CENTRAL NERVOUS SYSTEM

- [x] Handout
- [ ] Sheet
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- [x] Anatomy
- [ ] Physiology
- [ ] Pathology
- [ ] Biochemistry
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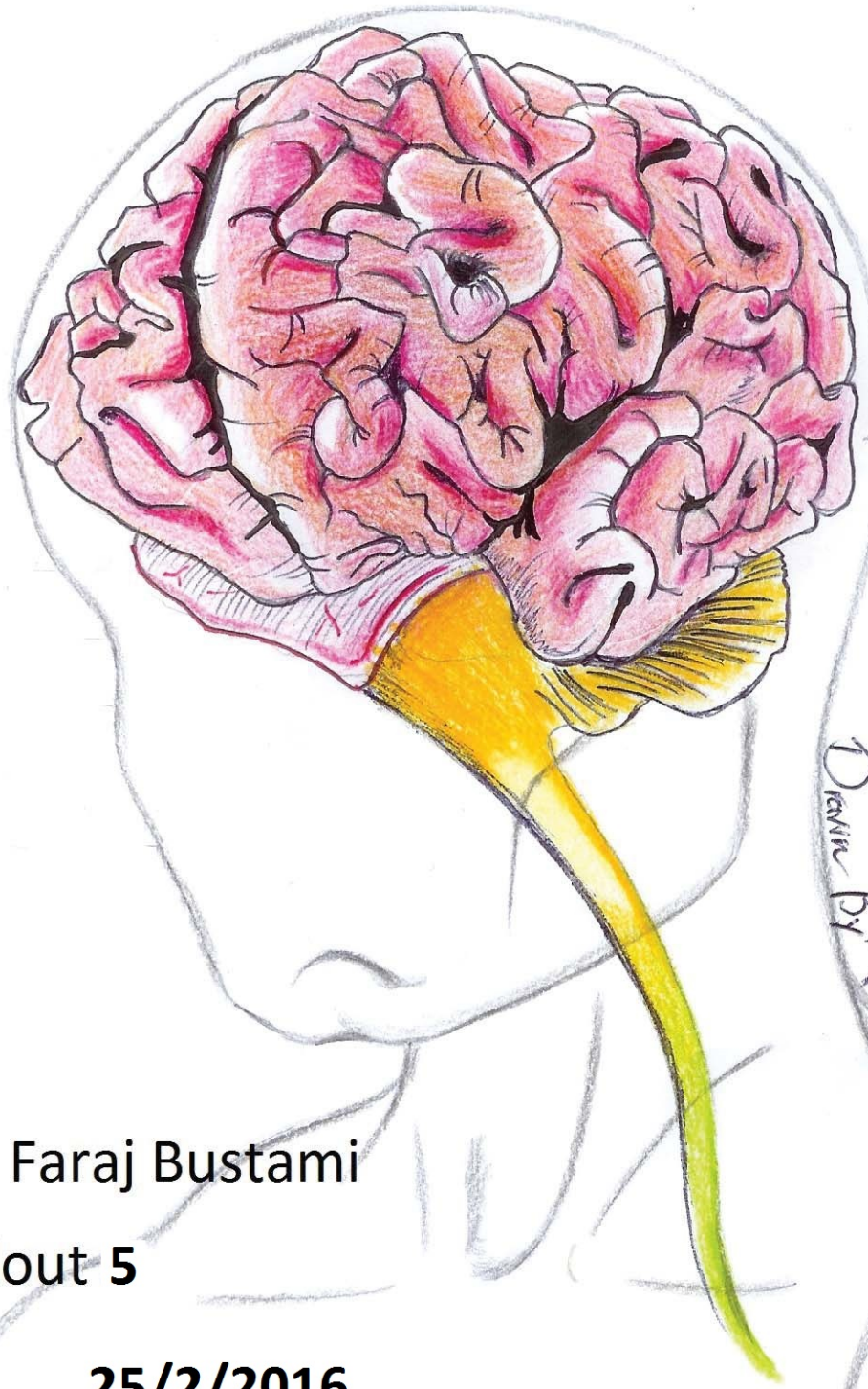

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Lec #: Handout 5

25/2/2016

EYEBALL

The eyeball is formed of three coats :

1. Fibrous coat : external.
2. Vascular and muscular coat : intermediate.
3. Nervous coat : internal.

Fibrous Coat

is formed of the cornea and sclera.

A. Cornea : transparent and forms the anterior sixth of the fibrous coat.

B. Sclera : is formed of dense white fibrous tissue (white of the eye). The optic nerve pierces the sclera about 3 mm. to the infero-medial side of the posterior pole of the eyeball.

The corneo-scleral junction (Limbus) presents a circular canal called the sinus venosus sclerae (*canal of Schlem*) into which the aquous humour is absorbed from the anterior chamber.

Vascular and Muscular Coat

is formed by the iris, ciliary body and choroid.

A. Iris : a circular diaphragm behind the cornea. It presents a central hole called the *pupil*. It contains the constrictor (sphincter) and dilator pupillae muscles.

The colour of the iris varies in different individuals due to presence of pigments. The space between the iris and cornea is called *anterior chamber*. The space between the iris and lens is called *posterior chamber*. The two chambers communicate through the pupil.

B. Ciliary body : composed of several parts :

a) *ciliary muscle* : which forms a muscular ring around the iris. It is formed of smooth muscle fibers arranged circularly and radially.

b) *ciliary processes* : which are irregular projections deep to the ciliary muscle. They lie lateral to the posterior chamber between the margins of the iris and lens. They secrete the aquous humour.

c) *ciliary ring* : which is a narrow vascular zone at the junction with the choroid.

N.B Aqueous humour is secreted into the posterior chamber from the capillaries of the ciliary processes & circulates into the anterior chamber through the pupil → from the anterior chamber it is drained into the anterior ciliary veins through the canal of Schlemm ⟹ Interference with drainage of the aqueous humour into the canal of Schlemm results in an increase of the intraocular pressure (Glaucoma) → This produces pressure atrophy of the retina causing blindness

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C. **Choroid** : is the largest part of the middle coat, lying between the sclera and retina. The choroid is formed of delicate areolar tissue which is highly pigmented and rich in blood vessels. Posteriorly, it is pierced by the optic nerve.

Nervous Coat

This coat is mainly formed by the retina. → outer pigmented layer; inner nervous layer

The retina is supplied by branches of the central artery of the retina which never anastomose together or with other arteries in the eyeball (i.e they are end-arteries)

The retinal veins collect into a central vein (its obstruction by embolism leads to sudden blindness)

Lens

— transparent, solid, elastic and bivonvex.

— lies between the iris and vitrious body.

— Its equator is blunt.

— The *suspensory ligament of the lens* is attached to the anterior surface of the capsule of the lens close to the the equator. Some fibers of the ligament are attached to the equator and posterior surface close to the equator.

The suspensory ligaments of the lens fixes the lens in position and connects it to the ciliary muscle. Therefore the curvature of the lens is affected by the contraction of the ciliary muscle and the degree of tension of the suspensory ligament. *

During looking to a near object the ciliary muscle reflexly contracts, the suspensory ligament gets loose and the curvature of the lens increase (accomodation).

— The elasticity of the lens begins to diminish after the age of fourty years → (Presbyopia)

— The transparency of the lens begins to diminish in old people, a condition known as *cataract.*

Vitreous Body

This is a transparent, structurelss, colourless gel-like substance which fills the concavity of the retina. It occupies about four-fifths of the eyeball and lies behind the lens.

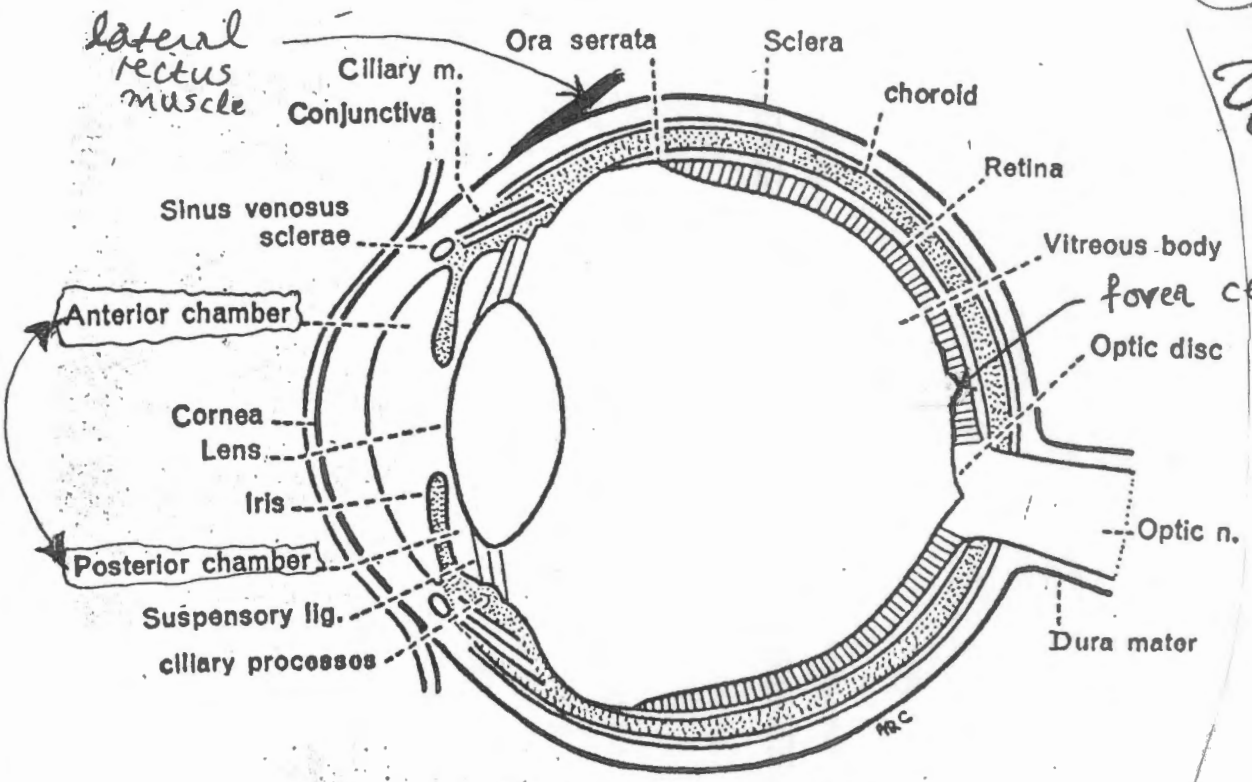
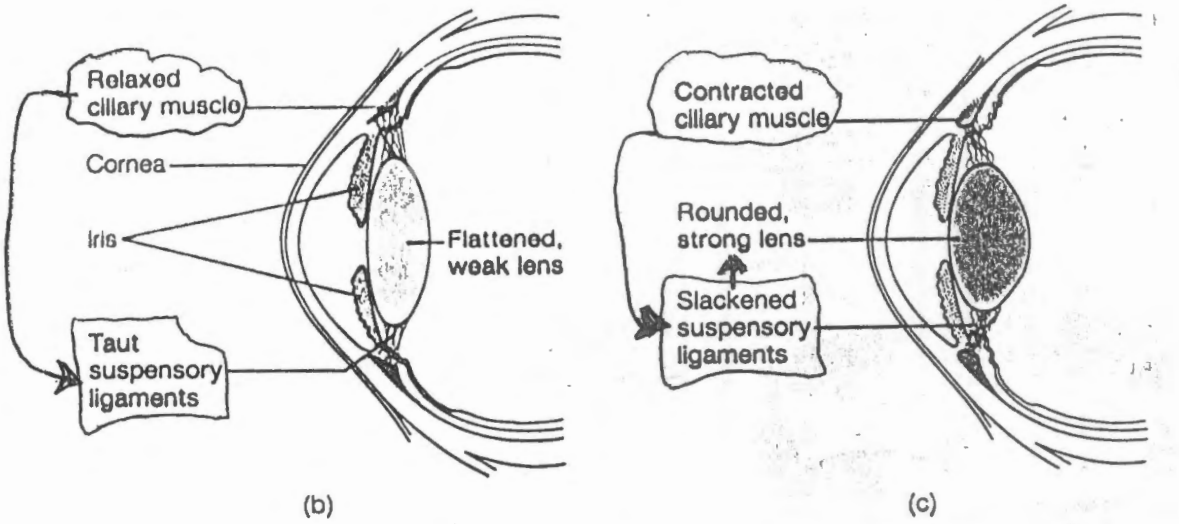


Fig. 174 Sagittal section of the eyeball.

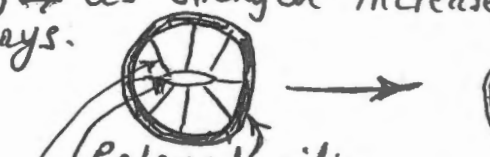
Retina: ① opposite the entrance of optic nerve (infero-medial to the posterior pole) the circular area of 1.5 mm diameter is known as optic disc → the depressed area of the optic disc is called the physiological cup → it contains no receptors (no rods or cones) & is therefore insensitive to light (physiological blind spot) ② At the posterior pole of the eye (3 mm lateral to the optic disc) → there is another depression of similar size called the macula lutea, it is avascular and yellow in colour → the centre of macula is further depressed to form the fovea centralis → This is the thinnest part of retina containing only cones & is the site of maximum acuity of vision ③ the retina consists of an outer pigmented layer & an inner nervous layer (its outer surface is in contact with the choroid & its inner surface is in contact with the vitreous body). In Retinal detachment انفصال الشبكية the outer pigmented layer remains attached to the choroid but the inner nervous layer separates out from the pigmented layer and displaced inward ⑤ the Retina is composed of 10 layers but ONLY 3 layers of major neurons →

Receptors (rods & cones) —① 1st order neurons— bipolar cells → 2nd order neuron — ganglion cells → third order neurons, its axons form — optic nerve



Accomodation تكيّف العين → increases the strength of the lens for near vision

1. The strength of the lens depends on its shape, which in turn is regulated by the ciliary muscle.
2. The ciliary muscle is a circular ring of smooth muscle attached to the lens by suspensory ligaments.
3. When the (ciliary muscle) is (relaxed) → the suspensory ligaments are taut مشدودة & pull the lens into a flattened weakly refractive shape ⇝ As the muscle (contracts) its circumference decreases, relaxing the tension in the suspensory ligaments → the lens becomes more spherical (more rounded) → its strength increases causing greater bending of light rays.



Relaxed ciliary muscle
↓
larger circumference
↓
Tense suspensory ligaments
↓
flattened lense
↓
weaker lense

Contracted ciliary muscle (by parasympathetic stimulation)
↓
Smaller circumference
↓
Slackened (relaxed) Suspensory ligaments
↓
more rounded lens
↓
Stronger lens

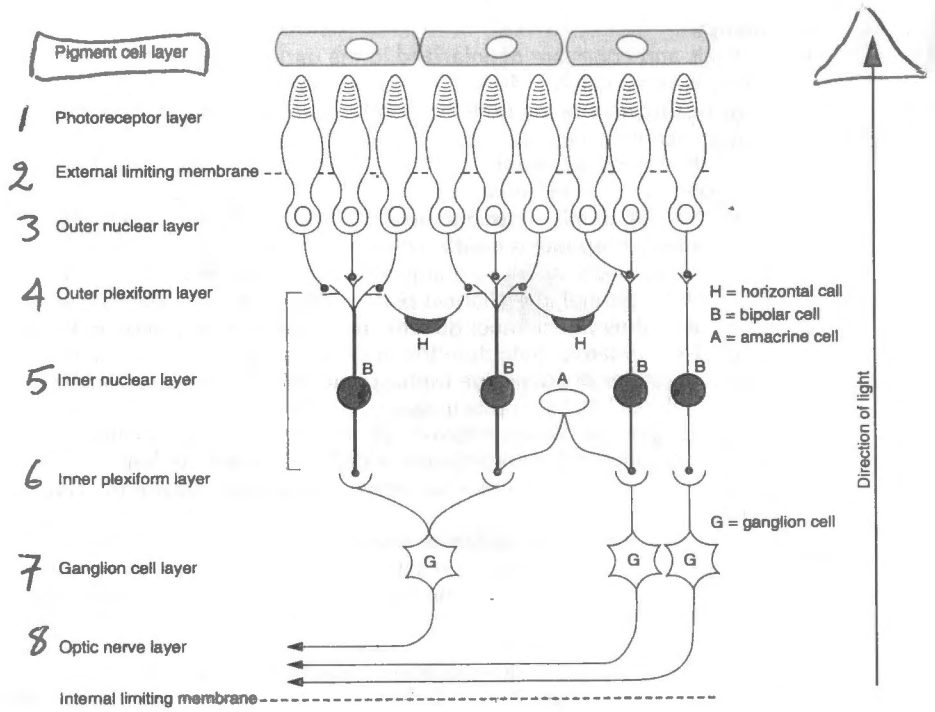


FIGURE 6-5. Organization of the retina. Photoreceptors converge on bipolar cells, which converge on ganglion cells. All of the receptors that convey information to a ganglion cell are part of that ganglion cell's receptive field.

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1) Photoreceptors → outermost layer (light has to pass through other layers before reaching receptors Except at foveal centralis)

2) External limiting membrane

3) outer nuclear layer → nuclei of Photoreceptors

4) outer plexiform layer → synaptic connections between photoreceptors, horizontal & bipolar cells

5) inner nuclear layer → nuclei of bipolar, horizontal & Amacrine cells

6) inner plexiform layer → synaptic connections between ganglion & bipolar cells

7) Ganglion cell layer → their axons form optic nerve

8) internal limiting membrane

C. **Energy transduction.** The **rods** and **cones** (Figure 6-3) are the photoreceptors of the eye.

1. **Morphology.** Both cell types consist of:
   a. An **inner segment containing the nucleus, abundant mitochondria,** and **synaptic vesicles**
   b. An **outer segment containing membranous disks**
      (1) The membranous disks are **continuously formed at the base of the outer segment and migrate toward the apex,** where they are sloughed off.
      (2) The membranous disks **contain a visual pigment,** called **rhodopsin,** which absorbs light rays.
         (a) **Rhodopsin** consists of a protein called **opsin** and a light-absorbing analogue of vitamin A (retinol) called **11-*cis* retinal** (Figure 6-4).
         (b) The amino acid composition of opsin determines the wavelength of light absorbed by the photopigment.
            (i) **Rods** contain a **single type of opsin**. The gene encoding for rod opsin is located on chromosome 3.
            (ii) **Cones** contain **three types of opsins** (**blue, green,** or **red,** depending on the portion of the visual spectrum they absorb best).

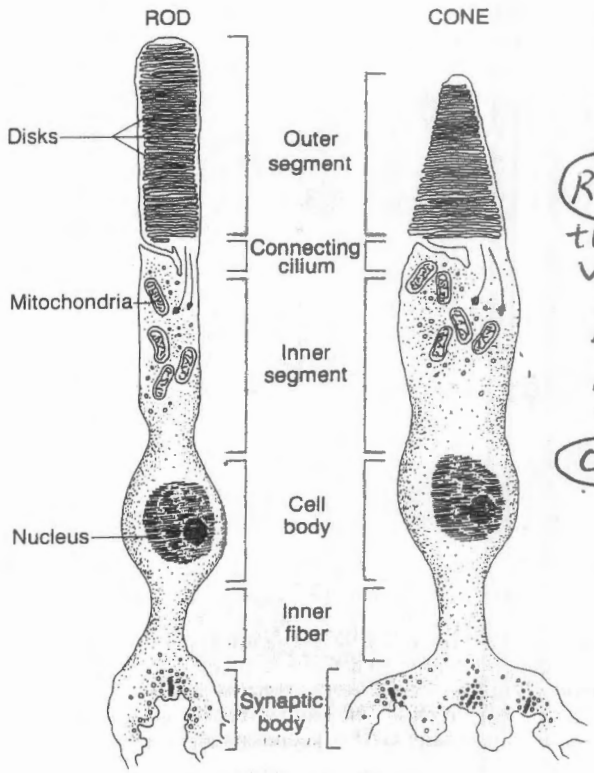

FIGURE 6-3. Morphology of rod and cone receptor cells. Cones, which are responsible for color perception and high visual acuity, are found in the fovea. Rods, which are responsible for night vision, are located in the peripheral retina.

Rods more sensitive to light than cones, Responsible for night vision. contain more rhodopsin in their outer segment. Can detect light entering the eye from any direction whereas cones respond only to light directly along their axis

Cones — daylight
high acuity (Concentrated in centre of retina)
colour vision
have 3 different Photopigment

Rods & Cones are DEPOLARIZED in the DARK? & Hyperpolarized in the light. The only receptors that respond to their specific stimulus by hyperpolarization.

   a. **Darkness.** Rods and cones are **depolarized** in the dark. Their resting membrane potential is low, approximately −40 mV.
      (1) The low resting membrane potential results from the **high Na^+ conductance of the outer segment** (see Figure 6-4A).
         (a) Na^+ flows into the cell through Na^+ channels in the outer segment and is transported out of the inner segment by Na^+-K^+ pumps.
            (i) **Na^+ channels** are **maintained in the open state** by **cyclic guanosine monophosphate (cGMP),** which is synthesized from guanosine triphosphate (GTP) by guanylate cyclase. When cGMP binds to the Na^+ channel, the channel opens. That is, in this case, cGMP acts by activating the channel directly, not by activating a protein kinase.
            (ii) The numerous mitochondria in the inner segment provide the large quantities of adenosine triphosphate (ATP) required to maintain the high Na^+-K^+ pump activity.
         (b) The large flow of current into the cell through the outer segment and out of the cell through the inner segment is called the **dark current**.
      (2) The low resting membrane potential allows **continuous release of synaptic transmitter**.
   b. **Light.** The photoreceptors **hyperpolarize** when stimulated by light. Absorption of light by rhodopsin initiates a series of reactions resulting in the hydrolysis of cGMP, the closing of the Na^+ channel, and the hyperpolarization of the cell (see Figure

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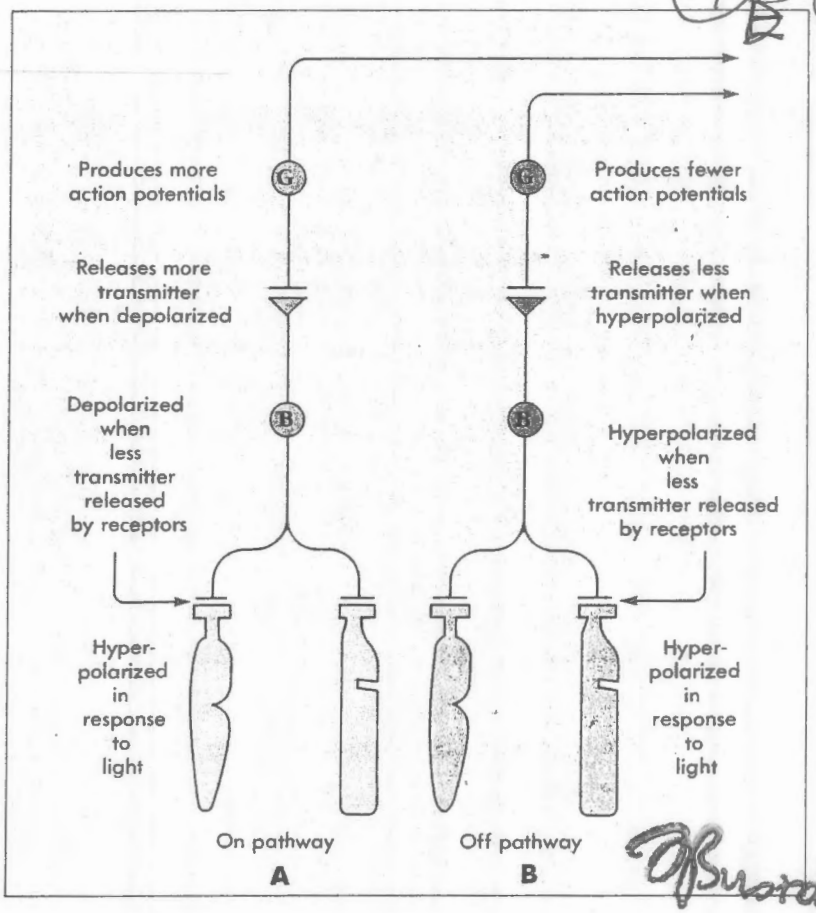

FIGURE 10-25
The response of the photoreceptors (both rods and cones) to light is always hyperpolarization. A The bipolar cell *(B)* in this pathway is excited by the decrease in transmitter release from the photoreceptors, that is, the transmitter had an inhibitory effect that was turned off. The bipolar excitation increases the number of action potentials in the ganglion cell *(G)* and therefore this is known as the ON pathway.
B Hyperpolarization of the photoreceptors decreases transmitter release, which inhibits the bipolar cell. This effect indicates that receptor cell transmitter has an excitatory effect on this class of bipolar cells. The inhibited bipolar cell releases less transmitter at its terminals on the ganglion cell, and this results in a decreased number of action potentials from ganglion cells in this pathway. This is therefore the OFF pathway.

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In the DARK → ganglion cells produce a low steady baseline rate of action potentials

In response to Illumination the activity of any particular ganglion cell either INCREASES (an ON response) or decreases (an off response)

The ON and Off pathways from receptor cells to ganglion cells are mediated by separate type of bipolar cells (bipolar neurons either depolarizing or hyperpolarizing) THESE DIFFER IN THEIR RESPONSE TO THE TRANSMITTER THAT IS CONTINUOUSLY RELEASED BY PHOTORECEPTORS IN THE DARK → the transmitter causes hyperpolarization in one type of bipolar cell and depolarization in the other

① Bipolar cells that are hyperpolarized by the photoreceptor transmitter in the dark becomes relatively depolarized when light excites the receptors → these constitute the ON pathway

② Those bipolar cells that are depolarized by the photoreceptor transmitter in the dark become relatively hyperpolarized when light excites the receptors and constitute the OFF pathway

- In the centre of the retina → yellowish region → macula lutea
- The fovea is a central depression in the macula lutea 0.3 mm diameter
- The fovea is the visual centre of the eye & the area of highest resolution !!!!
- optic disc → 3 mm to nasal side of fovea

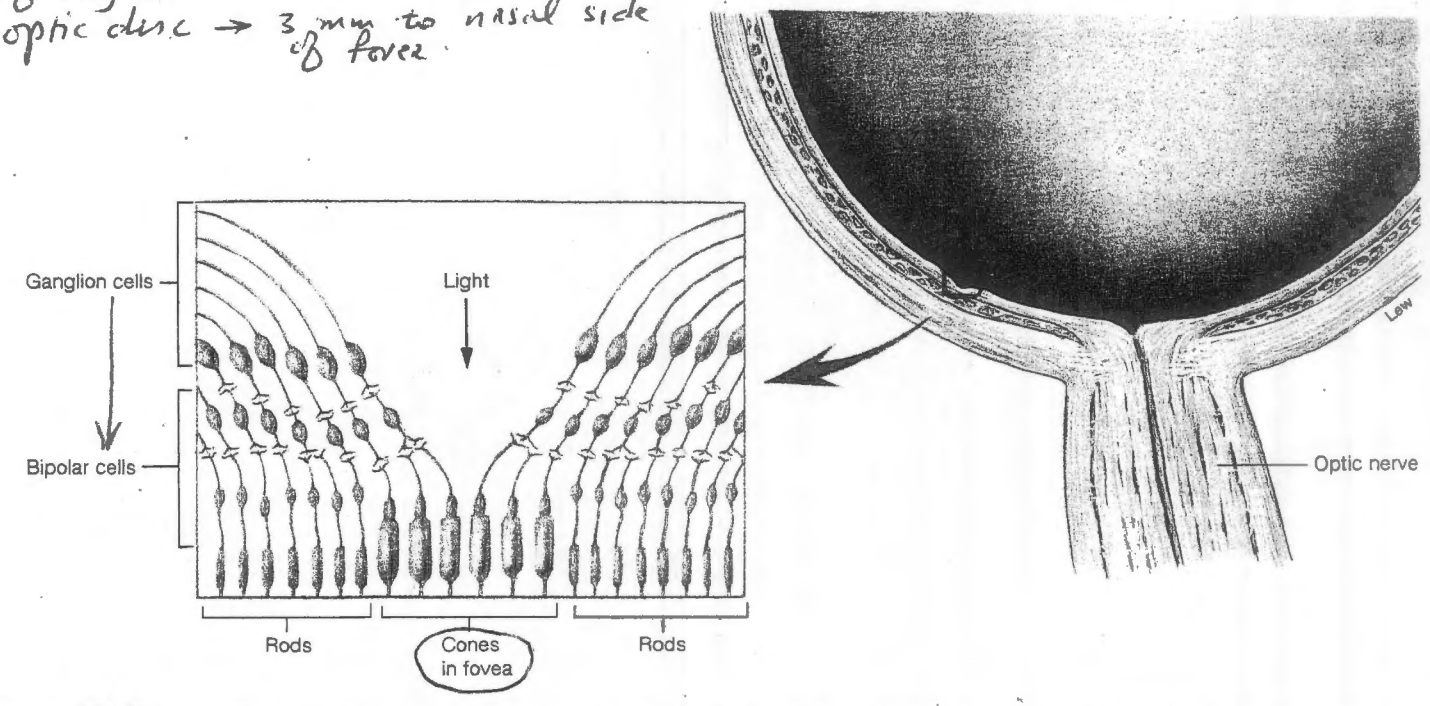


Figure 10.42 **The fovea centralis.** When the eyes "track" an object, the image is cast upon the fovea centralis of the retina. The fovea is literally a "pit" formed by parting of the neural layers. In this region, light thus falls directly on the photoreceptors (cones).

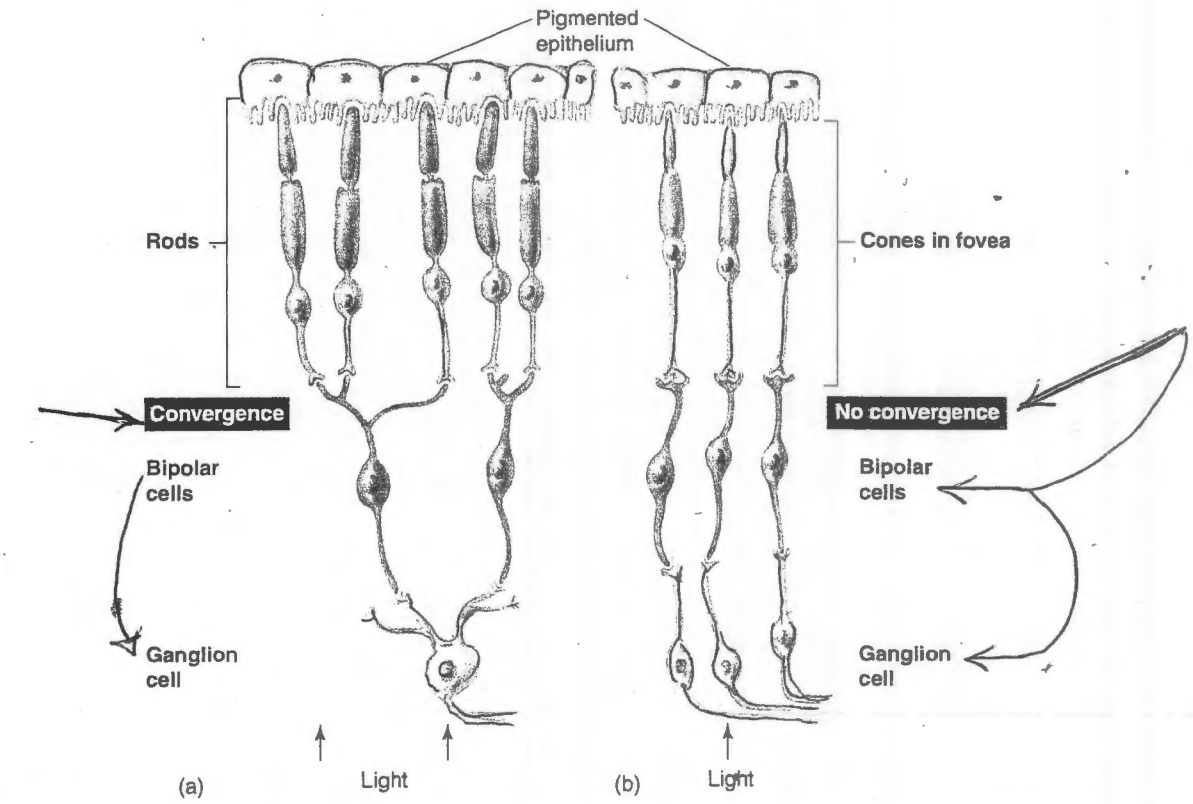


Figure 10.43 **Convergence in the retina and light sensitivity.** Since bipolar cells receive input from the convergence of many rods *(a)*, and since a number of such bipolar cells converge on a single ganglion cell, rods maximize sensitivity to low levels of light at the expense of visual acuity. By contrast, the 1:1:1 ratio of cones to bipolar cells to ganglion cells in the fovea *(b)* provides high visual acuity, but sensitivity to light is reduced.

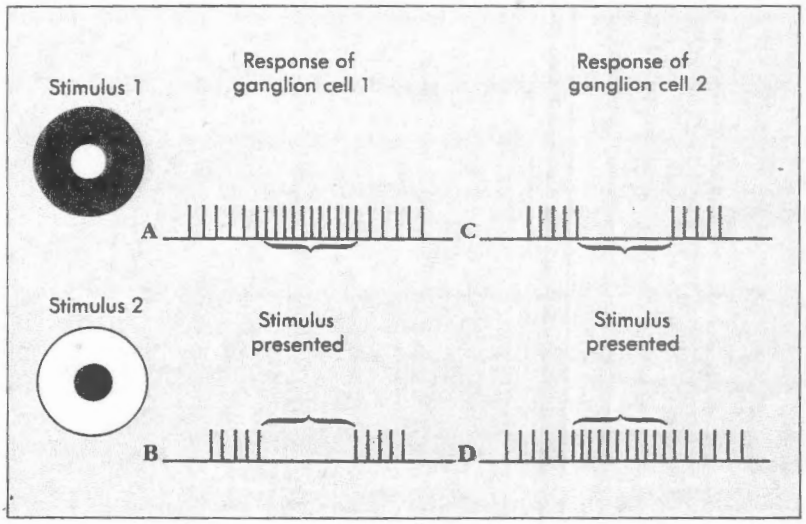


FIGURE 10-26
Electrical recordings from two categories of retinal ganglion cells that are responding to two stimuli. The traces show the rate of action potentials (indicated by *vertical spikes*) over time.
A Ganglion cell 1 is turned on (the frequency of action potentials increases) by a stimulus *(1)* consisting of a bright spot (the "center") surrounded by a dark background (the "surround").
B Ganglion cell 1 is turned off by a stimulus *(2)* consisting of a dark center surrounded by a bright background. It is therefore called an "ON center/OFF surround" cell. C Ganglion cell 2 is turned off by stimulus 1 and turned on *(D)* by stimulus 2. It is therefore called an "OFF center/ON surround" cell.

Typically ganglion cells have Receptive fields with central regions in which a Stimulus results either in A burst of action Potentials or a decrease in the steady low rate of action potentials → These are called ON centre and OFF centre ganglion cells

Most Receptive fields Combine excitation & inhibition → so that if light in the centre of the receptive field excites a ganglion cell → the same cells will be inhibited by light in a circular area around the centre (the Surround) → these are ON centre/OFF surround cells

In other ganglion cell → a spot of light falling on the centre is inhibitory while in the surrounding region it is excitatory these are OFF centre/ON surround cells

The opposite effects of stimulating the centre and Surround of a ganglion cell's receptive field are probably due to lateral connections of horizontal cell which block output from the centre pathway when a contrasting illumination falls on the surround. !!!

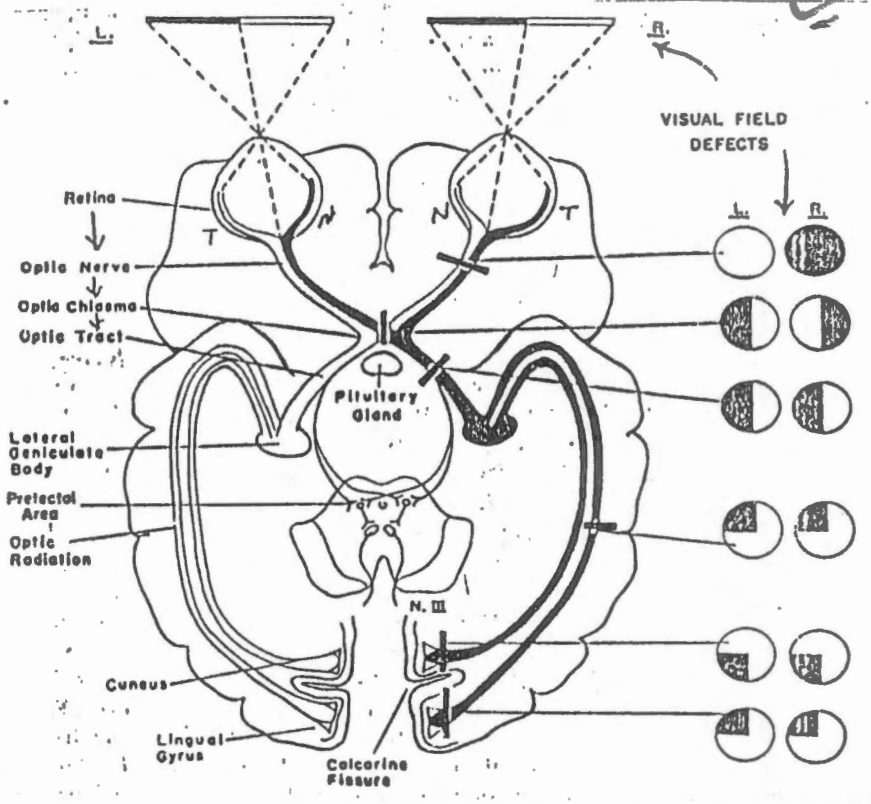
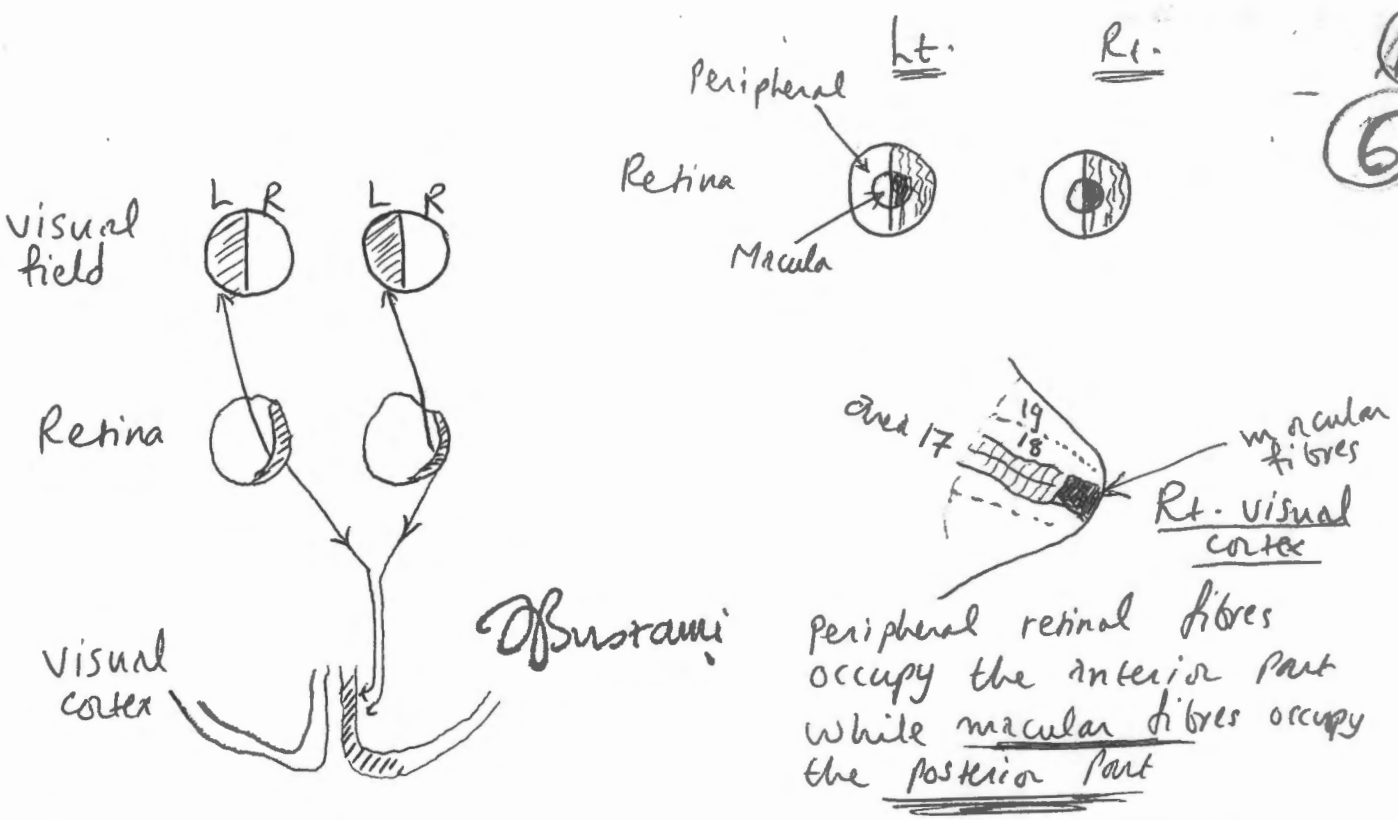


FIGURE 38. The visual pathway. On the right are maps of the visual fields with areas of blindness darkened to show the effects of injuries in various locations.

Lesion	Effect
optic Nerve	blinds the eye
optic chiasma	heteronomous bitemporal hemianopia
optic tract	contralateral homonymous hemianopia
optic radiation (lower part within temporal lobe)	contralateral superior homonymous quadrantinopia
(cuneus) gyrus (or) (superior part of optic radiation within parietal lobe)	contralateral inferior homonymous quadrantinopia

optic Principles ← Same as those of any camera
image that is formed is upside down (inverted)
turned left to right (reversed)

Light falling on the rods & cones of the retina (1st order neurons of the visual pathway) triggers a photochemical reaction in these cells — initiates nerve impulses → bipolar cells of retina (2nd order neurons) → ganglion cells (3rd order neurons) → axons converge toward the optic disc to form the optic nerve → pierce the sclera of eyeball → optic chiasma (close to the pituitary gland) fibres from the nasal halves of each retina CROSS while those from the temporal halves of each retina run Without Crossing → optic tract → lateral geniculate body of thalamus (it is the thalamic centre for vision; fibres of optic tract Synapse here → Cells of the geniculate bodies give rise to fibres which form the geniculo-calcarine tract OR optic radiation which end on the visual cortex → (area 17) on either side of the calcarine fissure within the occipital cortex
Note from the diagram → The right visual cortex — area 17 — receive visual impulses from the Rt. half of each retina → Left half of each visual field



Peripheral retinal fibres occupy the anterior part while macular fibres occupy the posterior part

A lesion of the optic tract behind the chiasm disconnects fibers from one half of each retina. If the right optic tract is destroyed, visual function is lost in the right halves of both retinae. *The result, however, is not described in terms of the retinae, but with reference to the disturbance that is produced in the visual fields.* In this instance there is blindness for objects in the left half of each field of vision, a condition known as left *homonymous hemianopia.* Even though one optic tract has been completely interrupted, vision is sometimes preserved in a small area at the fixation center, the area of the macula. Macular sparing cannot be explained anatomically, and opinions differ as to its significance. Lesions which destroy the entire visual area of the right occipital lobe, or all of the fibers of the right optic radiation, will also produce left homonymous hemianopia. Visual acuity of the parts of the retinae whose functions remain is not affected, and the patient may not be aware of the presence of hemianopia.

The *cuneus,* which is the gyrus above the calcarine fissure, receives visual impulses from the dorsal, or upper halves, of the retinae; the *lingual gyrus,* below the calcarine fissure, receives impulses that arise from the ventral, or lower halves. Thus a lesion that is confined to the right lingual gyrus cuts off visual impulses from the lower part of the right half of each retina. This produces a loss of vision in one quadrant, rather than hemianopia. Since the images which are focused on the lower part of the retina come from objects above the horizon line, there is, in this instance, an upper left quadrant defect (see Fig. 38). The visual impulses which go to the lingual gyrus travel in the ventral part of the optic radiation. Consequently, a lesion of the ventral fibers of the right optic radiation has the same effect as a lesion of the right lingual gyrus.

Lesions of the middle part of the optic chiasm are frequently produced by compression of these fibers from a tumor of the pituitary gland, or a craniopharyngioma which lies near the midline immediately behind the chiasm. The decussating fibers of the optic nerves are injured and visual impulses from the nasal halves of each retina are blocked. As a result, the left eye does not perceive images in the left half of its visual field, and the right eye does not record images in the right half of its field of vision. The defect is in the temporal field of each eye and is therefore called *heteronomous bitemporal hemianopia.*

Areas 18, 19

↓

Secondary (association) visual area

↓ function

① Recognition of what is seen

② connected to the frontal eye field (area 8) as well as with sup. colliculus → plays a key role in conjugate eye movements induced by visual stimuli

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Stimulation of area 18, 19 → hallucination of formed image

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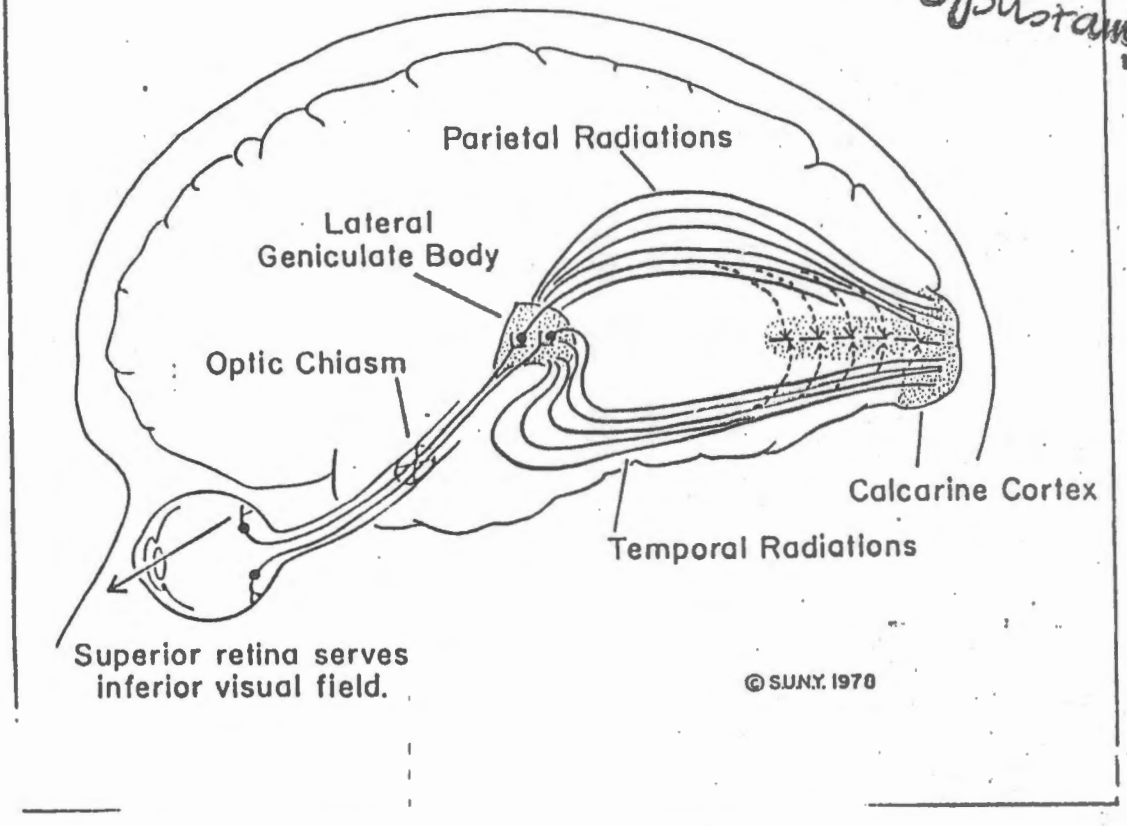
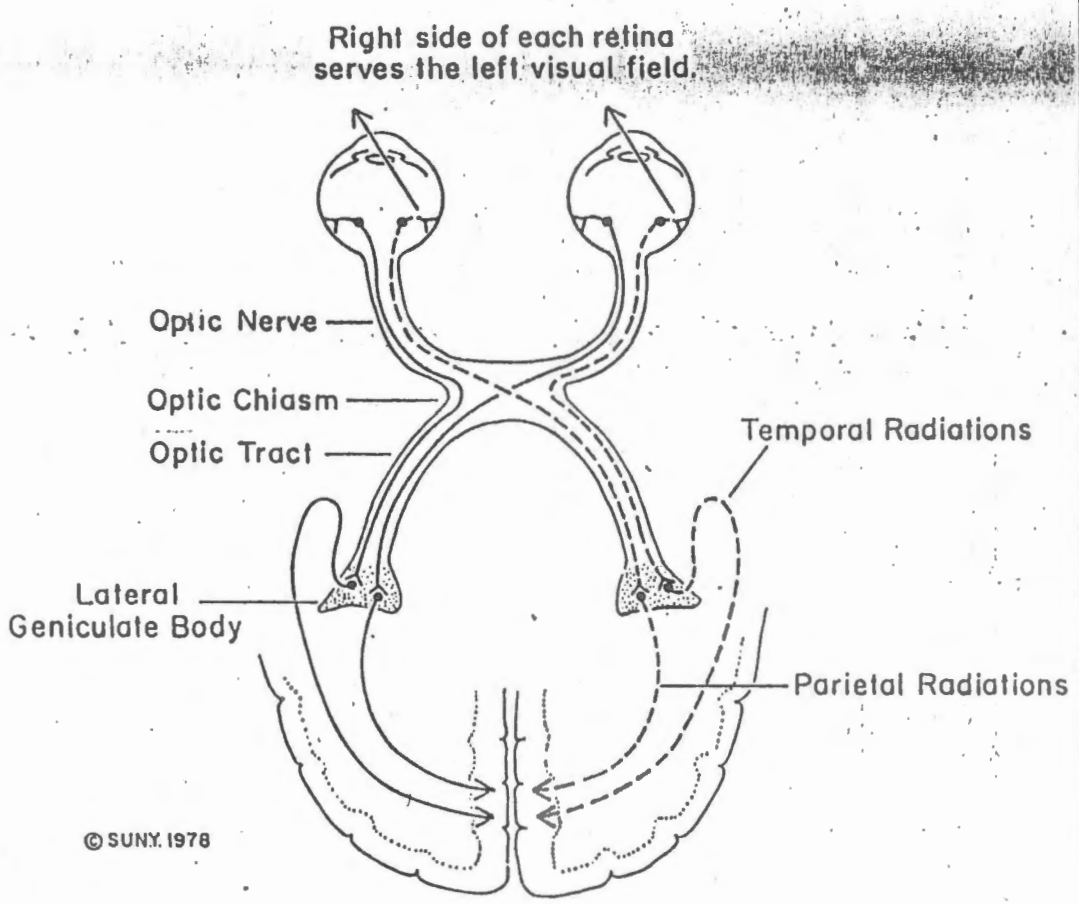
ablation (destruction) of area 18, 19 → visual agnosia (Patient is able to see objects but is unable to recognize them).


Parietal Radiations
Lateral
Geniculate Body
Optic Chiasm
Calcarine Cortex
Temporal Radiations
Superior retina serves
inferior visual field.
© SUNY. 1978


Right side of each retina
serves the left visual field.
Optic Nerve
Optic Chiasm
Optic Tract
Temporal Radiations
Lateral
Geniculate Body
Parietal Radiations
© SUNY. 1978

Ganglion cells of Retina

- Anatomically → Large alpha in peripheral retina; medium sized beta in central retina
- Location → in peripheral retina / in central retina
- input → mainly from rods / mainly from cones
- physiologically → correspond to Y cell also called M cell / ..... to X-cell also called P cell
  - connect to large cells in Magnocellular layers (layers 1+2) of LGB
  - connect to smaller parvocellular layers (layers 3–6) of LGB
- show On or off Centre–Surround pattern
- responsive to Colour Stimuli

Centre responds to one colour & the surround responds to the colour opposite it on a colour wheel e.g. an X-cell may have a Yellow-responsive centre & a blue responsive surround

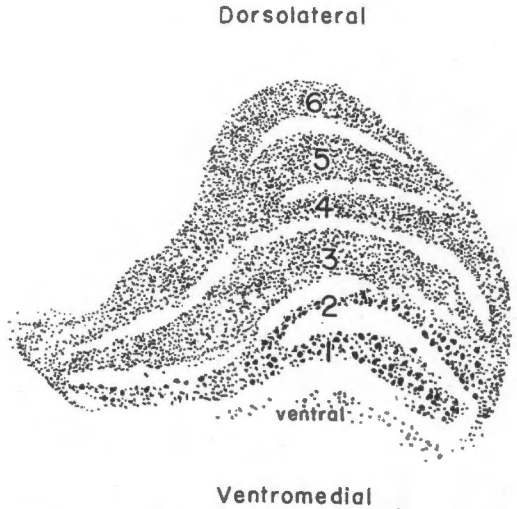


FIG. 9-16. Drawing of the cellular lamination of the lateral geniculate body. Laminae *1* and *2* constitute the magnocellular layers; the ventral nucleus is shown below. Crossed fibers of the optic tract terminate in laminae *1, 4* and *6;* uncrossed fibers terminate in laminae *2, 3* and *5*. (From Carpenter, *Human Neuroanatomy*, 1976; courtesy of The Williams & Wilkins Company.)

Ipsilateral and Contralateral Layers

The ganglion cell axons that arise in the *temporal* retina remain uncrossed as they pass through the chiasm and terminate in layers 2, 3, and 5 of the *ipsilateral* lateral geniculate nucleus. On the other hand, the axons that arise in the *nasal* retina cross in the chiasm and terminate in layers 1, 4, and 6 of the *contralateral* lateral geniculate (Fig. 20-9).

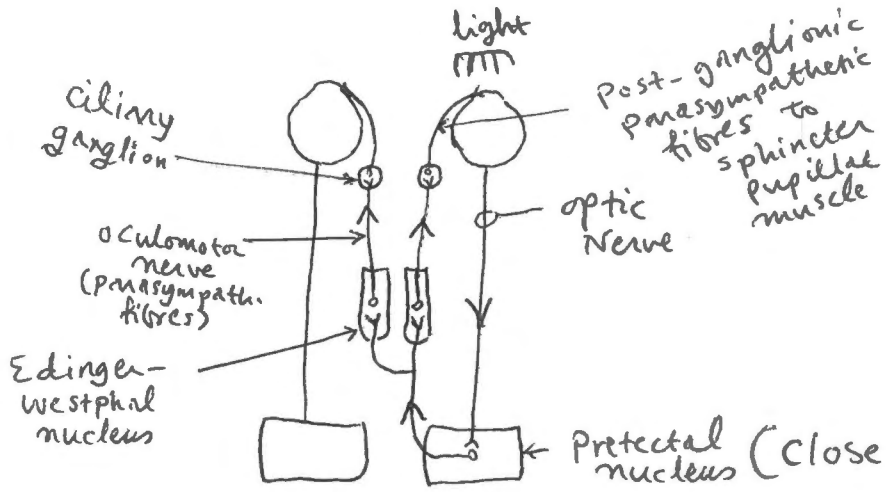
Recall → the Y(M) ganglion cell:

1. Receive their input mainly from RODS
2. have large receptive fields & thick rapidly conducting axons
3. Particularly sensitive to MOVING STIMULI

the X(P) ganglion cells

1. Receive input mainly from Cones
2. have small receptive fields & slower-conducting axons
3. tonically responsive to Stationary Stimuli (fixed stimuli)
4. Arise mainly in the central retina ⟹ Responsible for high-acuity Colour Vision

Light reflex



Mustansiriyah

Afferent

optic Nerve → optic chiasma → optic tract → pretectal nucleus (close to superior colliculus)

Edinger-Westphal nucleus of BOTH sides → preganglionic Parasympathetic fibres to Both ciliary ganglia → post-ganglionic parasympathetic fibres to sphincter pupillae of both eyes

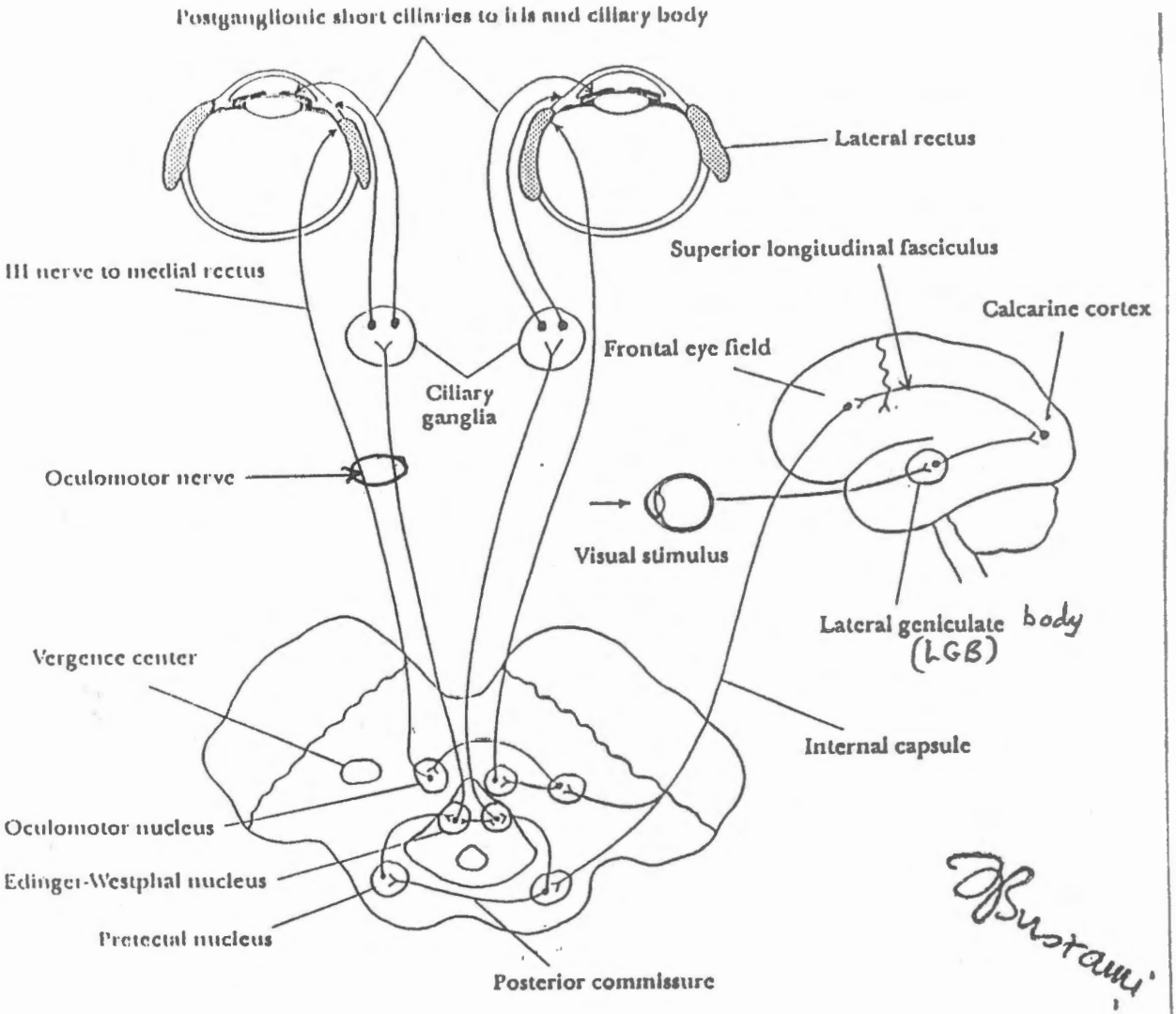
When light is thrown on one retina → BOTH pupils respond by constriction

- response of ipsilateral pupil → direct light reflex
- " " contralateral " → consentual "

* Lesion of optic Nerve → loss of both (direct, consentual) light reflex
* " " oculomotor → loss of direct light reflex
  → consentual light reflex is normal

The pathway for the accommodation-convergence reflex is thus different from that of the light reflex. This is supported clinically by a condition known as the Argyll Robertson pupil, in which the light reflex is lost while the accommodation-convergence reflex persists. The site of the lesion in this condition has not been established with certainty, but its etiology is known to be syphilis of the nervous system.

L → L



ACCOMMODATION REFLEX

Requires thickening of the lens, narrowing of the pupil, and convergence in order to see near objects clearly. The visual cortical stimulus relayed to the frontal eyefields is sent via the internal capsule to the pretectal nuclei and a midbrain tegmental reticular "vergence center". The pretectum organizes the required parasympathetic stimulus to the smooth muscle of the ciliary body and the iris through the Edinger-Westphal nucleus. The vergence center orchestrates bilateral stimulation of the medial recti (and inhibition of the lateral recti) through its connections with the MLF yoking sytem.

When the eyes are directed to an object close at hand, three different reflex responses are brought into cooperative action (Near-Point reaction)

1. Convergence: The medial recti muscles contract to move the eyes into alignment so that images in each eye focus on the same part of the retina. Otherwise the two images cannot be fused and diplopia will result.
2. Accommodation: The lenses are thickened as a result of Contraction of ciliary muscles in order to maintain a sharply focused image.
3. Pupillary Constriction: The pupils are narrowed as an optical aid to regulate the depth of focus. The constriction does not depend on any change in illumination and is separate from the light reflex.

* Central tegmental tract ⟹ conveys fibres from the basal ganglia and red nucleus (TO) → inferior olive → cerebellum

* 2 important nuclei are seen at the level of the inferior colliculus:

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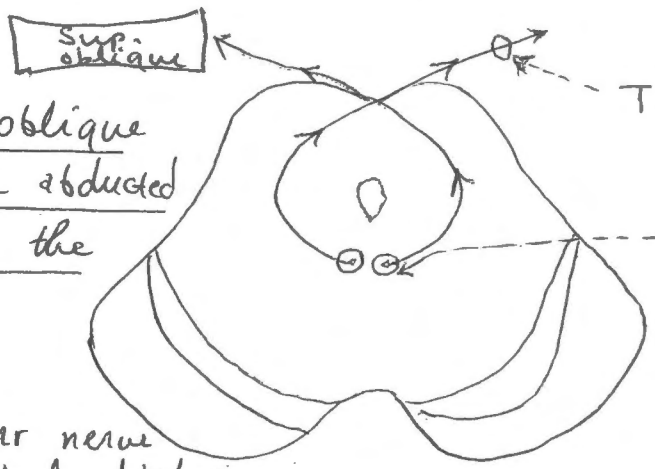
ⓐ Mesencephalic nucleus of trigeminal nerve

ⓑ Nucleus of the trochlear nerve → lies within the central gray matter. Axons of this nerve arch around the central gray → cross in anterior medullary velum → Emerg FROM DORSAL ASPECT OF MIDBRAIN

* The trochlear nerve is thus unique in two respects:

1. It is the only cranial nerve that emerges on the dorsal aspect of the brainstem
2. It is the only cranial nerve that crosses before emerging from brainstem.

* Because of decussation → lesion of the trochlear nucleus result in paralysis of the contralateral Superior oblique muscle, whereas lesion of the nerve after it emerges from the brainstem result in paralysis of the ipsilateral Superia oblique



Remember ⟹ the Sup. oblique acts by intorsion of the abducted eye & depression of the adducted eye

⇩

Patients with trochlear nerve lesion complain of Vertical diplopia especially when looking contralaterally down e.g descending stairs

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* The trochlear nucleus receives

- Bilateral cortical fibres
- Vestibular fibres from MLF concerned with coordination of eye movements

oculomotor nucleus → located dorsal to MLF at the level of the sup. colliculus

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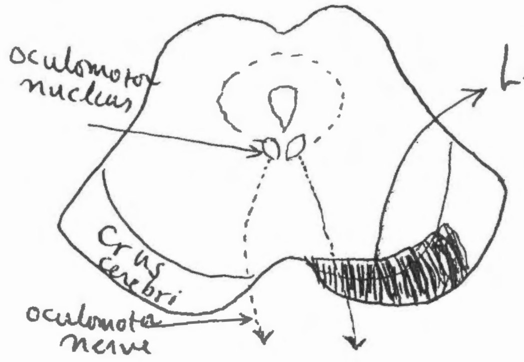
(11)

composed of

- lateral **Somatic** motor cell column
  - organized into subgroups for each of the extraocular muscles supplied by oculomotor nerve
  - Axons course through the tegmentum and emerge through the interpeduncular fossa medial to crus cerebri & run between the superior cerebellar artery and the posterior cerebral artery (important in relation to aneurysm) and supply
    - superior rectus
    - inferior rectus
    - medial rectus
    - inf. oblique
    - levator palpebrae superioris
  - Lesion of this component
    - (1) Downward & outward deviation of eyeball
    - +
    - (2) Drooping (Ptosis) of the upper lid

- medial **Visceral** cell column
  - includes
    - Edinger-Westphal nucleus → Concerned with light reflex
    - Nucleus of Perlia → concerned with accomodation → has not been identified in man
  - Axons of visceral cell column accompany those of somatic motor column as far as the orbit. In the orbit they part company and project to ciliary ganglion → Postganglionic fibres innervate
    - Sphincter pupillae m.
    - Ciliaris m.
  - (2) Smooth intraocular muscle
  - Lesion
    - (3) Dilated pupil
    - Unresponsive to light or accomodation



Lesion →
- ipsilateral (1)+(2)+(3)
- +
- contralateral upper motor neuron paralysis

* Alternating hemiplegia

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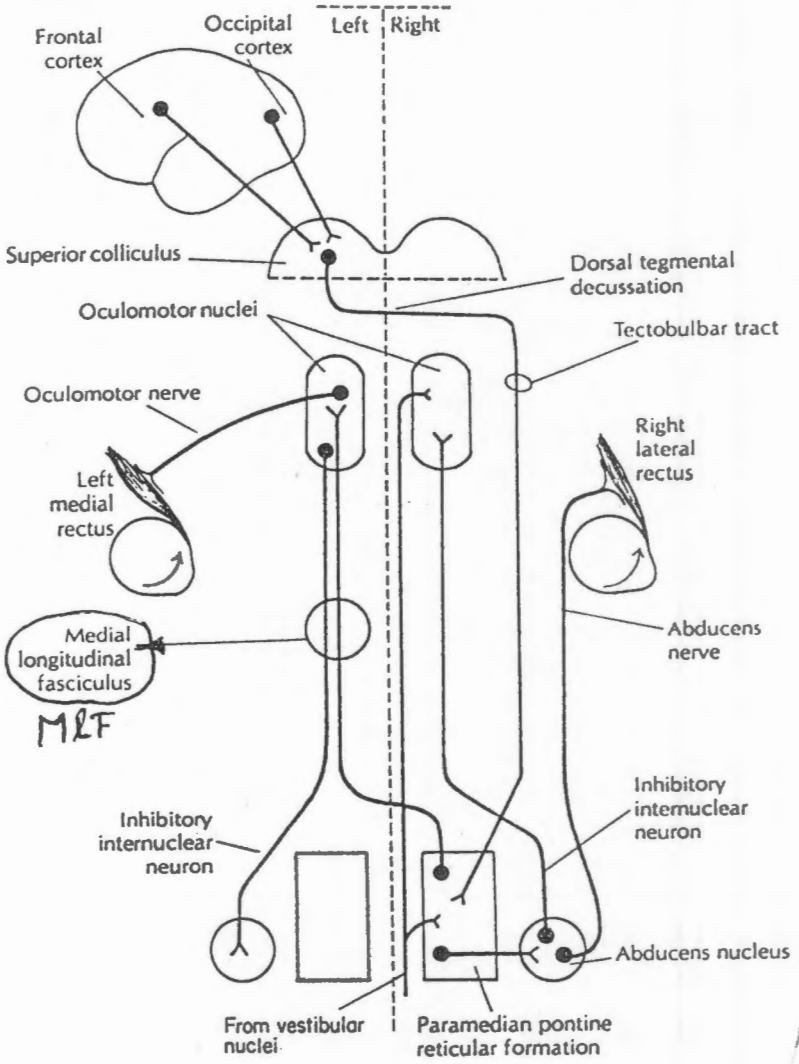
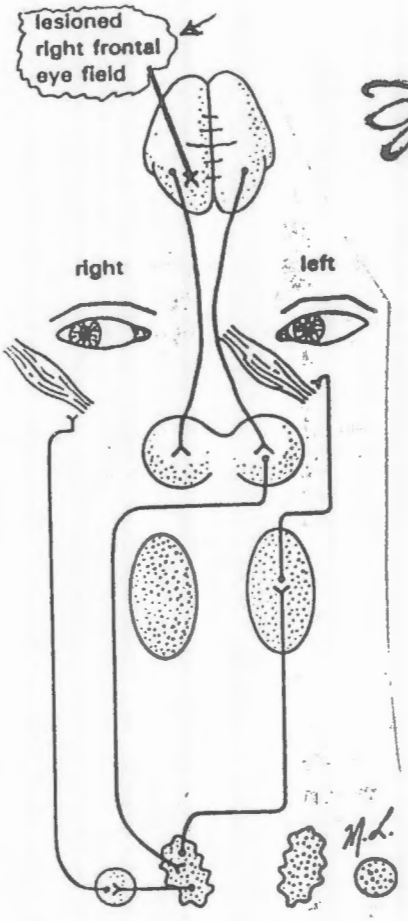
VOLUNTARY EYE MOVEMENTS

The area of the cerebral cortex that controls voluntary eye movements is the **frontal eye field**, located anterior to the motor cortex. Electrical stimulation of the frontal eye field results in conjugate deviation of the eyes to the opposite side. A destructive lesion there causes both eyes to deviate to the same side—looking away from the paralyzed side of the body if the motor cortex has been damaged by the same lesion. There are probably no direct corticobulbar fibers from any part of the cerebral cortex to the nuclei of cranial nerves III, IV, and VI. Instead, the voluntary control of eye movements is mediated by a polysynaptic pathway that involves the frontal cortex, superior colliculus, pretectal area, accessory oculomotor nuclei, and, finally, oculomotor, trochlear, and abducens nuclei (Fig. 8-4). (The





Right supranuclear ophthalmoplegia

PARALYSIS OF CONJUGATE LATERAL GAZE

Cortical Gaze Control

From frontal and occipital gaze control centers, the left side of the brain turns the eyes conjugately to the right. The frontal eye field initiates voluntary saccadic movements of the eyes ("Look to the right!"), while the occipital eye field initiates slower automatic pursuit movements ("Follow my finger!").

Ischemic stroke and cerebral hemorrhage are the most common causes for conjugate gaze paralysis because gaze paralysis from cerebral lesions only occurs immediately after acute lesions, disappears then, and can be revisualized only under special circumstances.

Internuclear Ophthalmoplegia

To understand so-called **internuclear ophthalmoplegia** one must recall certain information.

Three types of conjugate movement, i.e., convergent, parallel vertical, and parallel horizontal, were described previously.

The conjugate convergent as well as the vertical movements involve two pairs of nuclei that are situated close together, i.e., the oculomotor nuclei and the trochlear nuclei. The conjugate horizontal or lateral gaze movement involves a pair of nuclei which are far apart from each other, i.e., the abducens (right or left) and the oculomotor (left or right) (Fig. 13-7). It appears

1. that the cortical descending motor fibers stimulate the superior colliculus and that the superior colliculus sends fibers to a nucleus of the opposite side, i.e., the **parabducens nucleus,** which is located in the **paramedian pontine reticular formation (PPRF),** close to the abducens nucleus; and
2. that the parabducens nucleus stimulates the near-by abducens nucleus (concerned with the lateral rectus muscle) and also, through a path with other different fibers, the medial longitudinal fasciculus (MLF), the portion of the opposite oculomotor nucleus concerned with the medial rectus muscle.

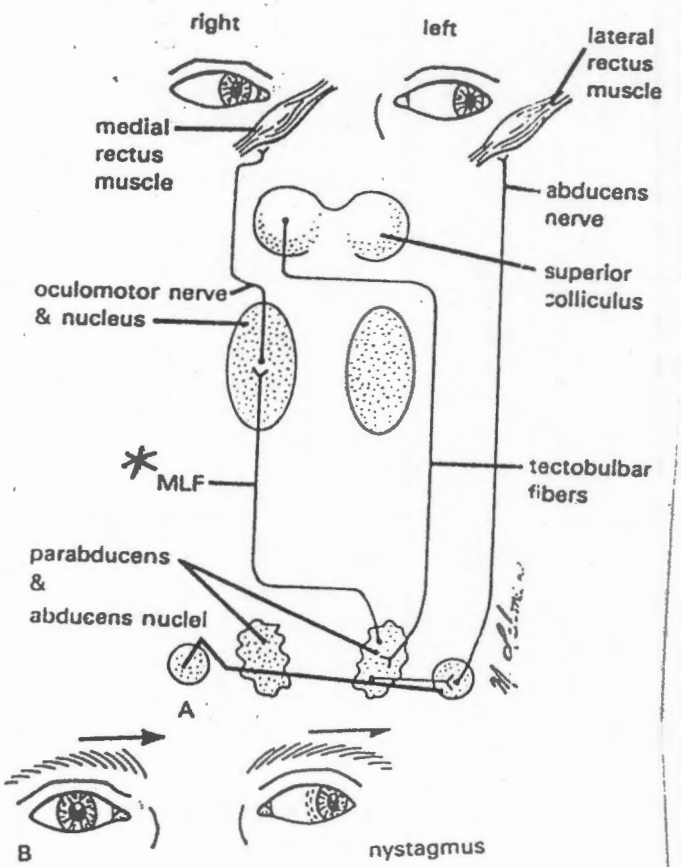


Fig. 13-7. (A) Pathway for lateral conjugate gaze; (B) right internuclear ophthalmoplegia.

A lesion of the MLF (affecting the path between the parabducens and oculomotor nuclei) produces internuclear ophthalmoplegia. The most common cause is multiple sclerosis.

If a lesion occurs in one MLF, e.g., the right MLF as in Figure 13-7, it is manifest when the patient tries to look laterally to the side opposite of the lesion. The medial rectus on the side of the lesion does not adduct; the abducting left eye moves laterally and displays **horizontal nystagmus** in **lateral gaze.** These signs of internuclear ophthalmoplegia are also known as **medial longitudinal fasciculus syndrome,** which usually is bilateral, affecting both MLF. This is an important syndrome as its verification pinpoints the causal lesion very precisely in a specific region of the brain stem, i.e., the region of the MLF in the upper pons between the abducens and oculomotor nuclei.

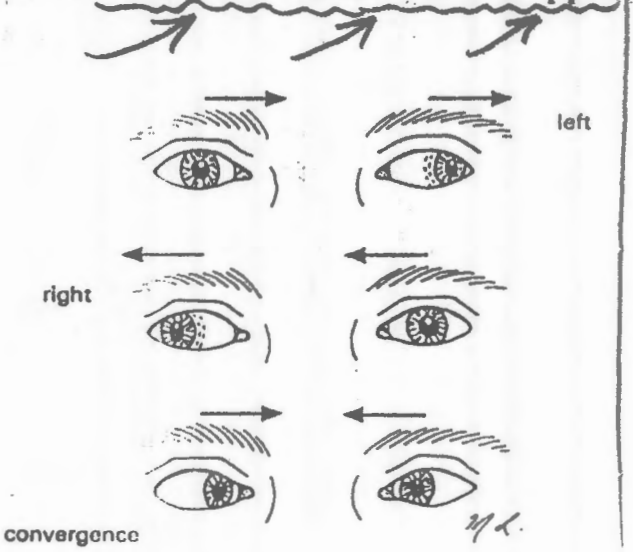
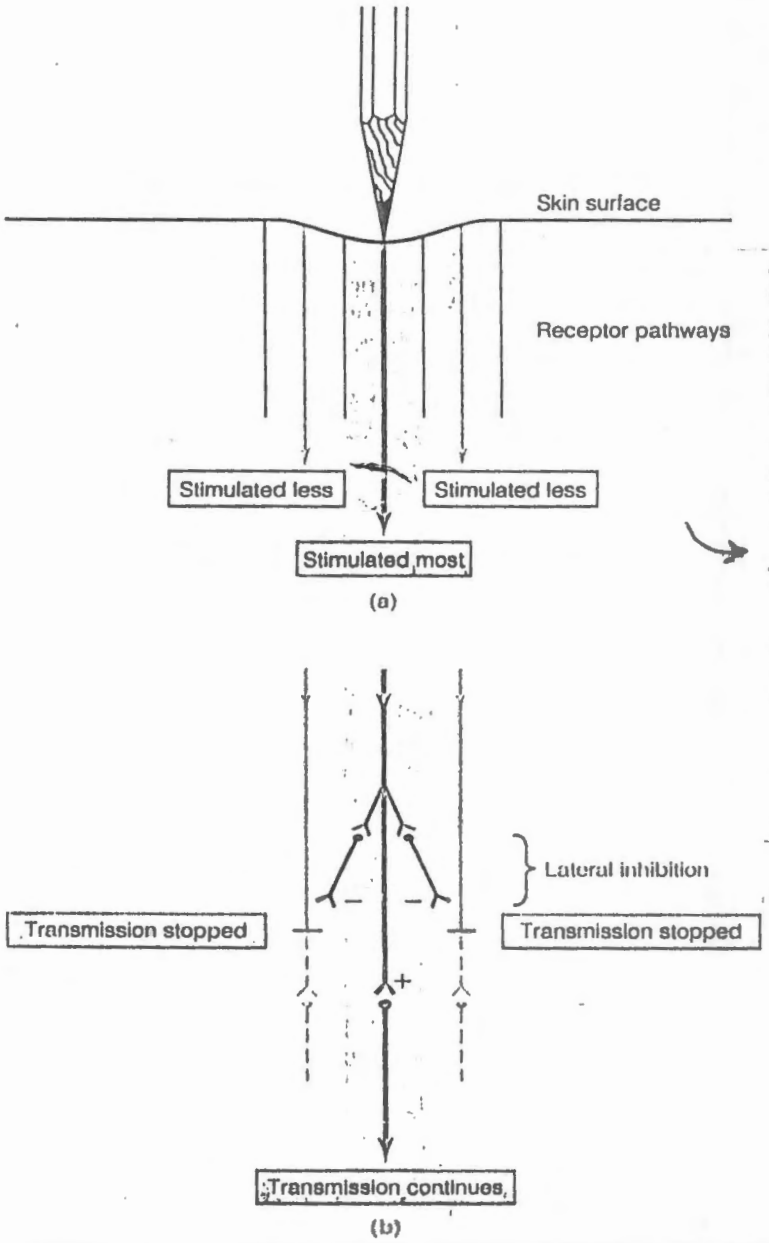


Fig. 13-8. Bilateral internuclear ophthalmoplegia.

A test to substantiate the diagnosis of internuclear ophthalmoplegia, when the described signs have appeared, consists in verifying that the patient is able to converge the eyes and make vertical movements of the eyes. A case of internuclear ophthalmoplegia affecting both MLF is illustrated in Figure 13-8.



• **FIGURE 6–7 Lateral Inhibition** (a) The receptor at the site of most intense stimulation is activated to the greatest extent. Surrounding receptors are also stimulated but to a lesser degree. (b) The most intensely activated receptor pathway halts transmission of impulses in the less intensely stimulated pathways through lateral inhibition. This process facilitates localization of the site of stimulation.

Besides receptor density, a second factor influencing acuity is **lateral inhibition**. You can appreciate the importance of this phenomenon by slightly indenting the surface of your skin with the point of a pencil (• Fig. 6–7a). The receptive field is excited immediately under the center of the pencil point where the stimulus is most intense, but the surrounding receptive fields are also stimulated, only to a lesser extent because they are less distorted. If information from these marginally excited afferent fibers in the fringe of the stimulus area were to reach the cortex, localization of the pencil point would be blurred. To facilitate localization and sharpen contrast, lateral inhibition occurs within the CNS (Fig. 6–7b). The most strongly activated signal pathway originating from the center of the stimulus area inhibits the less excited pathways from the fringe areas. This occurs via inhibitory interneurons that pass laterally between ascending fibers serving neighboring receptive fields. Blockage of further transmission in the weaker inputs increases the contrast between wanted and unwanted information so that the pencil point can be precisely localized. The extent of lateral inhibitory connections within sensory pathways varies for different modalities. Those with the most lateral inhibition—touch and vision—bring about the most accurate localization.

Properties of receptors

Receptors have the properties of adequate stimulus, excitability and adaptation.

(1) *Adequate stimulus* Each type of receptor is most sensitive to a specific form of energy, which is called its adequate stimulus, and is almost nonresponsive to the normal intensities of other forms of energy; e.g. light is the adequate stimulus for the rods and cones of the eyes but they do not respond to heat or cold (Fig. 17.10).

Pain receptors are not stimulated by a blunt object touching the skin, but they discharge as soon as the blunt object is pushed with enough force to damage tissues.

The sensation perceived as a result of stimulation of a receptor is called the *modality* of sensation. Thus, cold, warmth, touch and pain are different modalities of sensation.

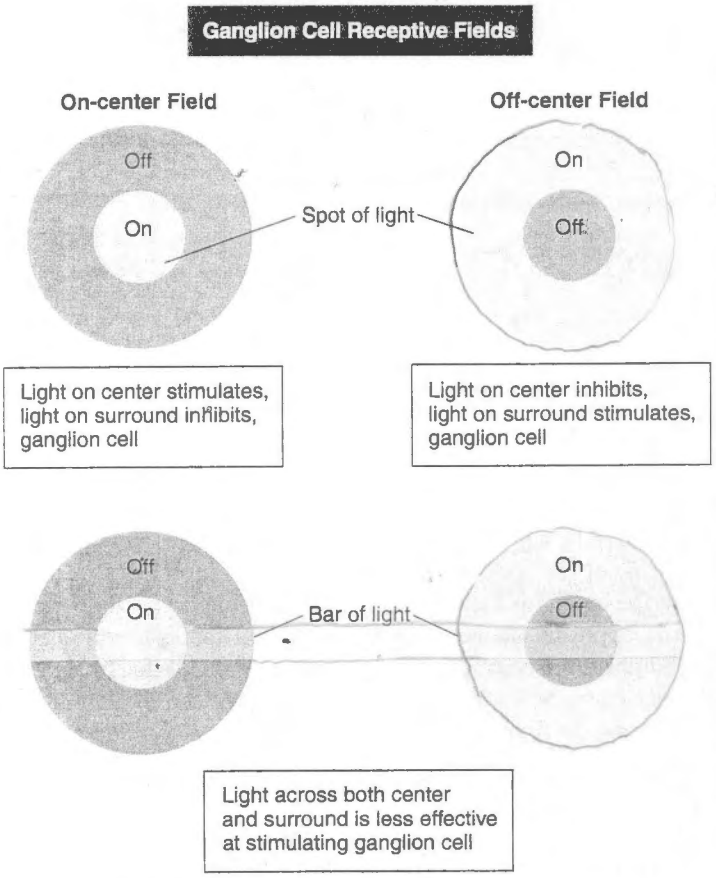


Figure 10.46 **Ganglion cell receptive fields.** Each ganglion cell receives input from photoreceptors in the retina that are part of the ganglion cell's "receptive field." Because of the antagonism between the field's center and its surround, an image that falls across the entire field has less effect than one that only excites just the center or surround. Because of this, edges of an image are enhanced, improving the clarity of vision.

What the Retina Tells the Brain

Ganglion cells are the retinal cells whose axons form the optic nerve, so their output is the final product of the information processing that occurs in the retina. The optimum stimulus for an ON center/OFF surround cell is a spot of light of the right size on a dark background. The optimum stimulus for an OFF center/ON surround cell is a dark spot on a white background. In some cases, the basic receptive field organization incorporates selectivity for colors. For example, a ganglion cell may be excited by a spot of green light on a red background but inhibited by a spot of red on a green background.

Each ganglion cell may send three different messages to the brain (Figure 10-27). A burst of action potentials constitutes a signal to the brain that most of the light falling on the cell's receptive field is on the excitatory part of the field. A decrease in the rate of action potentials means that most of the light falling on the receptive field is on the inhibitory part of the field. No change in the rate of action potentials means that light, if present, does not vary in intensity over its receptive field. In sum, the effect of lateral inhibition in the retina is to favor response to contrast in the visual field and to suppress response to uniformity, so the retina informs the brain of the locations of spots in the image where there is contrast, either of light intensity or of color.