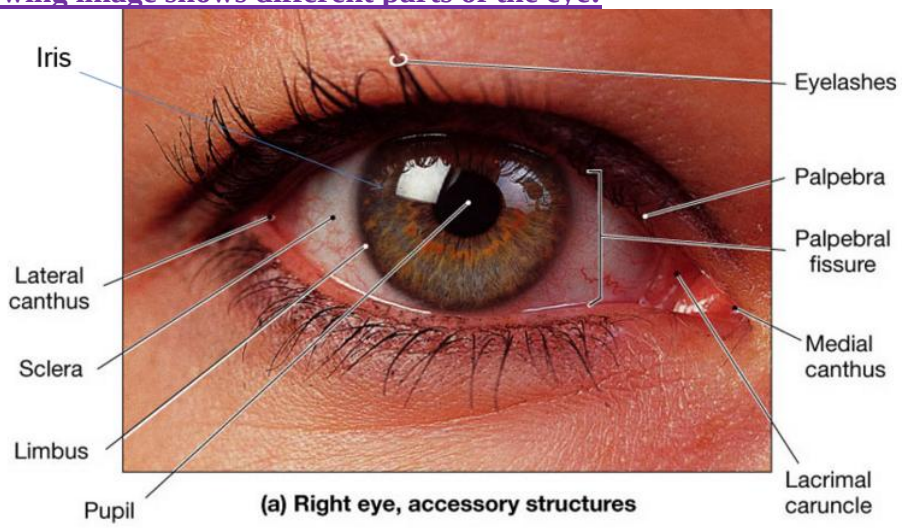
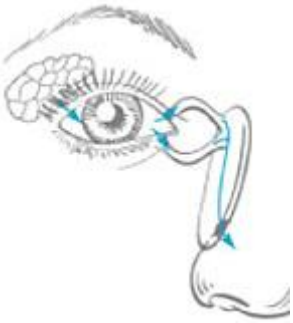
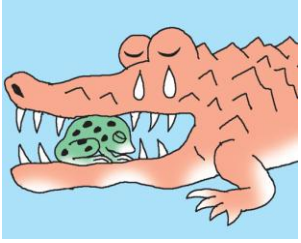
- In one second only, a lot of information is received by the vision.
- **The following image shows different parts of the eye:**



  - Notice that the iris is the colored part of the eye. It is mostly black in adults but it is usually colored in babies (Why?) → because melanocytes are still not developed and the pigment melanin is not produced.
- **Tearing can be of 3 types:**
  - **Basal**: which is occurring continuously in normal condition for moisture and clearance of the eye from dust.
  - **Reflexive**: this type occurs when there is irritation to the eye and it is usually associated with blinking.
    - ✓ Afferent: by 5th cranial nerve (trigeminal nerve).
    - ✓ Efferent: by 7th cranial nerve (facial nerve).
  - **Emotional**: this is a characteristic in humans (it is still not approved if animals can have emotional tearing). The composition of emotional tear is different (it has a lot of steroids and prolactin).
    - ✓ Emotional tearing is mediated by the cortex (cranial nerves are not included) → therefore, emotional tearing is not affected when there are lesions to cranial nerves.



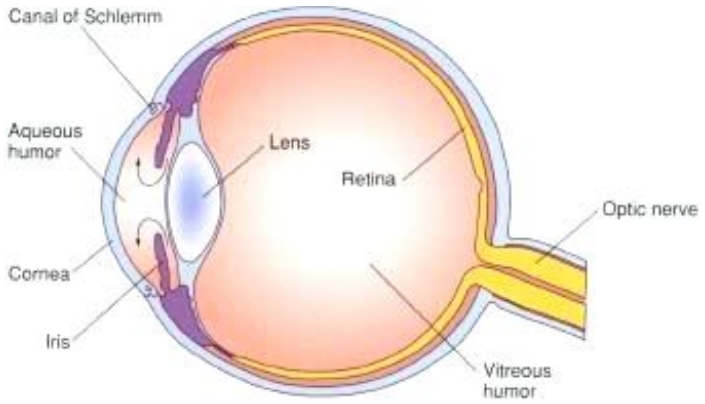
- **Flow of tears**: from lacrimal gland → to lacrimal ducts → to lacrimal canal → to naso-lacrimal duct → eventually reaching the nasal cavity (this explains why fluids come out of your nose when you cry).
- **Bell's palsy (leading to crocodile tears syndrome: دموع التماسيح):** in which there will be shedding of tears while eating (Why does this happen?) → a lesion occurs to the facial nerve followed by regeneration of fibers which will be directed toward the lacrimal gland instead of being directed toward salivary gland.



- **Why is crying evolved?** → it is evolved in a baby as a way of communication between him and his parents (a way to seek help). **The baby has 3 types of crying:**
  - **Basic.**
  - **Hunger.**
  - **Pain.**

    Notice that the mother can differentiate between these types of crying. Also, when the baby cries there will be no tears because the neural development of tearing is still not mature.

- **The part of the eye which is allowing light to enter it is an organic tissue**. This organic tissue of our eyes is enabling light to enter in a better and more effective way than that allowed by inorganic materials.
- **The iris of the eye has 2 types of muscle:**
  - **Circular muscles** → under the control of parasympathetic system → causing constriction of the pupil (miosis).
  - **Radial muscles** → under the control of sympathetic system → causing dilation of the pupil.
- **Accommodation**: representing changes which occur to the eye when an object is approaching. These changes include:
  - **Convergence of both eyes** (which means that both of them will be directed medially through the action of medial rectus muscle which is under the control of 3rd cranial nerve "oculomotor nerve").
  - **Increase in the power of the lens (increase in its convexity):** this action is mediated through ciliary muscles.
  - **Constriction of the pupil** (constriction occurs because the eye doesn't need light when an object is approaching): this action is mediated by parasympathetic system.
    - ✓ In accommodation, visual stimuli will be transmitted through optic nerve → to optic chiasma → to optic tract → to lateral geniculate body → eventually reaching the visual cortex. Therefore, a midbrain lesion will cause disappearance of pupil constriction associated with light reflex but pupil constriction associated with accommodation will not be lost.
- **In newborns, the neural pathway is still not developed. Therefore, they cannot see clearly.**
- **Aqueous humerus is the fluid which is present in the anterior segment of the eye**. It is produced and absorbed by ciliary body (absorbed through canal of Schlemm). This fluid functions in creating a pressure which will push the lens against vitreous humor (the gelatinous material in the posterior segment of the eye) and this will further push the retina (so it can be kept fixed in its place).
  - **If the absorption of this fluid is blocked** → there will be increased pressure → leading to increased pressure on the lens and vitreous humor → which will push hard on the retina leading to compression on blood vessels and loss of peripheral vision (because peripheral blood vessels are very tiny and therefore they are damaged by any minor increase in the pressure).

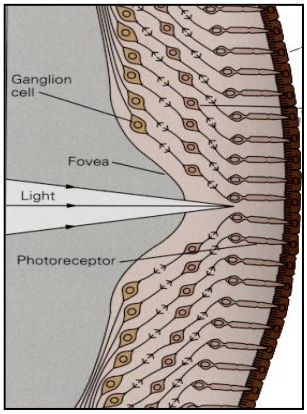


  - Vitreous humor is very transparent and if the material in it coagulates this will be removed by phagocytes.
- **There are 5 retinal cells:**
  - Photoreceptors which include (rods and cones).
  - Bipolar cells.
  - Ganglion cells.
  - Horizontal cells.
  - Amacrine cells.

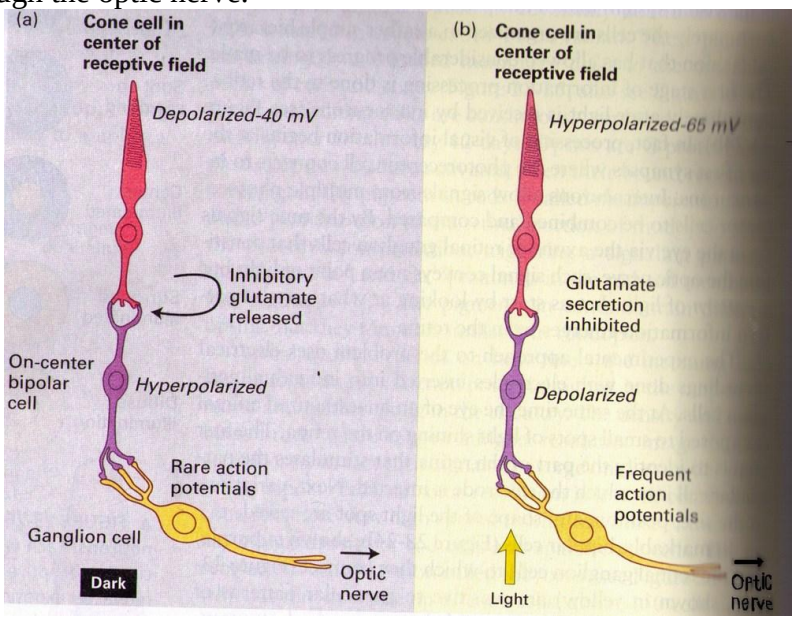
- ✓ Some say that these cells are neurons while others say they are modified cells (Why?) → because ganglion cells are able of producing action potentials (notice that the other 4 cells cannot generate action potentials but they have a resting membrane potential and they can be depolarized).
- ✓ The photoreceptors of the retina (rods and cones): are converting light energy into electrical energy (so the brain can deal with the received information).

- **There are 2 types of visual system:**
  - **The central vision system (cone system):** which is providing accurate, colored, detailed and quickly transmitted information of vision.
    - ✓ Notice that the cone system is stimulated by the presence of light. It is not stimulated at night (darkness) because there is no enough light to stimulate the cones and this explains why we cannot see colors at darkness.
  - **The peripheral vision system (rod system):** which is not accurate and providing blurred-uncolored vision.
    - ✓ Notice that this system is activated at night and functions in detecting any movement at the periphery after which a reflex will be mediated so you direct you central vision toward the moving object and you see it more clearly (in details).

- **When light enters the eyeball and reaches the retina** → it will pass directly to the pigmented epithelium and photoreceptors through the fovea → then information will be carried from them to bipolar cells → to ganglion cells which will generate action potentials traveling through the optic nerve.
  - **Note**: in the fovea, all other cells will be pushed away so light can be applied directly on photoreceptors (so the fovea is a depressed area on the retina caused by divergence of cells).



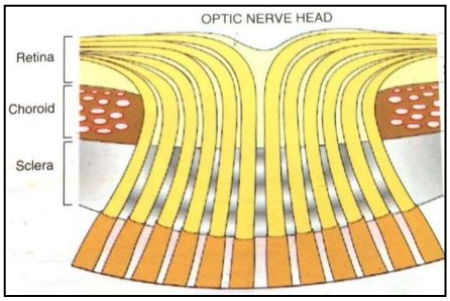
- **At night, cone cells are depolarized** releasing inhibitory glutamate and thus causing hyperpolarization of bipolar cells which will eventually result in rare action potentials from ganglion cells.
- **At day-time, cone cells are hyperpolarized** and thus glutamate release is inhibited → bipolar cells will be depolarized causing frequent action potentials (from ganglion cells) traveling through the optic nerve.



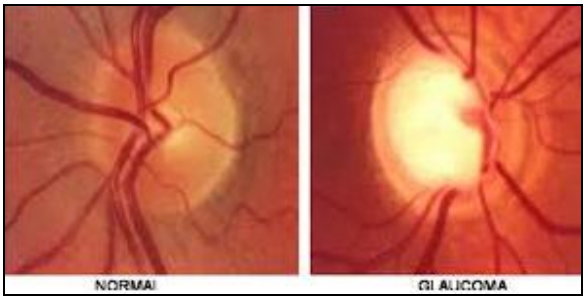
- **Amacrine cells**: they are horizontally oriented cells which might show action potentials. They function in detecting the intensity of light, direction of movement and circardian rhythm.
- **Ganglion cells are present in 3 groups:**

- **Y-ganglion cells**: which are detecting movement.
- **X-ganglion cells**: which are detecting details of the image.
- **W-ganglion cells**: which are detecting direction of movement in the field.

- **Pigments:**
  - **Rods pigment (rhodopsin):** retinal (precursor of vitamin A) + opsin protein (scotopsin).
  - **Cones pigment (color pigment):** retinal + opsin protein (photopsin).
- **Connections of rods and cones:**
  - 1 cone cells is connected to 1 bipolar cells which is in turn connected to 1 ganglion cell (central accurate vision).
  - 1 rod cell is connected to many bipolar cells which are in turn connected to 1 ganglion cell (so there is a loss of information leading to peripheral inaccurate vision).
- **All fibers of the ganglion cells will continue as the optic nerve in the optic disc**. Notice that the optic disc is a blind area that does not contain photoreceptors (the blind spot).



- **Cup of the optic disc**: it is the space where there is no fibers of ganglion cells entering the optic nerve (the cup is constituting only 0.3% of the optic disc). Notice that the cup: disc ration is increasing when there is glaucoma.



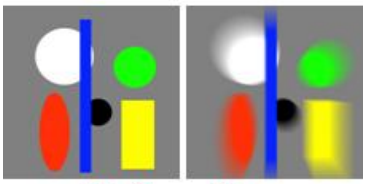
- **The fovea is very small and it is containing a lot of cons** (so it is responsible for the central vision) but the eye ball most move rapidly scanning the whole object which we aim to see in details (due to the small size of the fovea).
- **Comparison between rods and cons:**

Rods	Cones
– Specialized for dim light - night vision	– Specialized for day vision
– More photopigment: can detect single photons	– Less photopigment so lower sensitivity
– Saturate in daylight (adaptation)	– Saturate in intense light
– Low acuity - none in central fovea	– High density in fovea--> high acuity
– 1 photopigment - 500 nm absorption maximum	– Provide color vision: 3 types of cones each with different light sensitivity
– High level of convergence	– Low level (or no) convergence
– Less area of cortical presentation	– High cortical area presentation
– 120 million	– 8 million.

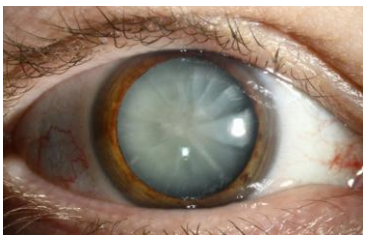
- **Why is the orientation of photoreceptors upside-down?**
  - Because the pigment is synthesized from down to up.

- The pigment must be retaken and synthesized again so it is not accumulated inside the cavity of the eyeball otherwise this will result in a condition known as retinitis pigmentosa.
    - ✓ Retinitis pigmentosa: is a genetic disease in which choroid cells have difficulty in engulfing the pigment → this accumulated pigment will absorb light and lead to loss of peripheral vision (because most of the accumulated pigment is in the periphery where rods are present).

- **In darkness: cGMP is increased in rods** leading to influx of sodium and calcium and eventually resulting in depolarization of the rods.
- **When light is present: cGMP is reduced in rods** leading to decreased efflux of sodium and calcium and eventually resulting in hyperpolarization of the rods.
- **Notice that retinine 1 will change from cis-form to trans-form with light.**
- **There are 3 types of the protein opsin** allowing us to see the 3 primary colors: red, blue and green.
- **Visual acuity**: when there are 2 dots stimuli falling on one cone cell → you will see both these dots as one dot (because the stimuli are falling on one receptor).
    - **In other words, when 2 stimuli are stimulating one receptor → they are perceived as one stimulus.**
    - **If the image is stationary (not moving) on the retina** → visual acuity is good.
    - **Blurred vision** occurs when the image is moving on the retina and thus falling on many cone cells (which means that each part of the image will be falling on one cone cell).
    - Blurred vision also results when you move your eyes rapidly during which different objects will be seen blurred in this phase → but blurred vision is corrected by the cortex (so we are not aware of it) by saccade masking → which means that during this rapid eye movement or when an object is moving rapidly you will be blind (flash suppression and image displacement suppression).


Motion Blur

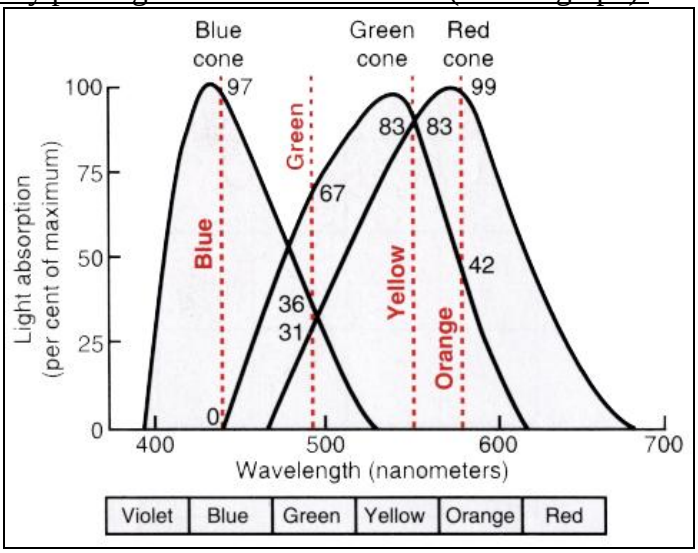
    - If there is a very rapidly moving object and you move your eyes focusing on the object (in the same velocity and direction) → you can see it.
- **In babies: the refractory system is still immature** → so they cannot see clearly until 8 months of age. Notice that most of the refractive power is occurring in the cornea. In the lens, the refractive power is less but is very important because it will focus the picture.
    - The cornea is not placing the image precisely on the retina and the lens is going to correct this condition.
    - The lens is a ball-like structure but it is stretched by zonule fibers (suspensory ligaments) which are attaching it to ciliary muscle.
    - If the refractive power of the lens is aimed to be increased → ciliary muscle contract → thus suspensory ligament will be relaxed → and the lens will become more biconvex (suitable for accommodation to see near objects).



    - It there is a far object → ciliary muscle will relax → thus suspensory ligaments will stretch the lens → so it becomes more flattened.
    - **Cataract (see the image):** the problem is in the denaturating (clotting) lens of the eye which leads to loss of transparency.
    - **Glaucoma**: in which a lot of water is accumulating in the anterior segment of the eye.

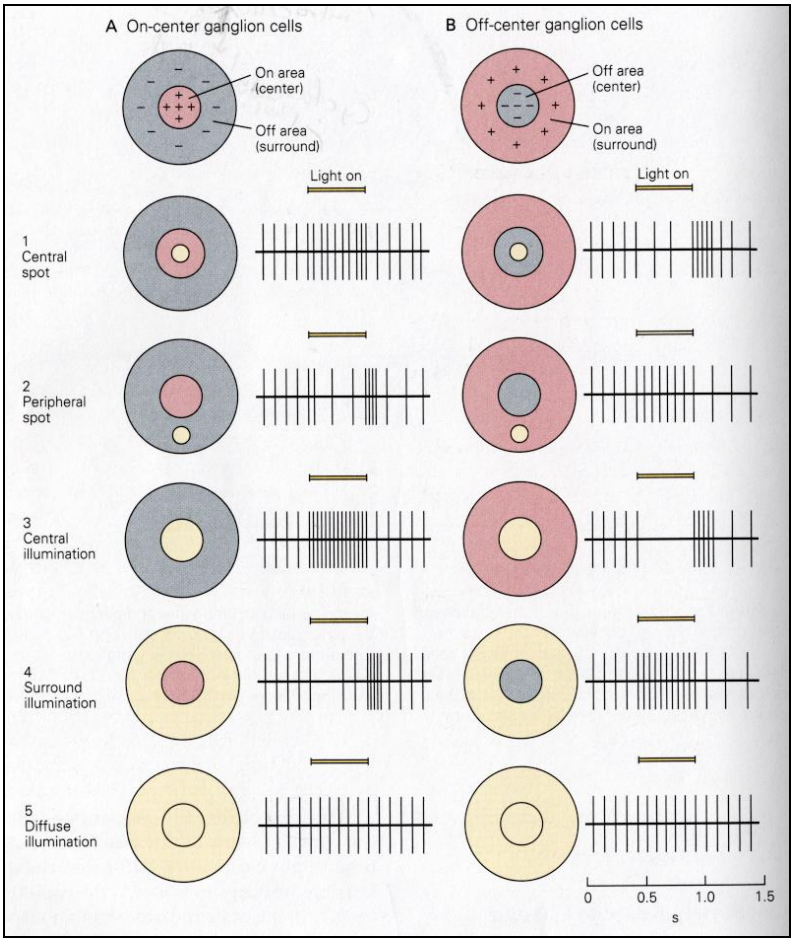

Normal Vision Cataract

- **Visible spectrum (colored vision):**
  - **Colored vision exists because we have 3 cone-systems (3 types of the protein opsin)**:
    - ✓ Each type of opsin (red, blue and green) is permitting the passage of light with different wave length (the visible spectrum is between 400-700 nm).
    - ✓ We don't see colors exactly the same because each person has his own cortex which will understand color in its own way.
    - ✓ Light is usually passing with mixture of colors (see the graph):

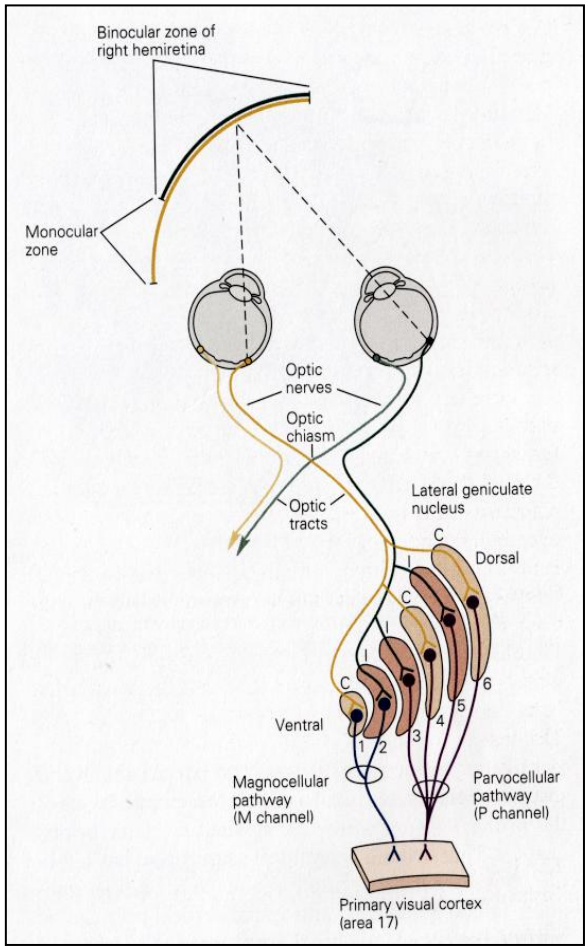


      - ❖ *For example, if the wave length of the light which is passing is 490 nm → this light will be composed of:*
        - 31% red color.
        - 36% blue color.
        - 67% green color.

- **Ganglion cells behavior:**
  - **Ganglion cells receptive field is circular, small and detecting dots of light.**
  - **There are cells stimulated by light (in day-time) and known as on-center ganglion cells:**
    - ✓ When you project a spot of light on the center of this area → there will be stimulation.
    - ✓ When you project a spot of light on the periphery of this area → there will be inhibition.
    - ✓ When you illuminate the whole central portion of this area → there will more stimulation (compared to the first condition).
    - ✓ When you illuminate the whole peripheral portion of this area → there will be more inhibition (compared to the second condition).
    - ✓ Diffuse illumination of central and peripheral portions of this area → back to normal state.
  - **There are other cells which are stimulated by darkness and known as off-center ganglion cells:**
    - ✓ When you project a spot of light on the center of this area → there will be inhibition.
    - ✓ When you project a spot of light on the periphery of this area → there will be stimulation.
    - ✓ When you illuminate the whole central portion of this area → there will be more inhibition (compared to the first condition).
    - ✓ When you illuminate the whole peripheral portion of this area → there will be more stimulation (compared to the second condition).
    - ✓ Diffuse illumination of central and peripheral portions of this area → back to normal state.

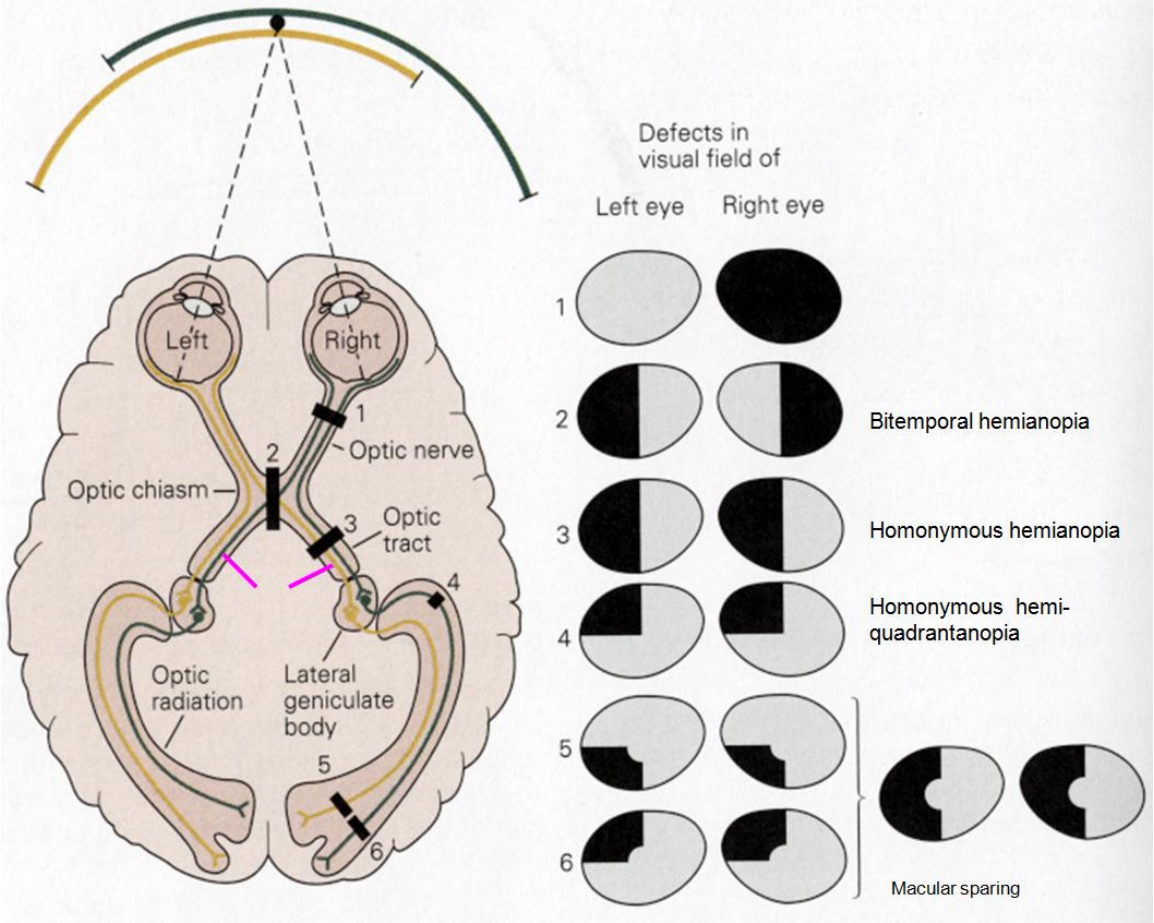


- **Visual information will be transmitted from retina → to ganglion cells → which will project as the optic nerve → then optic chiasma → then optic tract → eventually reaching the lateral geniculate body (LGB).**
  - **The nasal fibers which are transmitting visual information from temporal field will cross in the optic chiasma while the temporal fibers which are transmitting visual information from the nasal field will travel uncrossed on each side.**
  - **The LGB is composed of 6 layers:**
    - ✓ 4 layers will be forming the parvocellular pathway (responsible for knowing what is the object so it is connected with the cone-system).
    - ✓ 2 layers will be forming the magnocellular pathway (responsible for knowing the position of the object and is not related to visual acuity so it is connected with the rod-system). Fibers from magnocellular pathway will project to superior colliculi in the midbrain and aid in "visual grasp reflex".

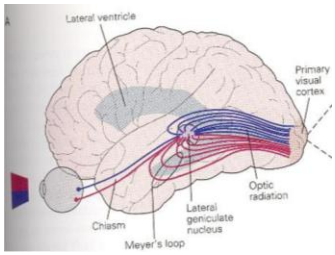


- **Notice that 80% of fibers in LGB are coming from the cortex** (fibers received from rods and cons are only constituting 20%) because the cortex will decide where will you pay attention and inhibit any other unwanted visual stimuli (selection). There are also some fibers originating from reticular system and going to LGB.
- **A newly-discovered 3rd pathway in LGB is the koniocellular pathway** → the function of which is still unknown but it may be involved in colored-vision.

- **Visual defects:**

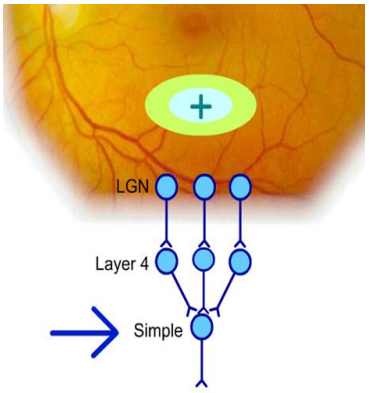


- Fibers from inferior half of the retina will receive visual information from upper visual field and then project to lower cortical regions while fibers from superior half of the retina will receive visual information from the lower visual field and then project to upper cortical regions.



- **Binocular vision**: there is an area in the visual cortex which will receive information from both eyes and this is functioning in perception of depth:
  - **As the object is near the eye → depth is increased.**
- In an infant, the two eyes compete for representation. If one eye sees poorly, the good eye has a competitive advantage and takes over the cortical representation of the bad eye. In the extreme case, the bad eye loses all its representation and become permanintly blind. This is called amblyopia (cortical blindness). The infant remains blind in one eye even if the function of that eye is restored to normal. The visual cortex is particularly sensitive to visual depriviation (plastic) in the first year of life. A cataract at birth which is not removed until after one year has a permanent effect. A similar depriviation in an adult has little effect. When a cataract develops in old age, vision is restored as soon as it is removed. This early sensitivity to competition in infants is called the critical period.
- **As mentioned earlier, information from the visual field are represented on the opposite side and upside-down on the visual cortex**. The fovea is represented by a big area in the visual cortex (which is almost equal to the area of peripheral vision) to be able to provide clear detailed vision.

- **Remember that ganglion cells have circular, small visual fields with on-off centers and they detect spots of light.**
- **In the visual cortex, ganglion cells will change their properties becoming lateral geniculate cells**. Each 2 lateral geniculate cells are projecting to one simple cell (therefore, each simple cell will have a bigger visual field than ganglion cells and lateral geniculate cells). Cortical simple cells are sensitive to lines and their orientation (as compared with ganglion cells which were detecting spots). The features of simple cells are:



  - **Specific retinal position**: which means that each simple cortical cell is receiving information from a sepcific visual field.
  - **Clear excitatory and inhibitory zones.**
  - **Specific axis of orientation.**
- **Complex cells:**
  - **Each of these cells is receiving information from multiple simple cells so they will have a very big visual field** (this visual field is the result of summation of the visual fields of ganglion cells and simple cells together).
  - **The visual field of complex cells is detecting bars or edges** (bigger than lines which are detected by simple cells). In addition it detects orientation and direction of movement (so complex cells are the only cells which are detecting movement → ganglion cells and simple cells do not).
- **The visual field is divided into small squares** → each square is falling on a specific area of the retina → then information from retina will move to 1mm columns in the visual cortex (each of these columns is receiving information from 1 square). Afterthat, some information from the visual cortex will be transmitted to:
  - **Temporal lobe** (to check if we have previous memories about what is this object). Therefore, information going to the temporal lobe are coming from the fovea (clear, high acuity with rapid conduction).
  - **Parietal lobe** (to reach a conclusion about where is this object).
- **Summary:**
  - **Information are transmitted from visual fields to specific retinal cells:**
    - ✓ X-cells: which are in the center.
    - ✓ Y-cells: which are in the periphery.
  - **Then, information will be transmitted to lateral geniculate body which is composed og 6 layers:**
    - ✓ 4 layers forming parvocellular pathway: responsible to know what is the object.
    - ✓ 2 layers forming magnocellular pathway: responsible to know where is the object.
  - **Eventually, information will reach the "what and where" systems (temporal and parietal lobes respectively).**
- **Frontal eyefield is responsible for voluntary eye movement.**
- **Involuntary fixation system**: is the one in which information will go to the occipital and parietal lobes so we first see the object and then initiate a reflexive movement of the eye. This reflexive eye movement is executed by superior colliculus (which is present in the midbrain and has the map of the visual field and instantaneous information about the actual position of the eye). From superior colliculus, information will be transmitted to 3rd, 4th and 6th cranial nerves which are innervating extraoccular muscles responsible for eye movement.