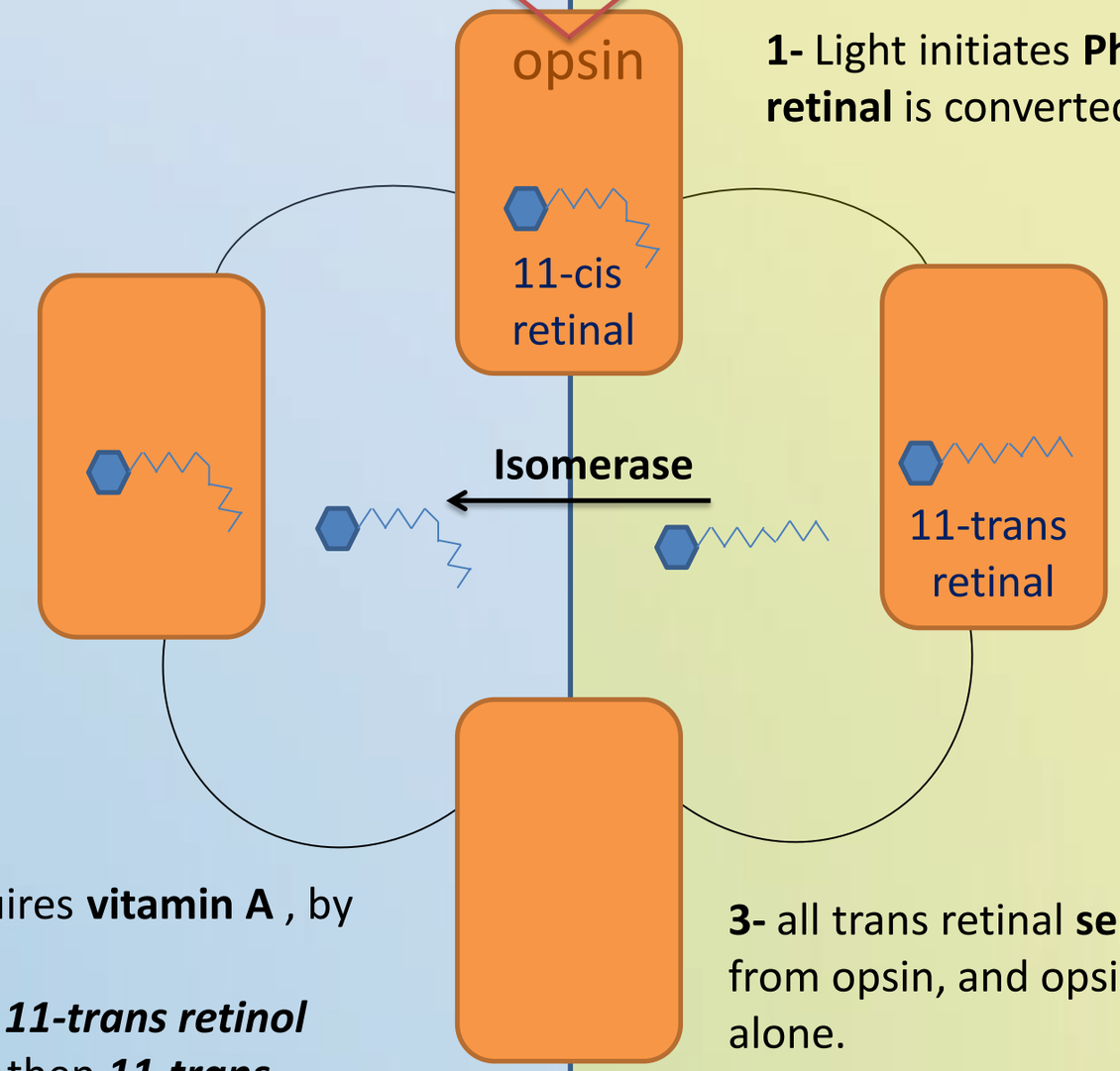
A-P in Ganglion cells

Visual Cycle

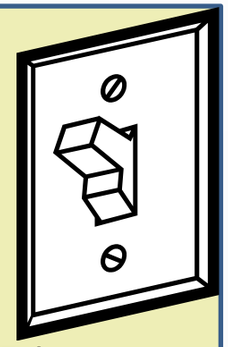
In rods & cones



Scotopsin or Photopsin



1- Light initiates **Photoisomeriztion** , **11-cis retinal** is converted to **all trans retinal.**



2- series of conformational changes produce :
Metarhodopsin II
(opsin+all trans retinal)

↓

Activates **Gt protein**

↓

Activates **phosphodiesterate**

c GMP
5’ GMP

↓

Na^+ channels close

3- all trans retinal **separates** from opsin, and opsin remaines alone.

4- 11-cis retinal regeneration requires **vitamin A** , by which :
11-trans retinal first converted to ***11-trans retinol*** “which is one form of vitamin A” , then ***11-trans retinol*** enzymatically converted to **11-cis retinal**

- **Rhodopsin** is a light sensitive chemical **= Opsin + Retinal**
  - **Opsin** has two types : *photopsin* in cones & *scotopsin* in Rods
  - **Retinal** has two forms : 11-cis inactive & 11-trans active

  Its preduced in the retina from Vitamin A , from dietary beta-carotene.
  - **Opsin** cannot bound to Retinal unless it is in the **inactive form** (11-cis)
- The amount of rhodopsin in the receptors therefore varies inversely with the incident light level.
- Rhodopsin-retinal visual cycle **in the rod**

showing decomposition of rhodopsin during exposure to light and subsequent slow reformation of rhodopsin by the chemical processes.

-Ach
-Glutamate
-Dopamine
-Serotonine
-GABA
-SubstanceP
-Somatomedin
-VIP
-Enkephalins
-Glucagons
-Neurotensin

In Dark : (at rest)
all transmitters are continuously (steadily) released by depolarization of rods.

In light : (stimulation)
Hyperpolarization of the receptors decrease neurotransmitter release, (inhibitory or excitatory).

Excitatory & Inhibitory neurotransmitter involved in vision

On-Off patterns

>Useful video

- There are two types of **Bipolar cells** : on-center & off-center
- *On-center cell* is affected by the inhibitory neurotransmitters, while *Off-center* affected by excitatory neurotransmitters.
- Both **ganglionic cells** of the on&off-center cells will be excited and fire an action potential.
  - In light the hyperpolarization of photoreceptors results in decrease both:

Excitatory
neurotransmitters

↓

Affects the **off-center** Bipolar cell

Hyperpolarization of Bipolar and Horizontal cell

↓

Decreasing of neurotransmitters released by off-center cell leading Ganglion cell to decrease its firing rate leading into a reduction in Action Potential.

نفس فكره
سالب x سالب = موجب

Inhibitory
neurotransmitters

↓

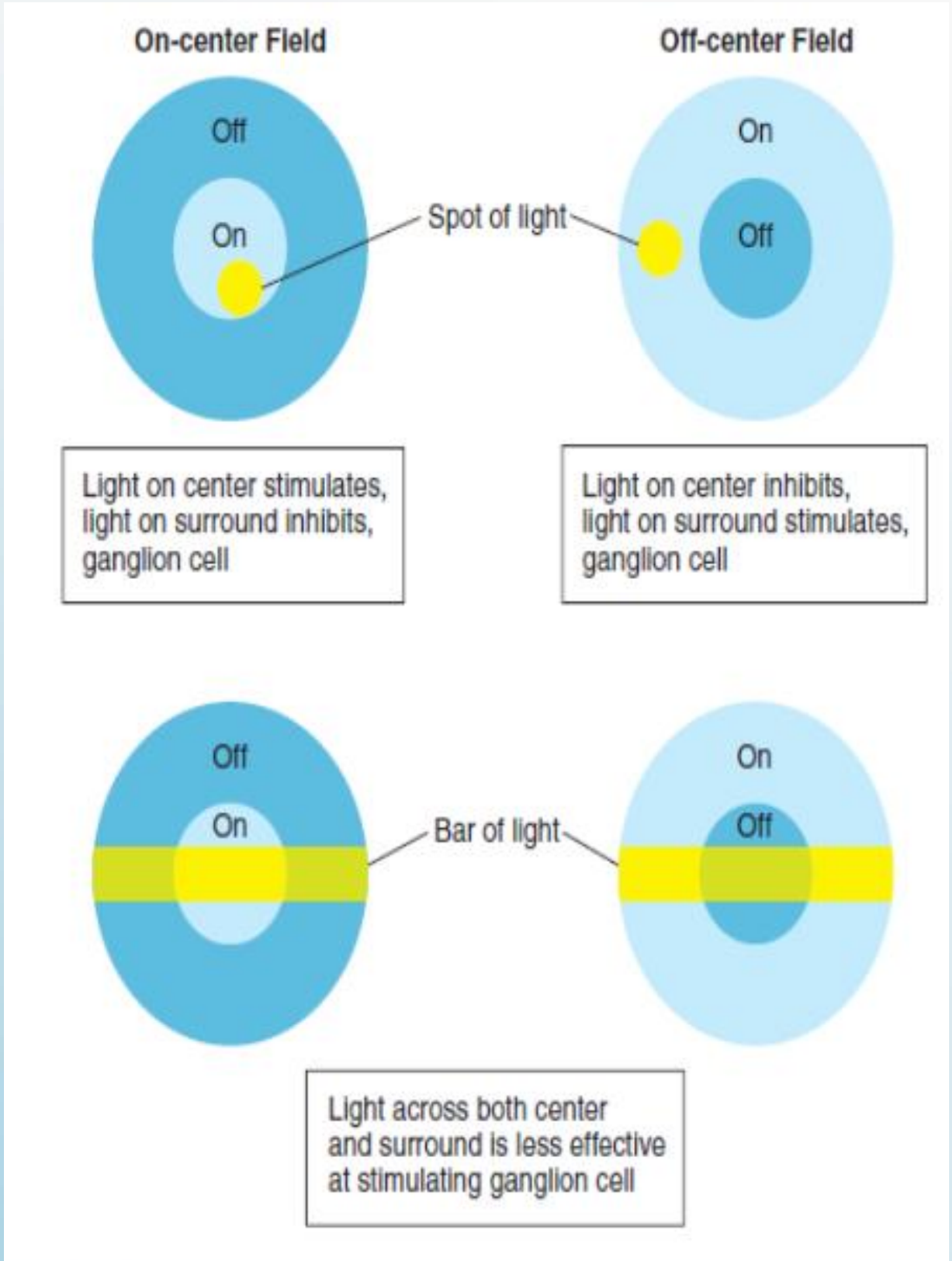
Affects the **on-center** Bipolar cell

Depolarization of Bipolar cell

Because inhibition of the inhibition is excittion

↓

Depolarization of Ganglion cell “increased firing rate” produce an Action Potential



- Receptive field is arranged for each two Bipolar cells there is one Horizontal cell positioned between them.

1. when light hits , they are **all hyperpolarized**
2. Photoreceptors synapse directly on Bipolar cells in the outer plexiform layer of retina
3. Bipolar cells shown as two concentric circles :

inner called on-center : which receive directly from photoreceptors

surrounded called off-center : which receive from adjacent photoreceptor by Horizontal cells , which shows the opposite response of center because horizontal cells are inhibitory.

- stimulation of both the center and surround produces only a mild response (due to mutual inhibition of center and surround).

Nyctalopia (Night Blindness)

- Night blindness (also called nyctalopia) is the inability to see well at night or in poor light. It is not a disease, but rather a symptom of an underlying disorder or problem, especially untreated nearsightedness.

- **What Causes Night Blindness?**

Night blindness is due to a disorder of the cells in the retina that are responsible for vision in dim light. It has many causes, including:

- Vitamin A deficiency : Vitamin A deficiency cause rods , cones & retinal degeneration & loss of rods.

- Nearsightedness
- Glaucoma
- Glaucoma medications that work by constricting the pupil
- Cataracts
- Diabetes
- Retinitis pigmentosa
- Keratoconus

Light adaptation

- If a person moves from dim to enlightened area light seems intensely and even uncomfortably bright until the eyes adapt to the increased illumination and the visual threshold rises in 5 minutes. **(Male Slides)**

- Less light sensitive pigments

> Increase In Visual threshold

> Decrease Visual sensitivity

> Na^+ channels remain close

> Na^+ current decreases

- If a person has been in bright light environment for hours, large portions of the photochemicals in both rods and cones will have been **reduced to retinal and opsins**. Further more, much of retinal of both rods and cones will have been converted into Vitamin A. Because of these two effects, the concentrations of the photosensitive remaining in the rods and cones are considerably reduced, and the sensitivity of the eye to light is correspondingly reduced. This is called light adaptation. (Guyton And Hall).

Dark adaptation

- If a person moves from brightly lighted surroundings to a dim lighted area the retinas slowly become more sensitive to light as the individual becomes accustomed to the dark **[it takes 20 min]** for dark vision **(only gross features but no details or colors).**

- If a person remain in darkness for a long time, the retinal and opsins in the rods and cones are converted back into light sensitive pigments. Further more, Vitamin A is converted back into retinal to increase light sensitive pigments.

20 min for dark adaptation are for regeneration of rhodopsin → increase sensitivity of rods to light → a drop in visual threshold .

Other Mechanisms Of Light And Dark Adaptation

- In addition to adaptation caused by changes in the concentrations of rhodopsin or color photochemicals, the eye has two other mechanisms for light and dark adaptation :

1. **First :** **Change in pupillary size,**
   this can cause adaptation of approximately 30-fold within a fraction of second because of changes in the amount of light allowed through the pupillary opening.
2. **Second :** **Neuronal adaptation,**
   involving the neurons in the successive stages of the visual chain in the retina itself and in the brain. That is, when light intensity first increases, the signals transmitted by bipolar cells, horizontal cells, amacrine cells, and ganglion cells are all intense .

However, most of these signals decrease rapidly at different stages of transmission in the neural circuit . Although the degree of adaptation is only a few fold rather than the many thousand fold that occur during adaptation of the photochemical system, neural adaptation occurs in fraction of a second, in contrast to the many minutes to hours required for full adaptation by photochemicals.

14 Physiology of color vision

CNS

Sources :

- **Femal slides**
- **Male slides**
- **Gyton unit X, chapter 50 page 615**

Objectives:

(1) Define color vision
(2) Identify and describe the mechanism of color vision
(3) types of cones, including the range of spectral sensitivity
(4) color blindness
(5) Identify color vision theory
(6) Describe the items needed for any color perception
(7) Compare different types of color blindness

Nopia = blindness
Nomaly = weakness

Definition of color vision

It the ability to discriminate between different colors.

It's also named as "Cone vision" because colors will be sensed by **cones only**.

1. Cones is located on & around fovea.
2. The type of retinal gnglion cells that transmit the color is "X cells".
3. Color vision is considered as photopic vision.
4. There are 3 primary colors (blue – red – green)
5. Black is the sensation produced by the absence of light & it is a positive sensation
6. The blind eye do not see black, it sees nothing.
7. Sensation of extraspectral colors as yellow, white, orange, purple,…,etc can be produced by mixing properties of the blue, red & green in different combinations.
8. For any color, there is a complementary color produces the sensation of white when properly mixed together.

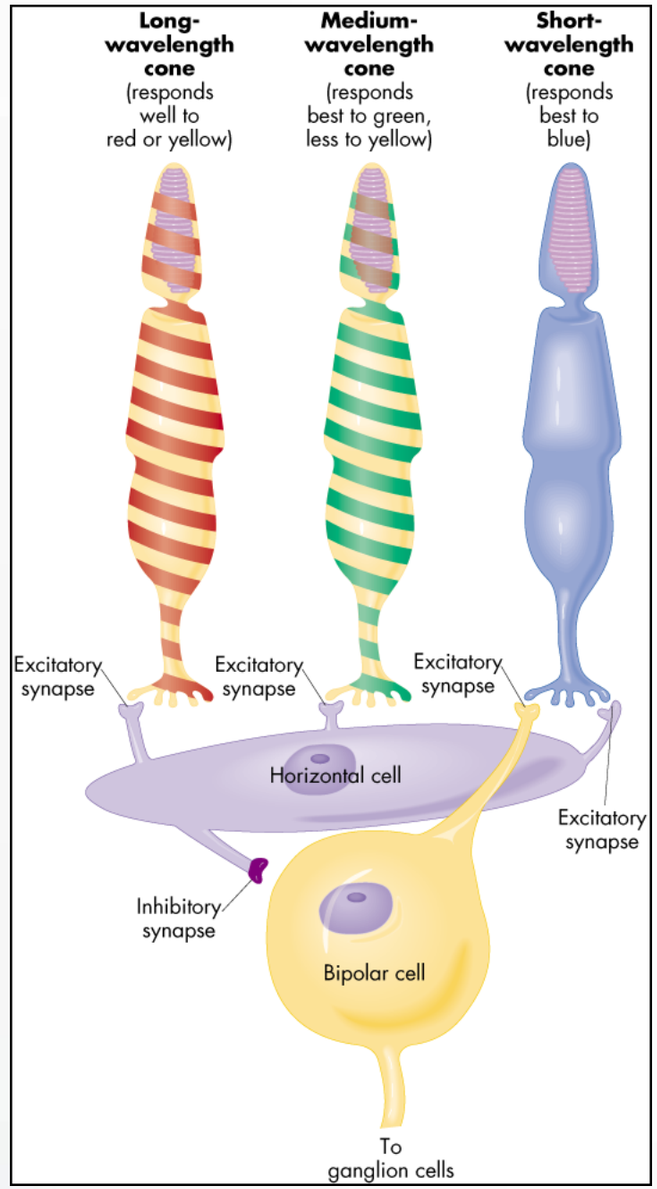
Colors have 3 attributes :

- Hue
- Intensity
- saturation (degree of freedom from dilution with white)

Color vision theory (Young-Helmholtz theory)

We have 3 kinds of cones, each has a specific photopigment (rhodopsin) & it is sensitive to one of the 3 primary colors

	Blue cone system	Green cone system	Red cone system
Pigment	S pigment Blue sensation pigment	M pigment Green sensation pigment	L pigment Red sensation pigment
Wave length	Short 440 nm	Middle 535 nm	Long >535 nm
Notes	Sense blue color	Sense green color & less to yellow Absorb light at green portion	Sense red & yellow Absorb light at red portion



Sensation of any color determined by:
1- wave length of light.
2- amont of light absorbed by each cone.
3- frequency of impulses from each cone system to ganglion cells which is determined by wave length of light.

Each cone system respond to its color at a lower threshold than needed to sense other colors i.e red cones respond to red or yellow color at a lower threshold than to green color

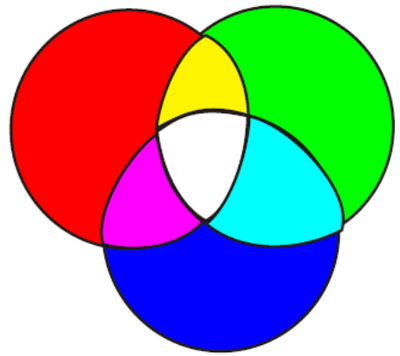
Color vision is coded by different responses in ganglion cells that depends upon the wave length of stimulus which determine frequency of impulses in ganglion cells

Color perception

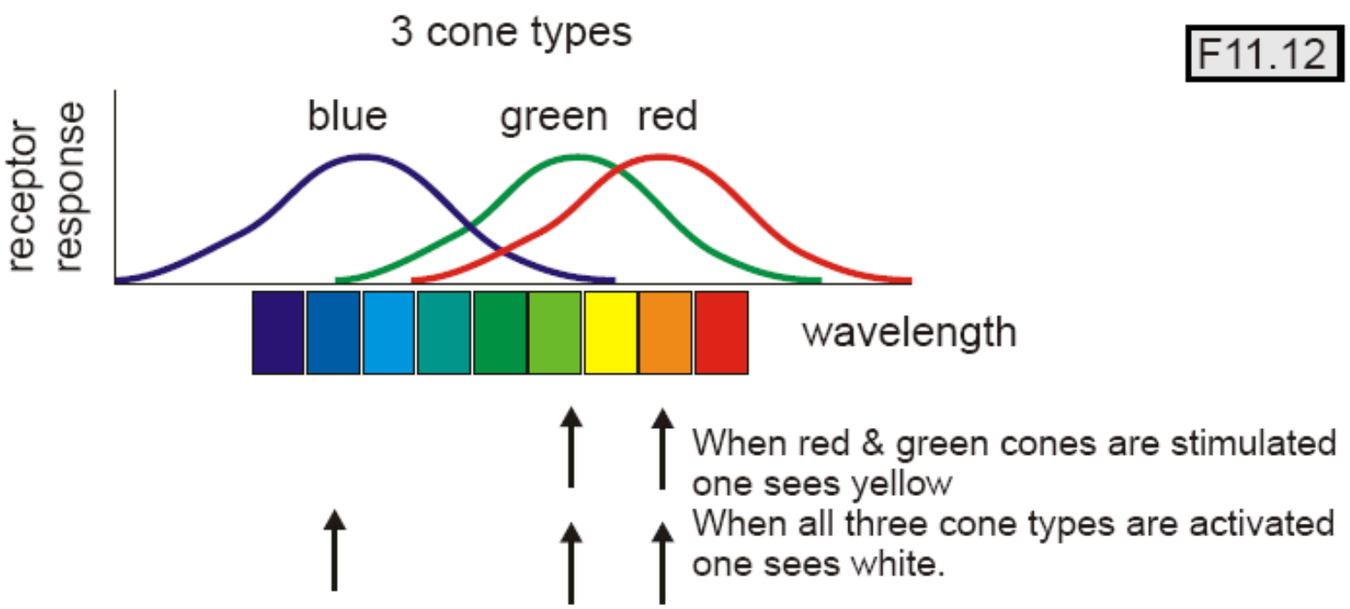
The color perception in the brain depends on the amount of activity in each of the 3 cone systems

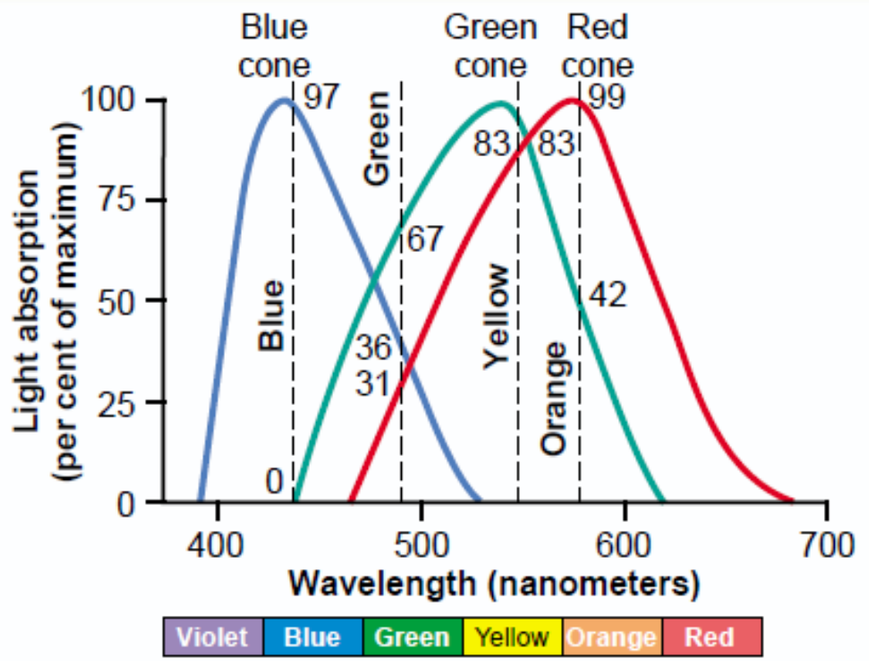
perception of orange	perception of yellow	perception of blue
due to stimulation of 99% of red cones & 42% of green cones & 0% of blue cones (so ratio is 99:42: 0)	due to stimulation of 50% of red cones & 50% of green cones & 0% of blue cones (so ratio is 50:50: 0)	due to stimulation of 0% of red cones & 0% of green cones & 97% of blue cones (so ratio is 0:0: 97)

Perception of white is due to equal stimulation of blue, red & green cones because white is a combination of all wave lengths



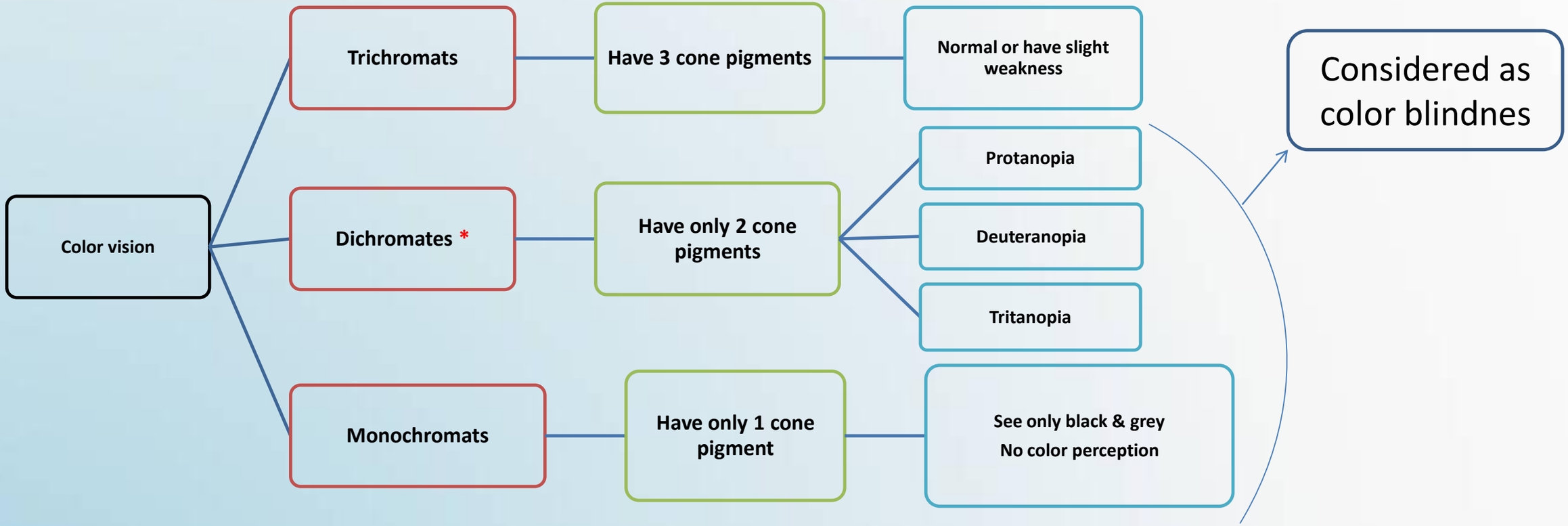
The effect of mixing different wavelengths of light





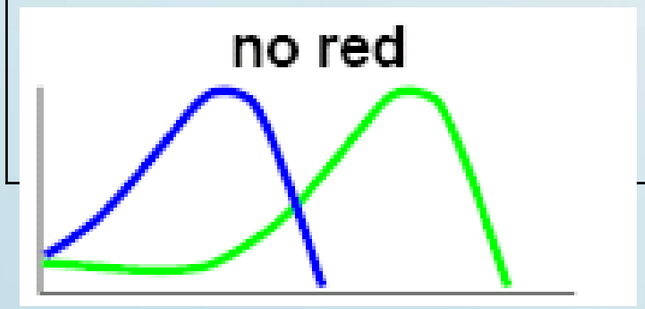
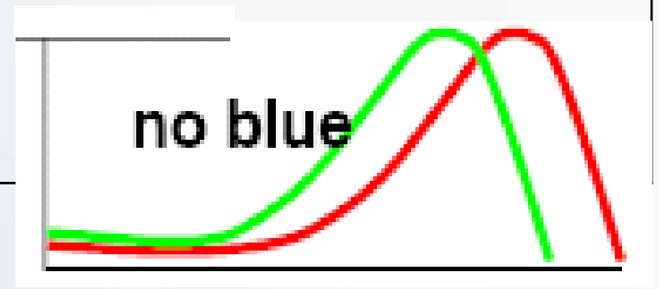
Color blindness

- There is gene for rhodopsin on chromosome(3)
- There is gene for blue sensitive S 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 there gene) the person can not see or distinguish some colors from others



* It means that he can see **only 2** of the 3 basic colors (Blue , Green , Red)

Dichromats

Protanopia Red - blindness	Deutranopia green - blindness	Tritanopia blue - blindness
- No red cones system. - Person has shortened spectrum wave length - If only weakness in red color vision is called protanomaly.	- No green cones system. - Person see only long & short wave length) - If only weakness in green color vision is called deutranomaly.	- No blue cones system. - If only weakness in blue color vision is called tritanomaly.
		

Test of color blindness

Ishihaha chart

Red-green blindness

- Green & red cones see different colors between wave length 525-675 nm & distinguish them.
- If these cones are absent, the person can not distinguish 4 colors (red – green- yellow- orange) .
- He can not distinguish red from green (primary colors) so called red – green blindness.

- It is x-linked disease transmitted from females to their male sons.
- **Never** occur 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(their gene is on x chromosome).
- 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.

NOTE : people who have any kind of blindness **can't** see the white color because it is combination of all .

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