

EYEBALL

The eyeball is formed of three coats :

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

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1
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B
Burstane

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 presents a circular canal called the sinus venosus sclerae (canal of Schlem) into which the aqueous 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 aqueous 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



- 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.

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 biconvex.
- lies between the iris and vitreous 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 equator. Some fibers of the ligament are attached to the equator and posterior surface close to the equator.

The suspensory ligament 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 (accommodation).

- { The elasticity of the lens begins to diminish after the age of forty years. *(Presbyopia)*
- The transparency of the lens begins to diminish in old people, a condition known as *cataract*.

Vitreous Body

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

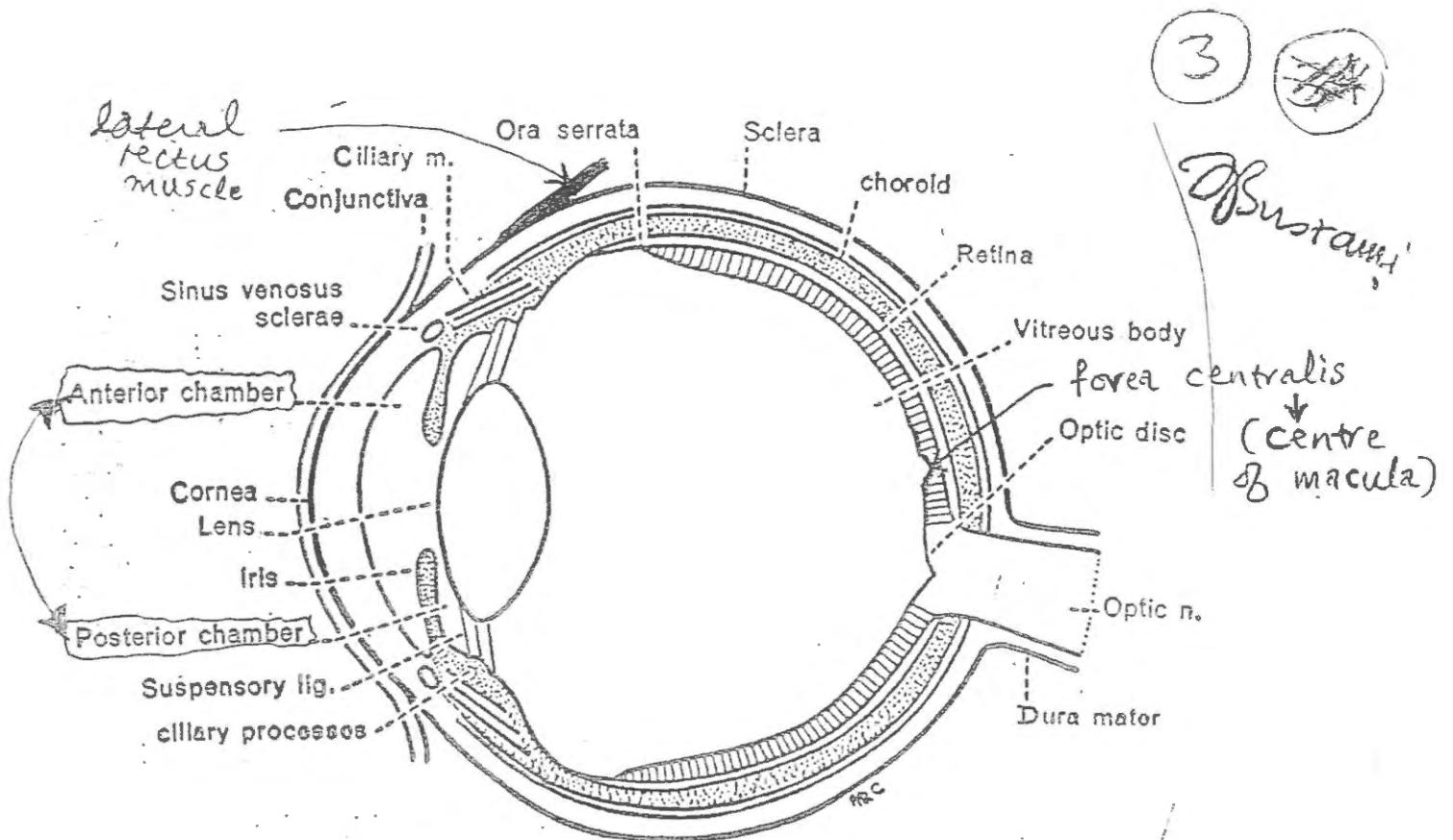
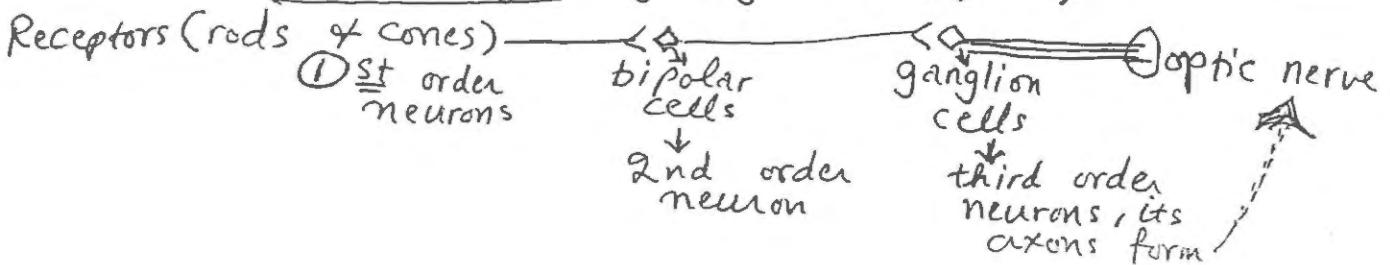


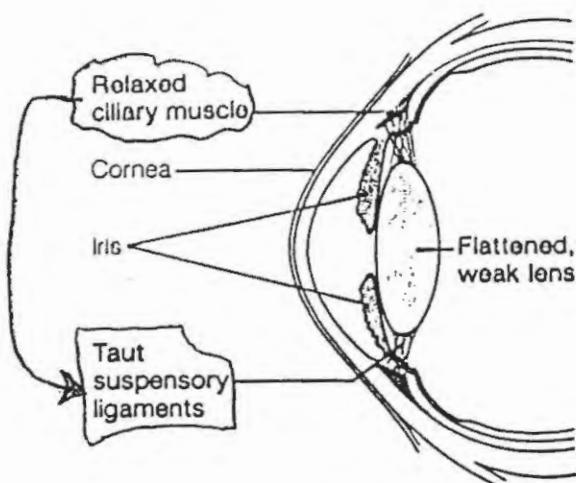
Fig. 174 Sagittal section of the eyeball.

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 ~~it will~~ 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 are

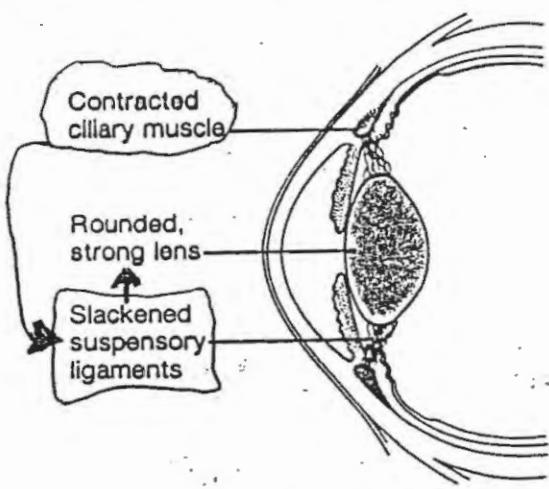


Obstacles

Obstacles



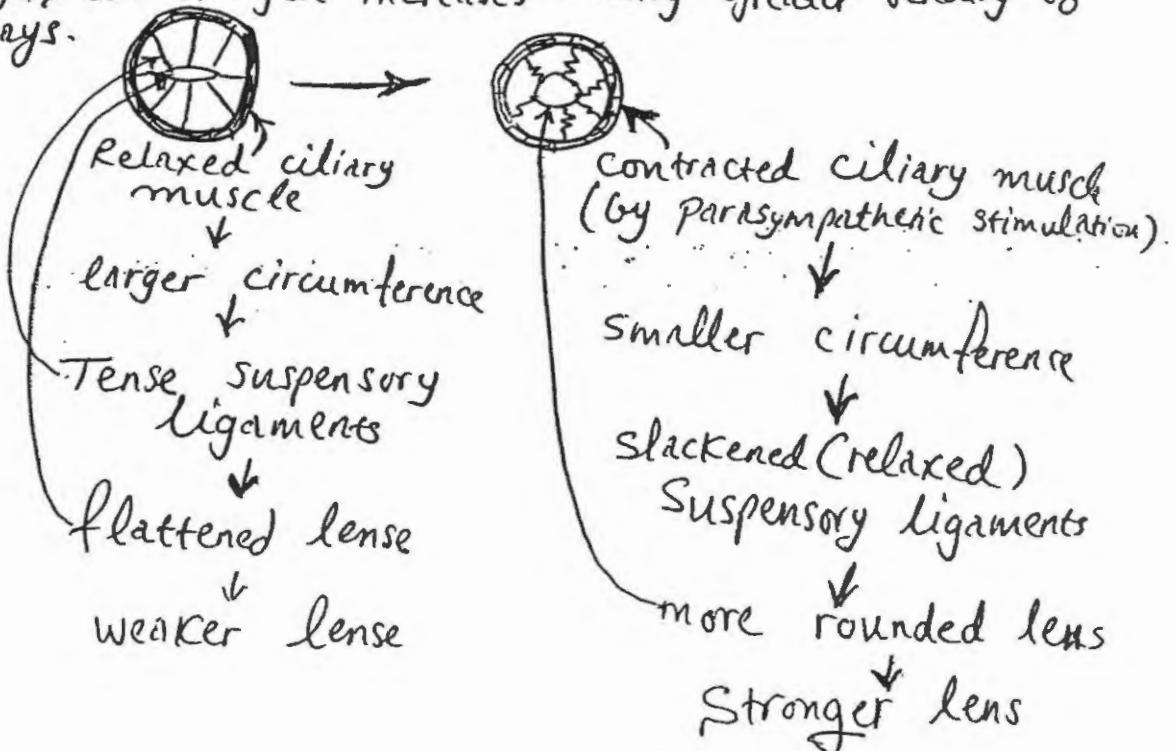
(b)



(c)

Accommodation \rightarrow 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 \rightarrow the suspensory ligaments are taut \rightarrow pull the lens into a flattened weakly refractive shape \rightsquigarrow As the muscle contracts its circumference decreases, relaxing the tension in the suspensory ligaments \rightarrow the lens becomes more spherical (more rounded) \rightarrow its strength increases causing greater bending of light rays.



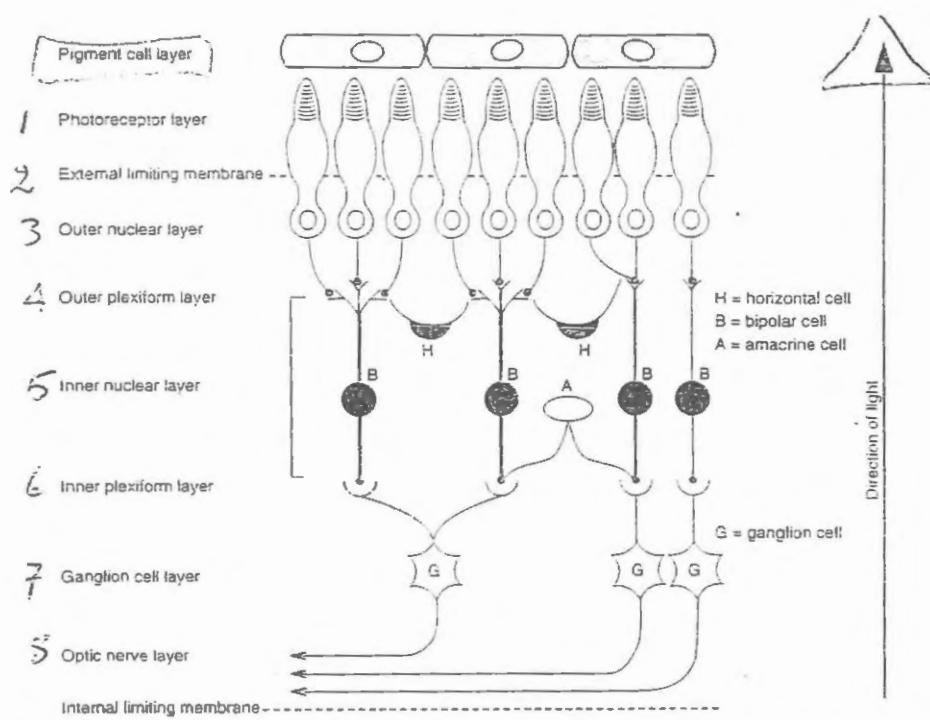


FIGURE 6-5. Organization of the retina. Photoreceptors converge on bipolar cells, which converge on ganglion cells. All of the receptors that convey information to a ganglion cell are part of that ganglion cell's receptive field.

- 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

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

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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).

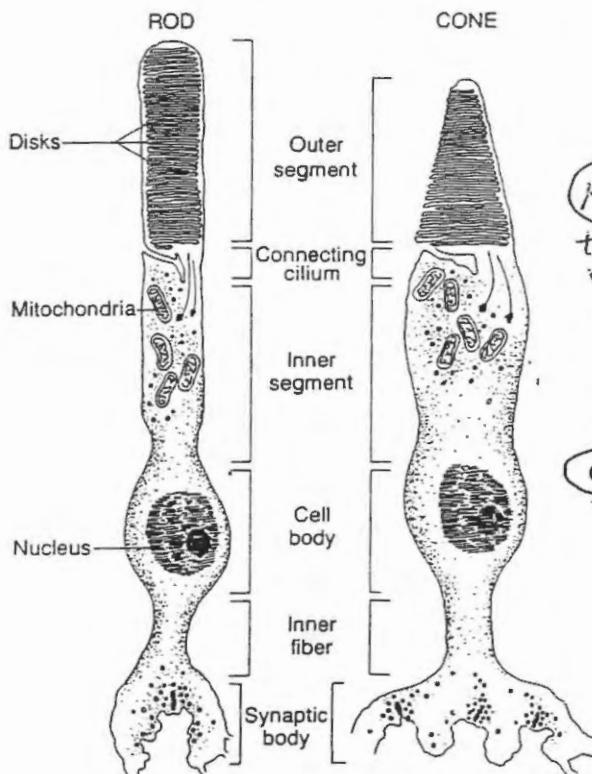


FIGURE 6-3. Morphology of rod and cone receptor cells. Cones, which are responsible for color perception and high visual acuity, are found in the fovea. Rods, which are responsible for night vision, are located in the peripheral retina.

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 day light high acuity (concentrated colour Vision in centre of retina) 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.

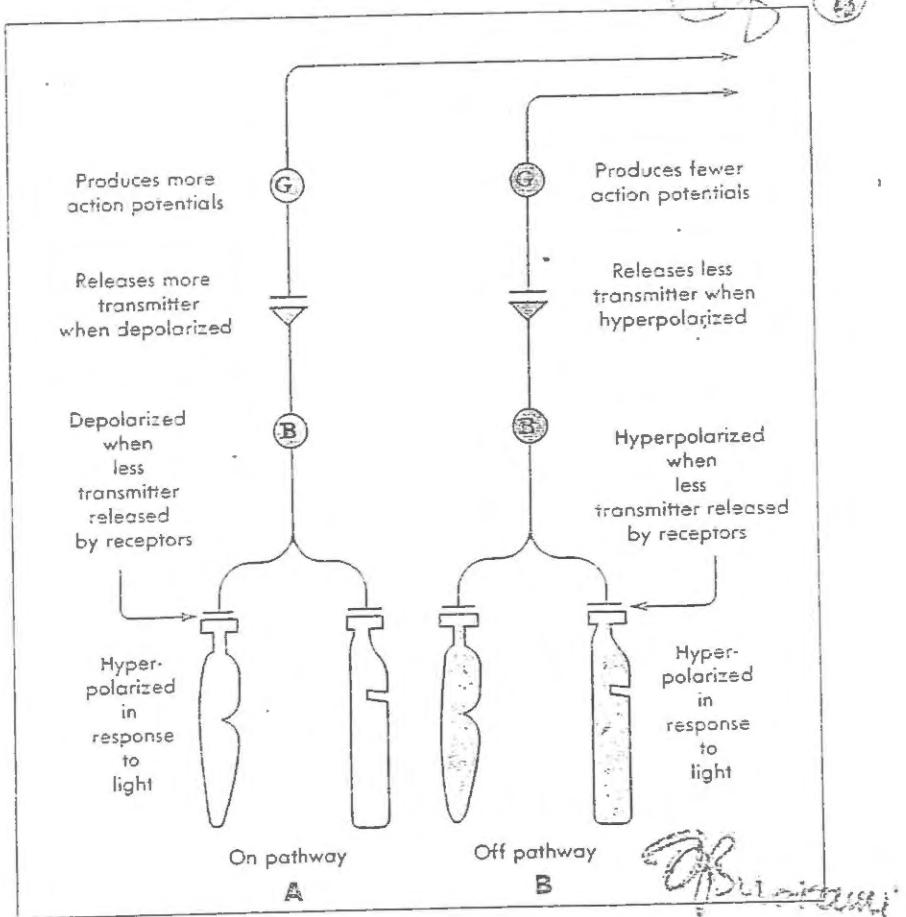
- a. Darkness. Rods and cones are depolarized in the dark. Their resting membrane potential is low, approximately -40 mV .
 - (1) The low resting membrane potential results from the high Na^+ conductance of the outer segment (see Figure 6-4A).
 - (a) Na^+ flows into the cell through Na^+ channels in the outer segment and is transported out of the inner segment by $\text{Na}^+ - \text{K}^+$ 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 $\text{Na}^+ - \text{K}^+$ 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 inactivation of the Na^+ channels, and hyperpolarization of the cell (see Figure

QUESTION

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.



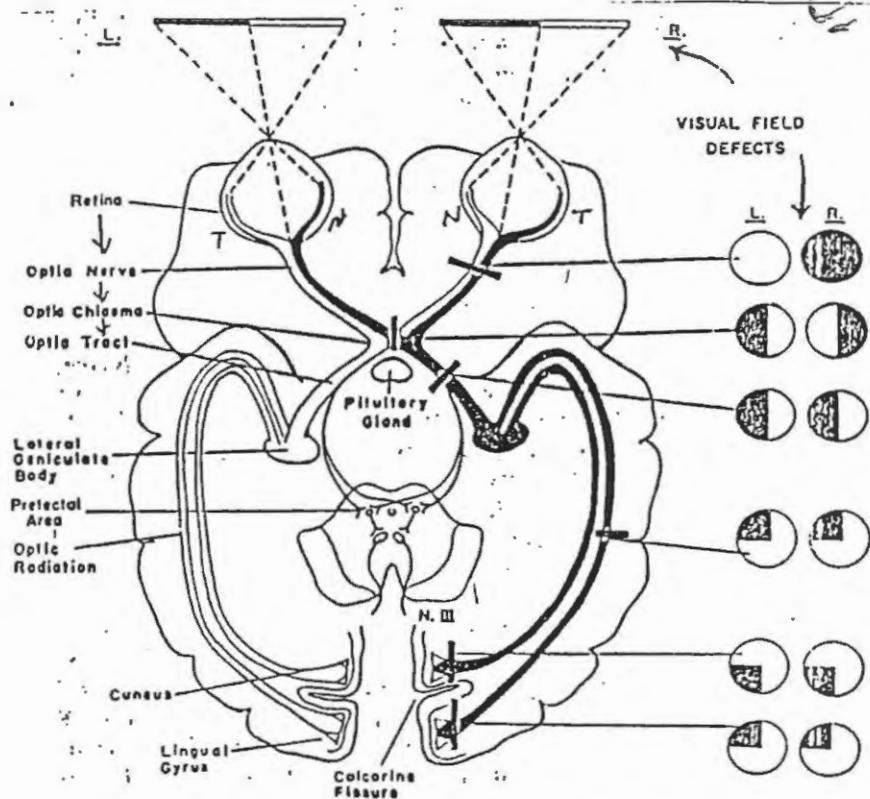
In the DARK → ganglion cells produce a low steady baseline rate of action potentials

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.

① Bipolar cells that are hyperpolarized by the photoreceptor transmitter in the dark become relatively depolarized when light excites the receptors and 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.

Obstetrics (5)

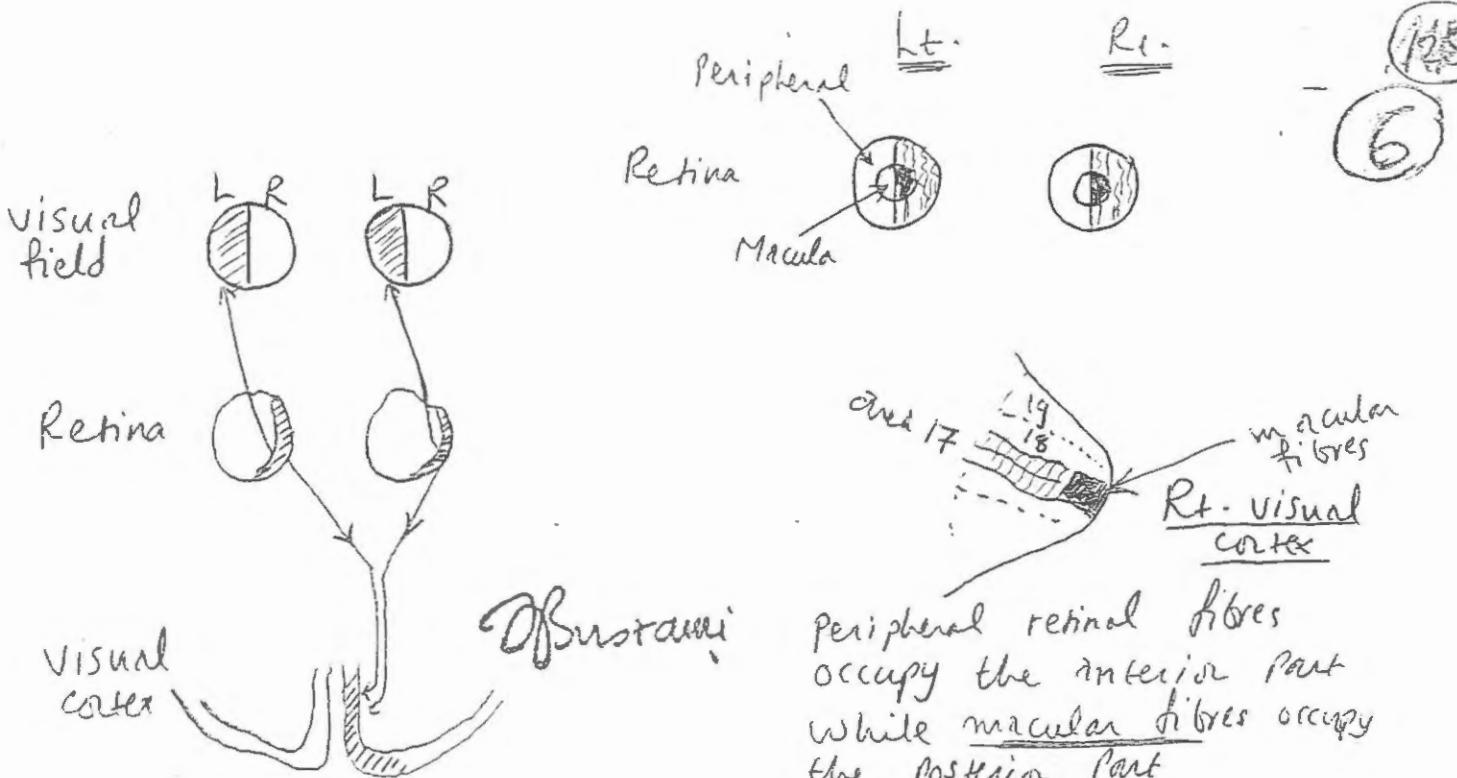


Lesion ↓	Effect
optic nerve	blinds the eye
optic chiasma	heteronomous bitemporal hemianopia
optic tract	contralateral homonymous hemianopia
optic radiation (lower part within) temporal lobe	contralateral superior temporal lobe homonymous quadrantanopia gyrus
superior part of optic radiation within parietal lobe	contralateral inferior homonymous quadrantanopia

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.

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 → 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 - receives 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

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

stimulation of area 18, 19
→ hallucination of formed image

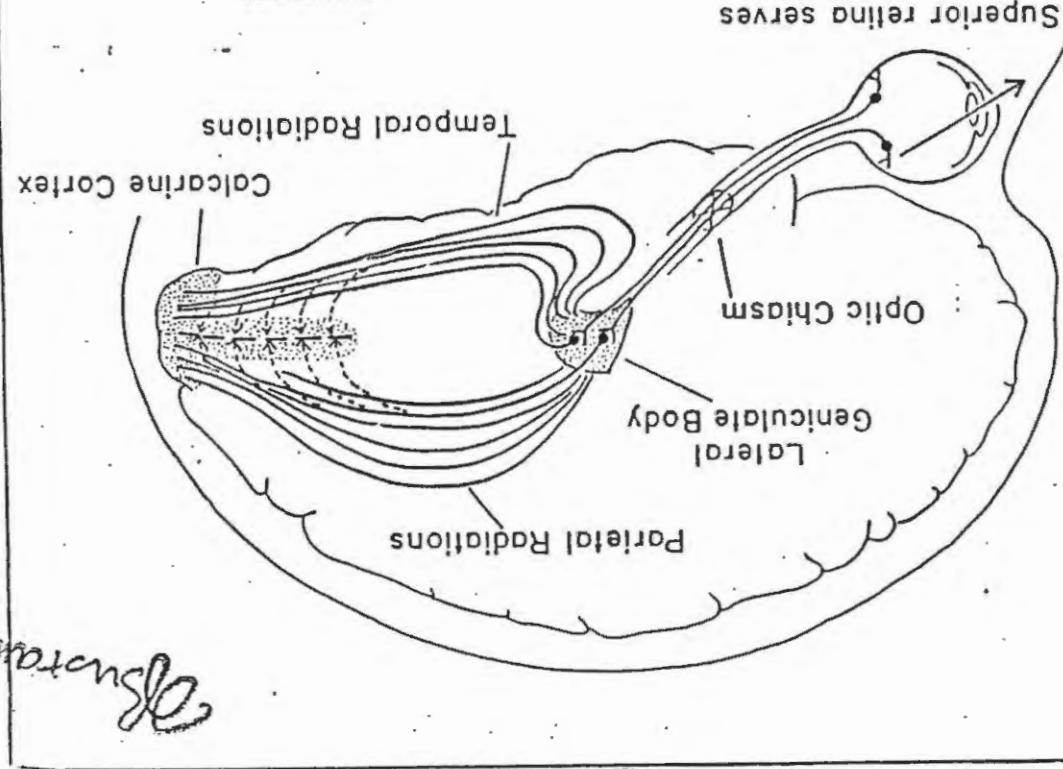
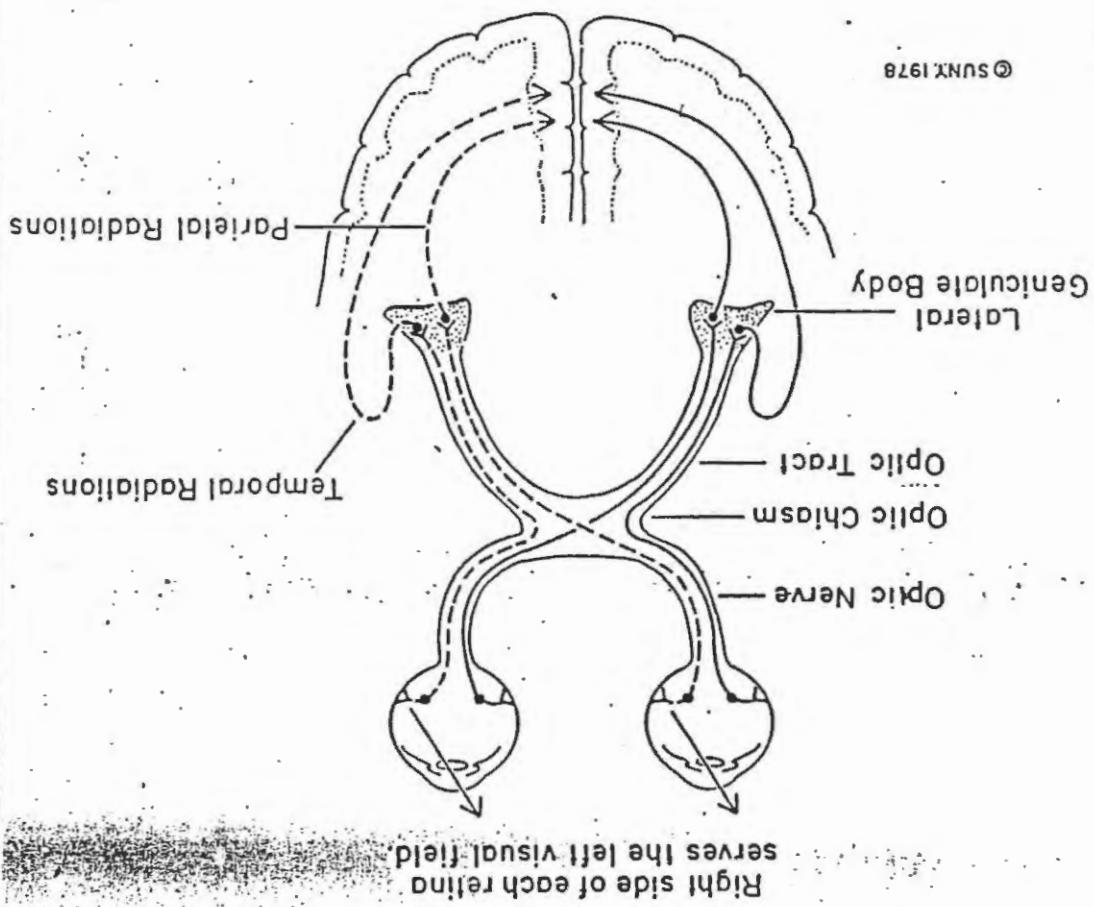
ablation (destruction) of area 18, 19
→ visual agnosia (Patient is able to see objects but is unable to recognize them).

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

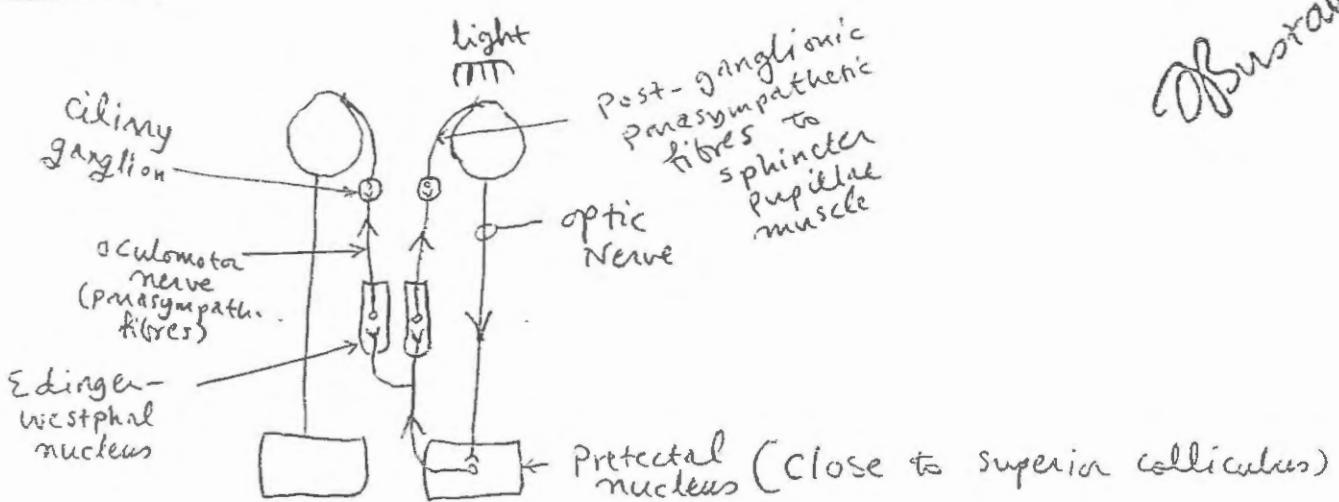
optic radiation, will also produce left homonymous hemianopia. Visual acuity of the parts of the retinae whose functions remain is not affected, and the patient may not be aware of the presence of hemianopia.

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.



Light reflex



Afferent

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

post-ganglionic
Parasympathetic
fibres to sphincter
pupillae of both
eyes

← Preganglionic
Parasympathetic
fibres to ←
Both ciliary
ganglia

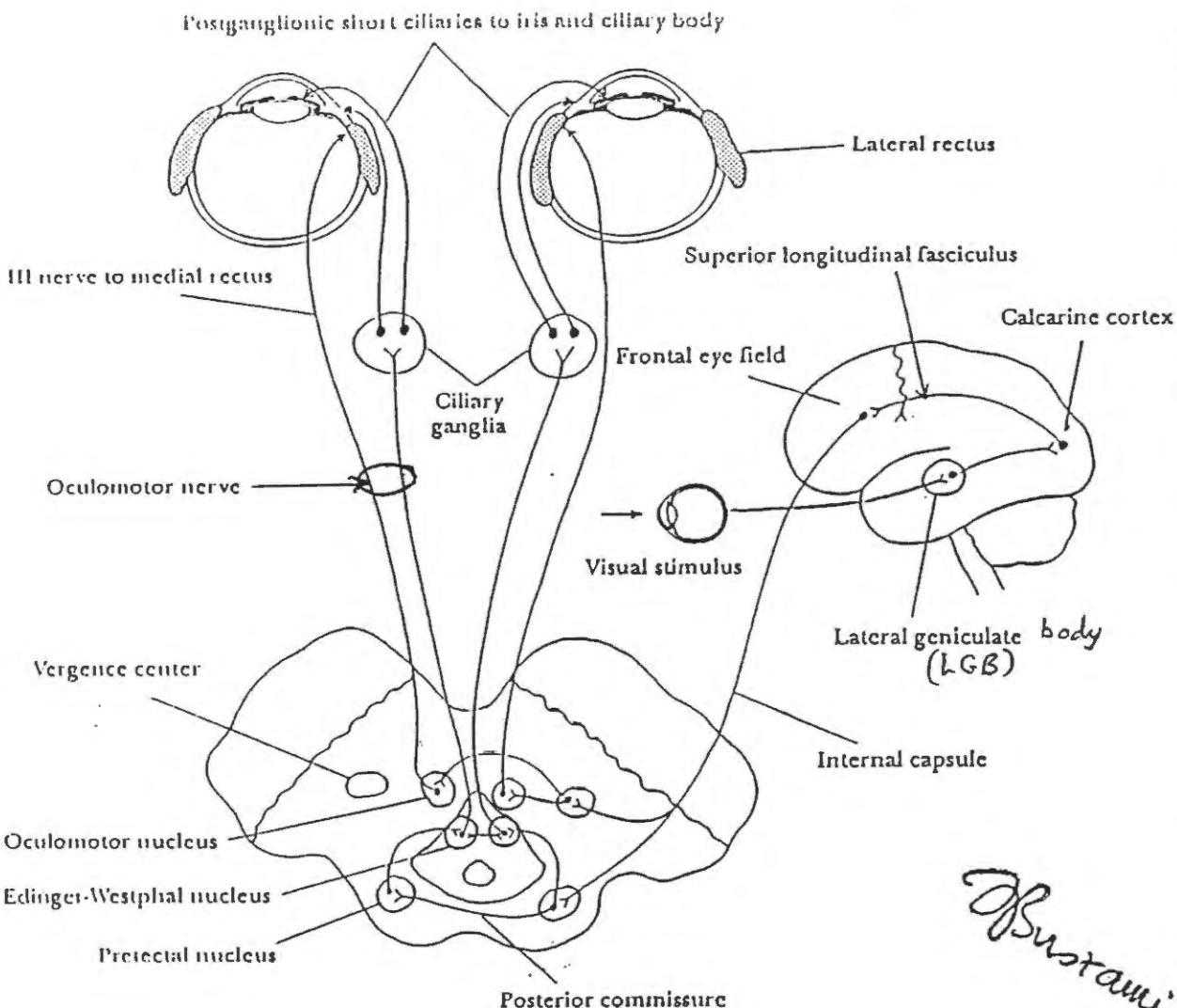
Edinger-Westphal
nucleus of BOTH
sides

When light is thrown on one retina → BOTH pupils respond by constriction < response of ipsilateral pupil → direct light reflex & contralateral → ^{reflex} consensual "

* Lesion of optic Nerve → loss of both < direct & consensual light reflex
* = oculomotor → loss of direct light reflex
consensual 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 eye fields is sent via the internal capsule to the preoptic nucleus and a midbrain tegmental reticular "vergence center". The preoptic 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 system).

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

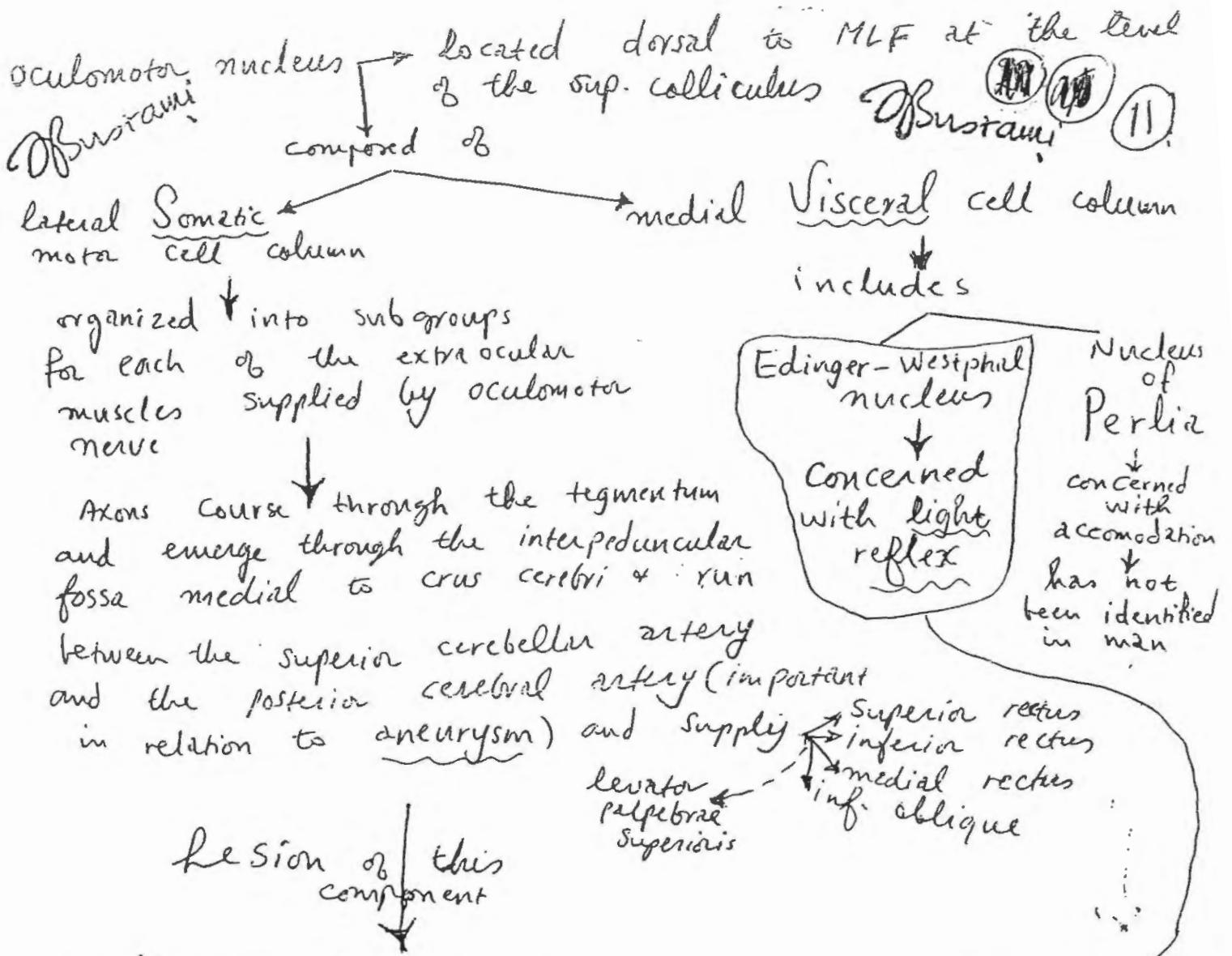
1. Convergence: The medial recti muscles contract to move the eyes into alignment so that images in each eye focus on the same part of the retina. Otherwise the two images cannot be fused and diplopia will result.
2. Accommodation: The lenses are thickened as a result of Contraction of ciliary muscles 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 \Rightarrow conveys fibres from the pretectal area and red nucleus (TO) \rightarrow inferior olive \rightarrow cerebellum
- * 2 important nuclei are seen at the level of the inferior colliculus: Obstansus Obtusans
- (a) Mesencephalic nucleus of trigeminal nerve
- (b) Nucleus of the trochlear nerve \rightarrow lies within the central gray matter. Axons of this nerve arch around the central gray \rightarrow cross in anterior medullary velum \rightarrow 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 \rightarrow 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 superior oblique



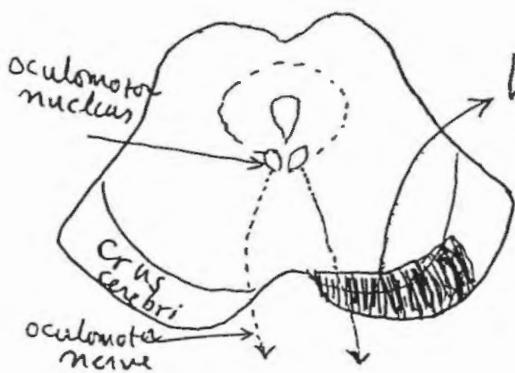
Patients with Trochlear nerve lesion complain of Vertical diplopia especially when looking contralaterally down e.g. descending stairs

- * The Trochlear nucleus receives bilateral contralateral fibres Vestibular fibres from MLF concerned with coordination of eye movements



① Downward & outward deviation of eye ball

② Drooping (ptosis) of the upper lid



- 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.
- ① Smooth introcular muscle
 - ② Alternating hemiplegia
 - ③ Dilated pupil Unresponsive to light or accommodation
- Olfactory

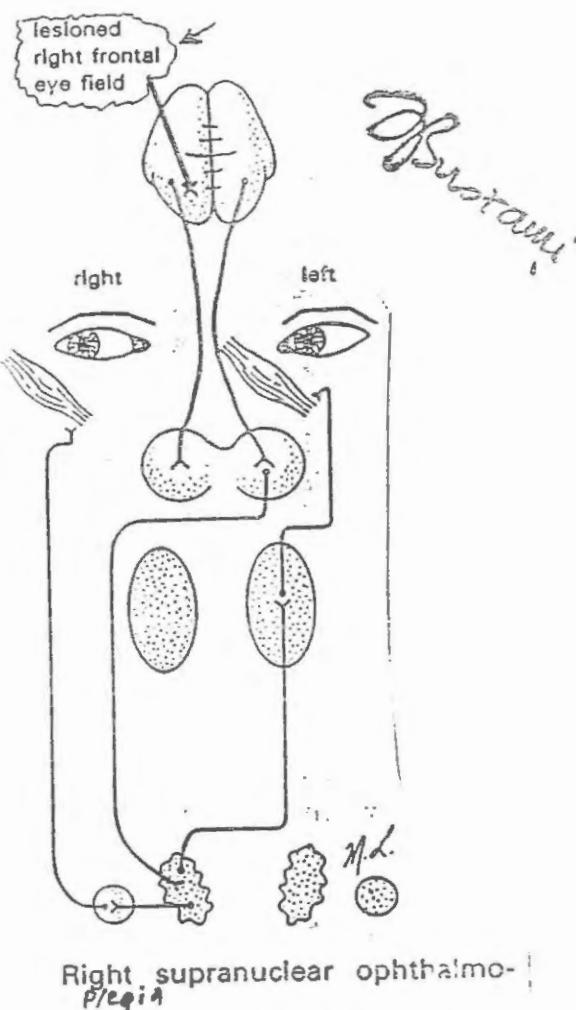
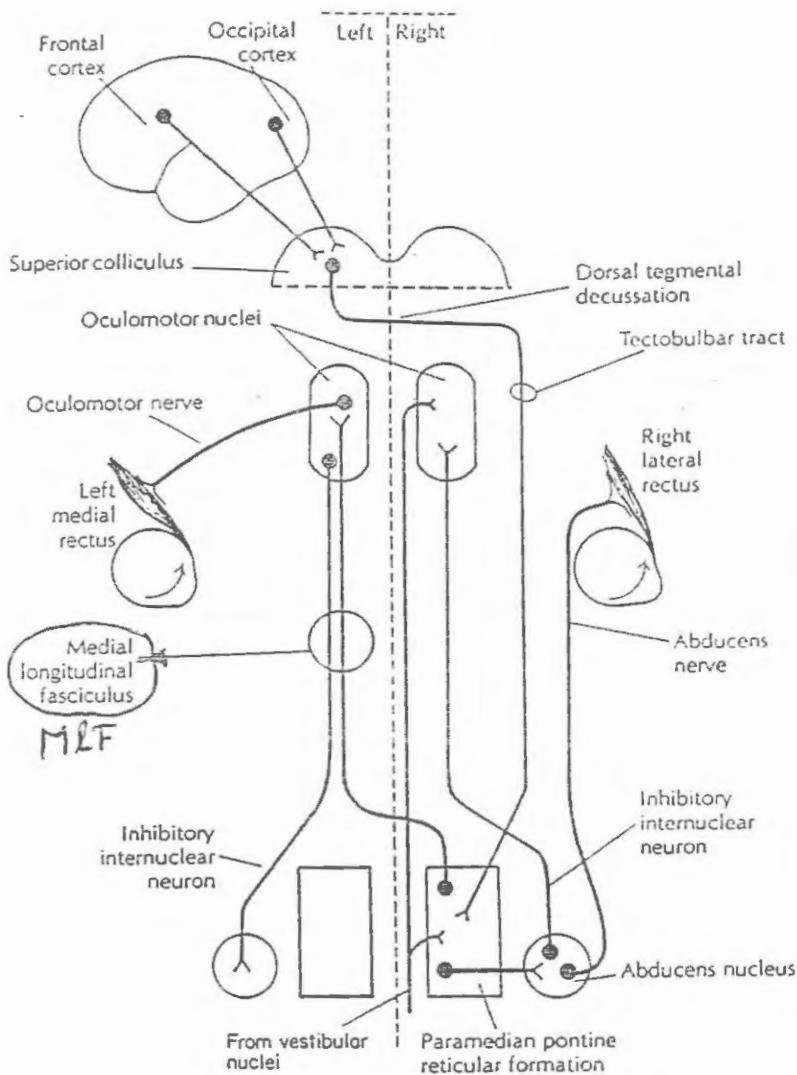
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VOLUNTARY EYE MOVEMENTS

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

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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

(3)

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

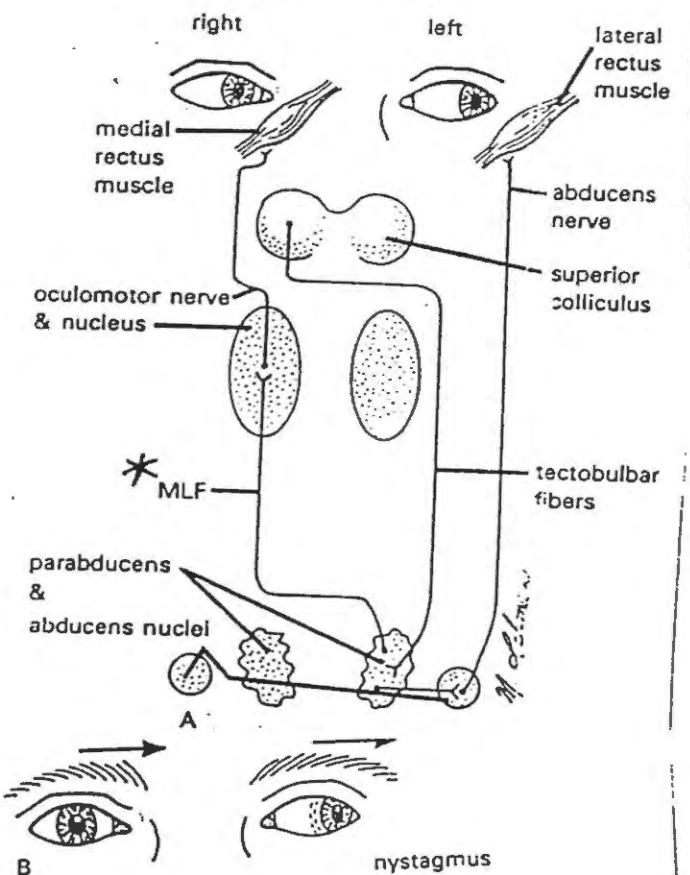


Fig. 13-7. (A) Pathway for lateral conjugate gaze; (B) right internuclear ophthalmoplegia.

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.

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

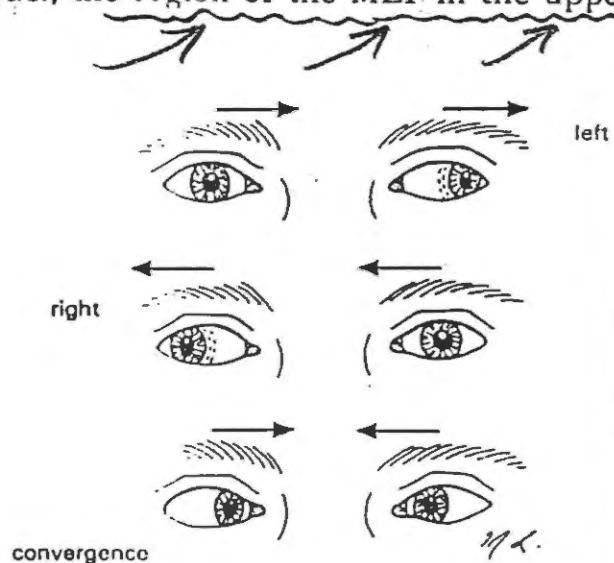
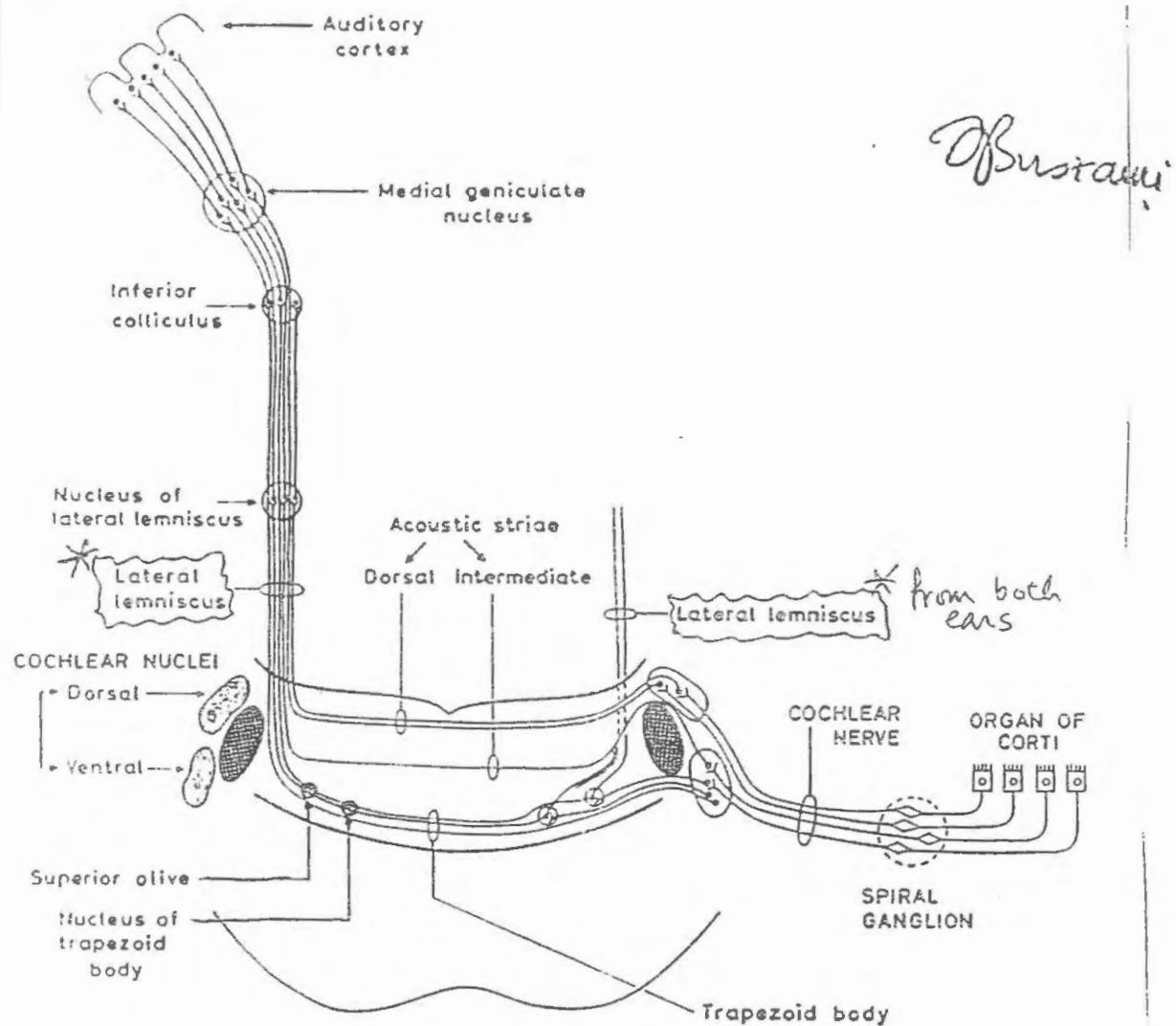


Fig. 13-8. Bilateral internuclear ophthalmoplegia.

pons between the abducens and oculomotor nuclei.

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.

OBSTRAUMI



Observe:

- (1)
- (2)
- (3)
- (4)

Figure 7.6. Schematic diagram of the auditory pathways.

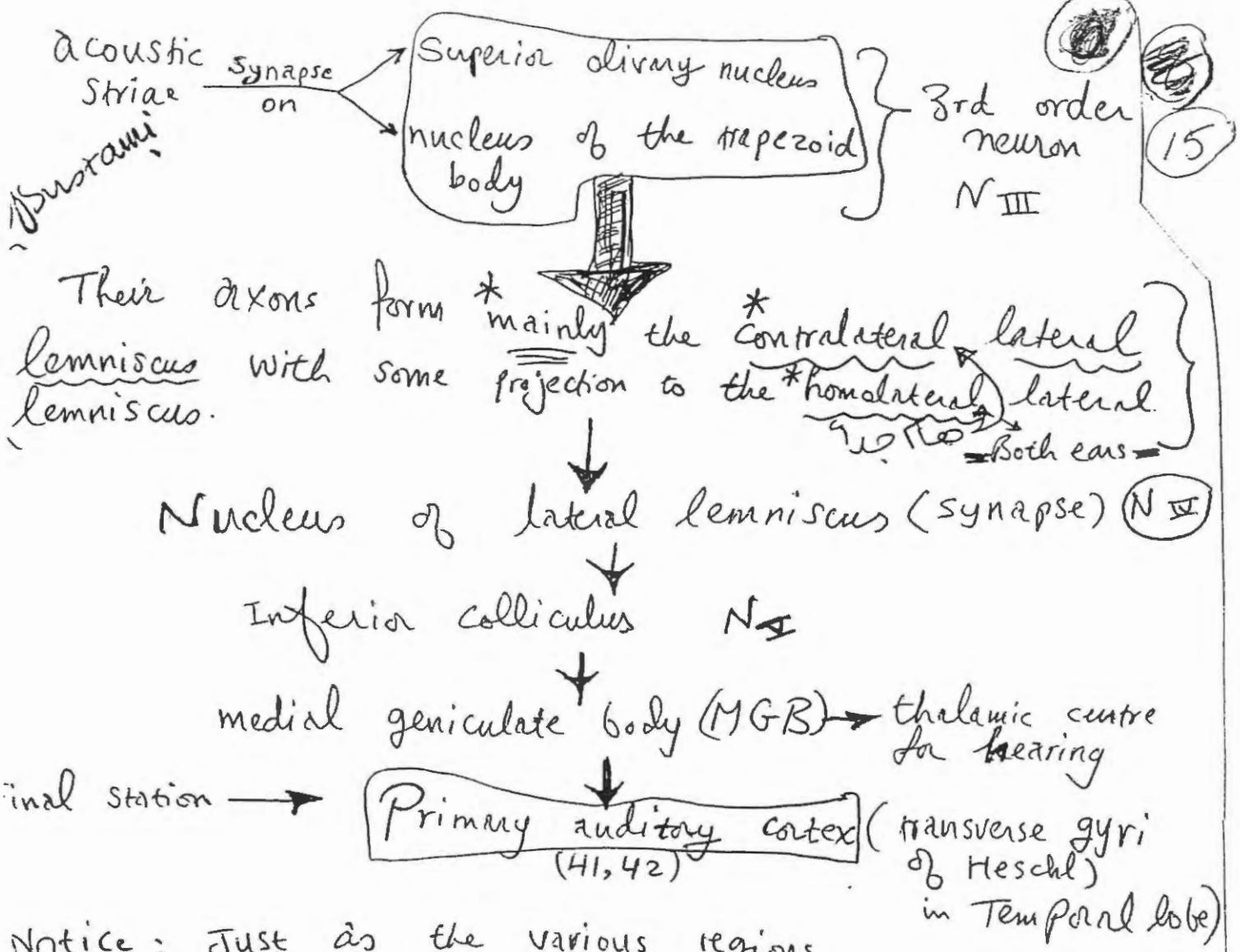
Nerve fibres in the cochlear nerve → central processes of bipolar neurons in the spiral ganglion (N I) located in the modiolus of the inner ear. The peripheral processes are linked to the hair cells of the auditory end organ in the organ of Corti.

cochlear nerve fibres Synapse on the cells of ^{dorsal}
^{ventral} ^{N II} cochlear nuclei

dorsal cochlear nuc. Receive fibres coming from basal turns of the cochlea mediating High frequency sounds whereas the ventral cochlear nucleus receive fibres from the apical turns of the cochlea mediating low frequency sound

Second order neurons (N II) from the cochlear nuclei run through the tegmentum of the pons forming the acoustic striae

- * DORSAL acoustic stria → formed by axons of neurons in the dorsal cochlear nucleus
- * Intermediate " " " → " " " " = =
- * Ventral " " " → " " " " = =

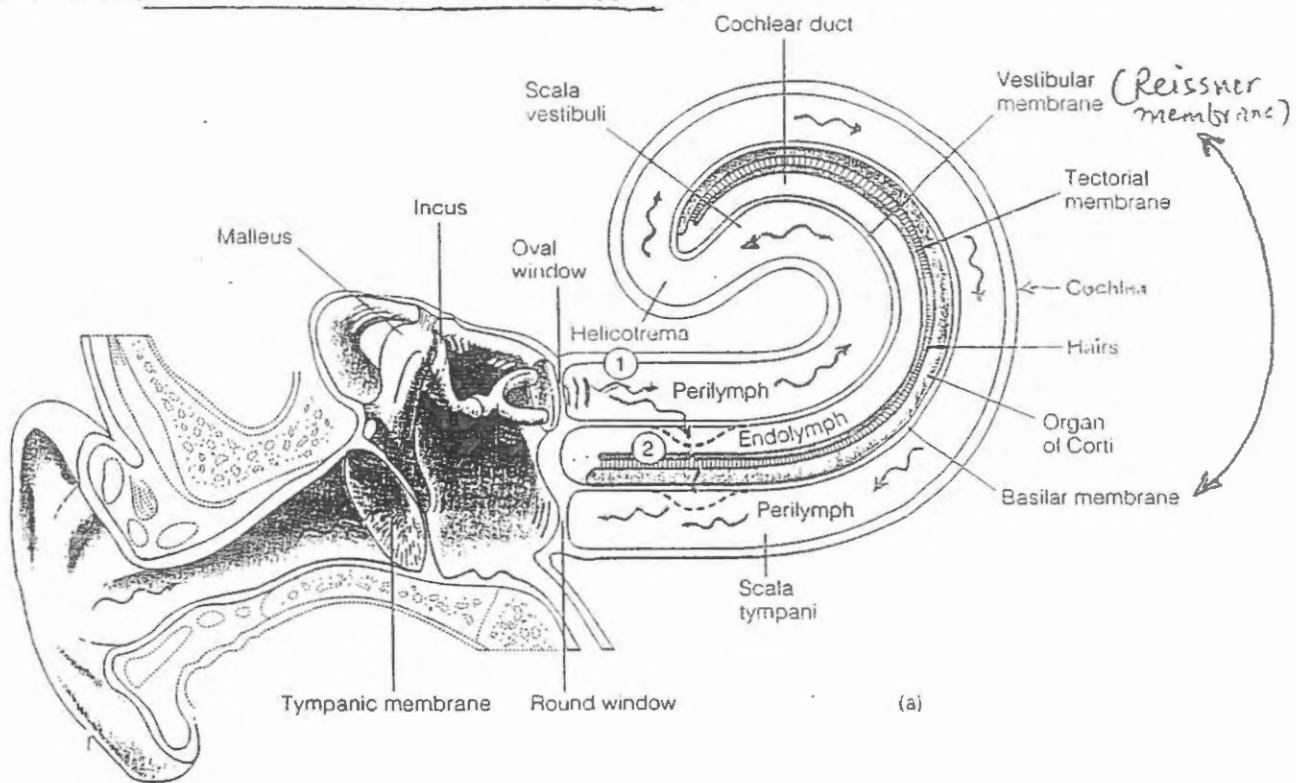


Notice: Just as the various regions of the basilar membrane are associated with particular tones → the auditory cortex is also TONOTOPICALLY organized ➡ Each region of the basilar membrane is linked to a specific region of the auditory cortex in the temporal lobe

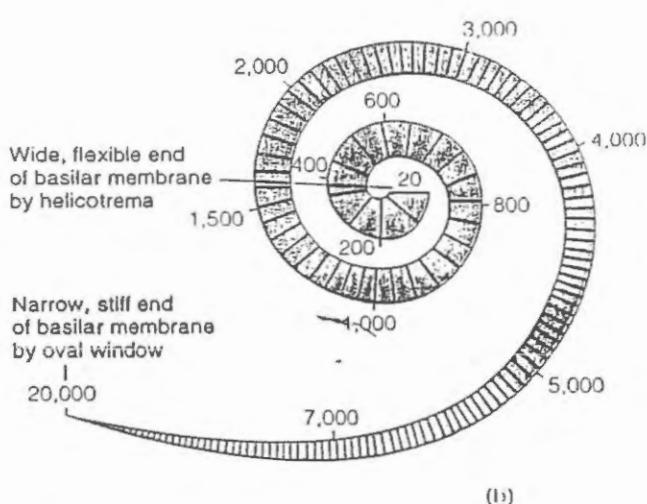
The Primary auditory cortex appears to perceive DISCRETE SOUNDS while the surrounding auditory association cortex (area 22) → INTEGRATES the SEPARATE SOUNDS INTO A COHERENT MEANINGFUL PATTERN

16 *Burstein* (b) (c)

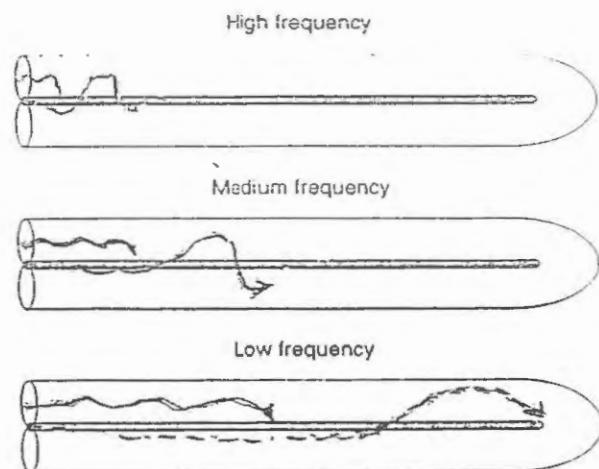
- **FIGURE 6-36 Transmission of Sound Waves** (a) Fluid movement within the perilymph set up by vibration of the oval window follows two pathways: (1) through the scala vestibuli, around the helicotrema, and through the scala tympani, causing the round window to vibrate; and (2) a "shortcut" from the scala vestibuli through the basilar membrane to the scala tympani. The first pathway just dissipates sound energy, but the second pathway triggers activation of the receptors for sound by bending the hairs of the hair cells as the organ of Corti on top of the vibrating basilar membrane is displaced in relation to the overlying tectorial membrane. (b) Different regions of the basilar membrane vibrate maximally at different frequencies. (c) The narrow, stiff end of the basilar membrane nearest the oval window vibrates best with high-frequency pitches. The wide, flexible end of the basilar membrane by the helicotrema vibrates best with low-frequency pitches.



(a)

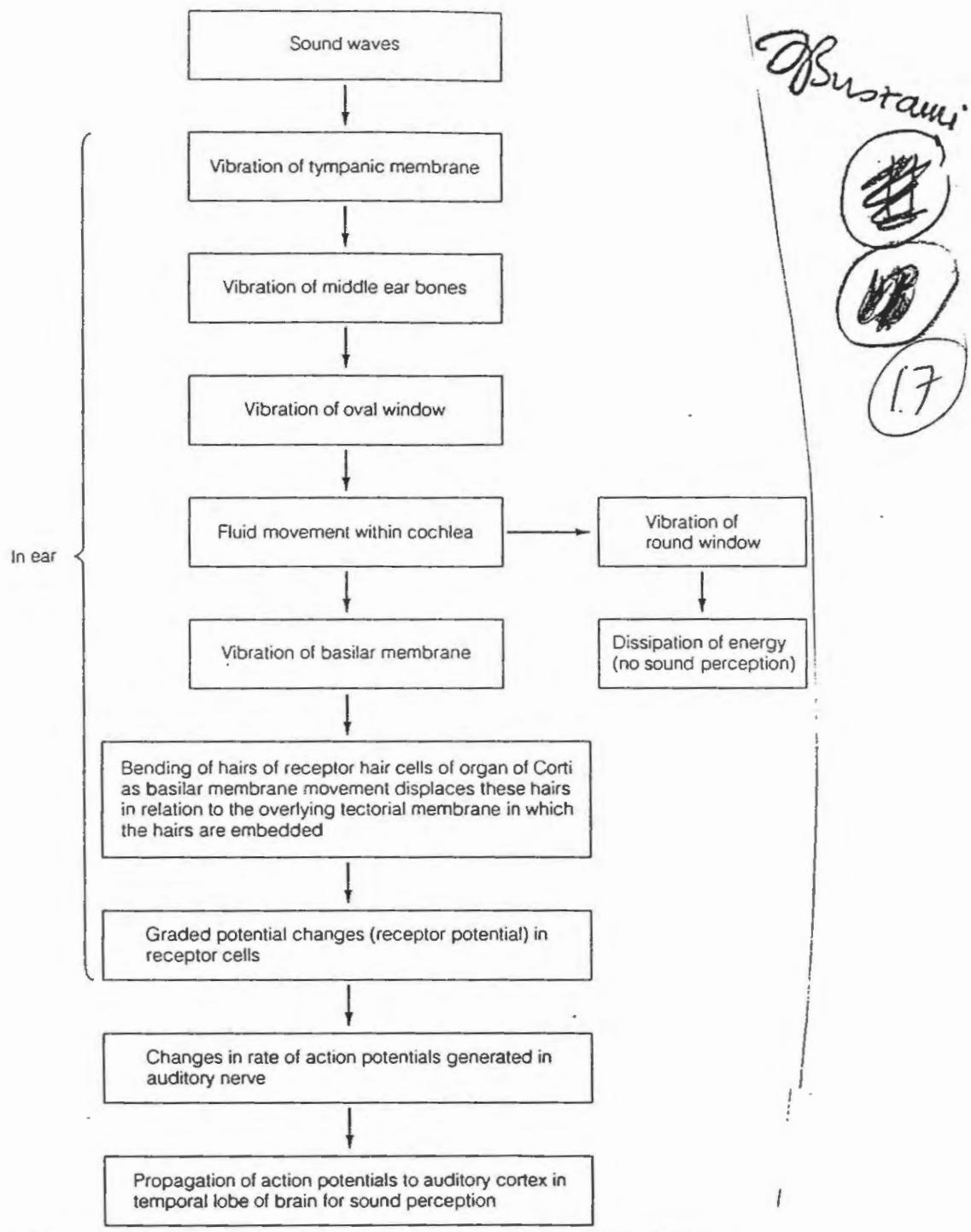


(b)



(c)

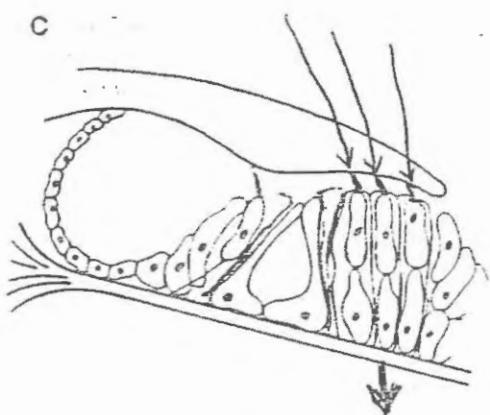
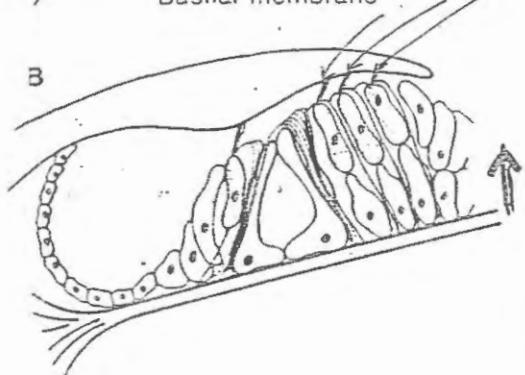
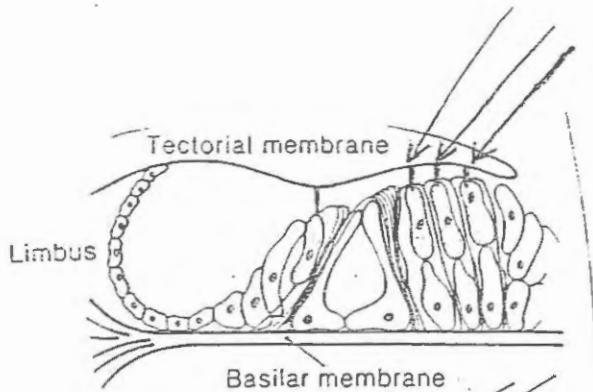
The numbers indicate the frequencies with which different regions of the basilar membrane maximally vibrate.



Pressure waves of frequencies associated with sound reception take a "shortcut." Pressure waves in the upper compartment are transferred through the thin vestibular membrane, into the cochlear duct, and then through the basilar membrane into the lower compartment, where they cause the round window to alternately bulge outward and inward. The main difference in this pathway is that transmission of pressure waves through the basilar membrane causes this membrane to move up and down, or vibrate, in synchrony with the pressure wave. Since the organ of Corti rides on the basilar membrane, the hair cells also move up and down as the basilar membrane oscillates. Because the hairs of the receptor cells are embedded in the stiff, stationary tectorial membrane, they are bent back and forth when the oscillating basilar membrane shifts their position in relationship to the tectorial membrane (Fig. 6-37). This back-and-forth mechanical deformation of the hairs alternately opens and closes mechanically gated ion channels (see p. 81) in the hair cell, resulting in alternating depolarizing and hyperpolarizing potential changes—the receptor potential—at the same frequency as the original sound stimulus.

Thus, the ear converts sound waves in the air into oscillating movements of the basilar membrane that bend the hairs of the receptor cells back and forth. This shifting mechanical deformation of the hairs alternately opens and closes the receptor cells' channels, which bring about graded potential changes in the receptor that lead to changes in the rate of action potentials propagated to the brain. In this way, sound waves are translated into neural signals that can be perceived by the brain as sound sensations (Fig. 6-38).

Up-and-down movement of the basilar membrane & tectorial membrane causes the Stereocilia extending from the hair cells to bend BACK & FORTH



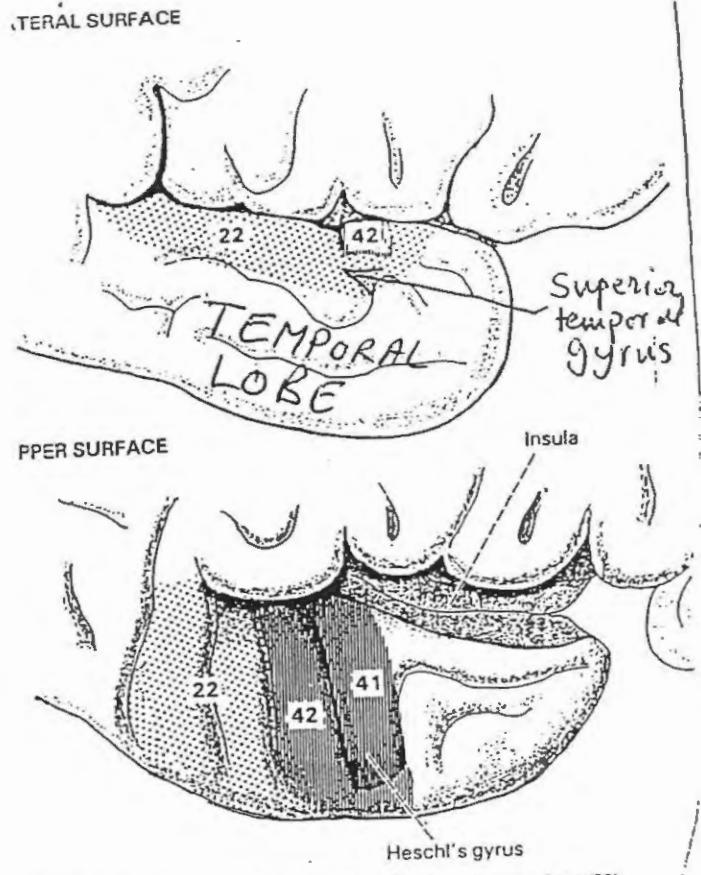
Depolarize

hyperpolarize

B - When the organ of Corti moves upward (with the basilar membrane) \rightarrow the stereocilia bend A WAY from the limbus & depolarize

C - When the organ of Corti moves downward (with the basilar membrane) \rightarrow the stereocilia bend toward the limbus & they hyperpolarize

Upstream



Auditory cortex (Fig. 30-9)

The primary auditory cortex (areas 41 and 42 of Brodmann) includes the gyrus of Heschl on the upper surface of the superior temporal gyrus, and the adjoining part of the temporal operculum of the insula. 'Columnar organization' is obvious, the 'columns' being in fact stripes disposed mediolaterally. Each stripe is an isofrequency band, and the cortical arrangement is tonotopic: high tones excite the posterior stripes and low tones excite the anterior ones. The stripes are maximally excited from the contralateral sound field. Virtually all of the neurons are binaural.

19

18

Auditory association cortex (area 22)

- * occupies the lateral surface of the superior temporal gyrus
- * It receives short association fibres from the primary cortex & INTEGRATES INCOMING SOUNDS WITH AUDITORY MEMORY STORES

* Area 22 has been subdivided into six cytoarchitectural areas → The most important is Wernicke's sensory speech area

lesion of the

① Cochlea
② Cochlear Nerve
cochlear nuclei

Complete ipsilateral deafness

Lesion of the lateral lemniscus → try auditory cortex

Bilateral partial deafness greatest in the contralateral ear

Lesion of the auditory association cortex → Word deafness?
the person fails to understand sounds or spoken words even though they are heard

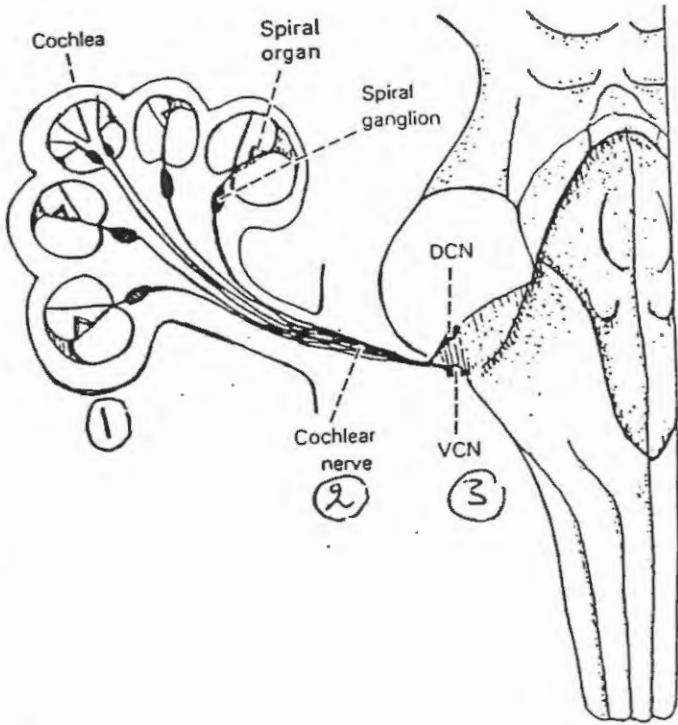
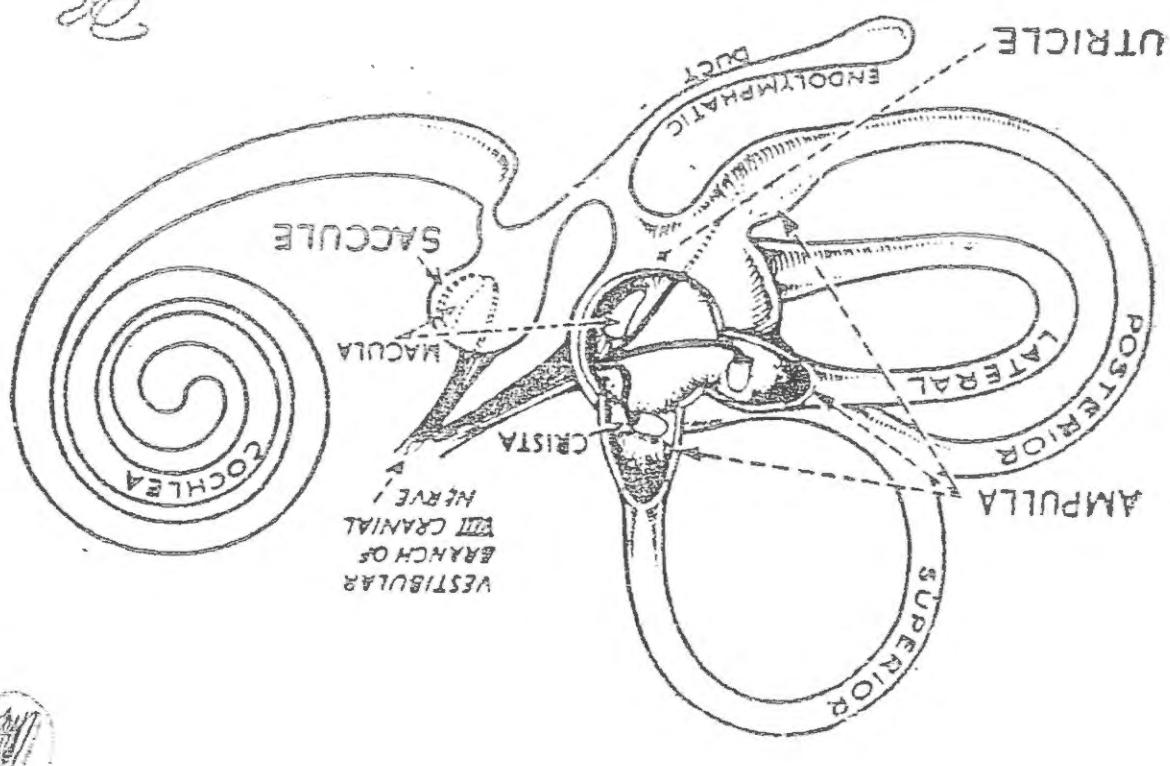
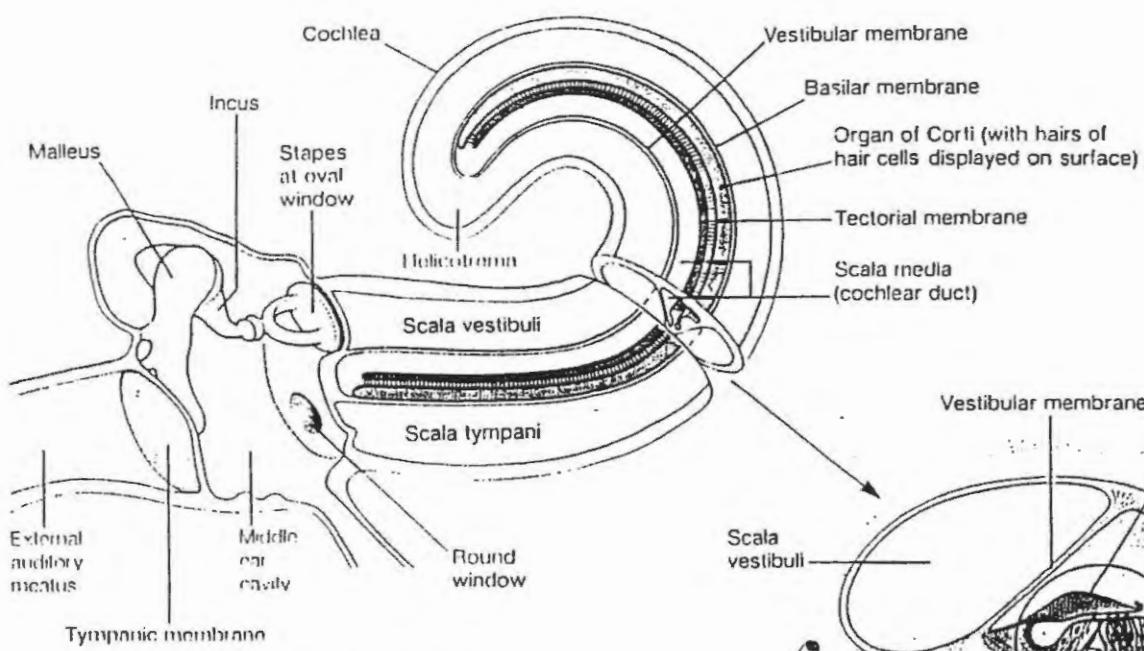


Fig. 30-2 Spiral ganglion and cochlear nerve. The nerve terminates in dorsal (DCN) and ventral (VCN) cochlear nuclei.

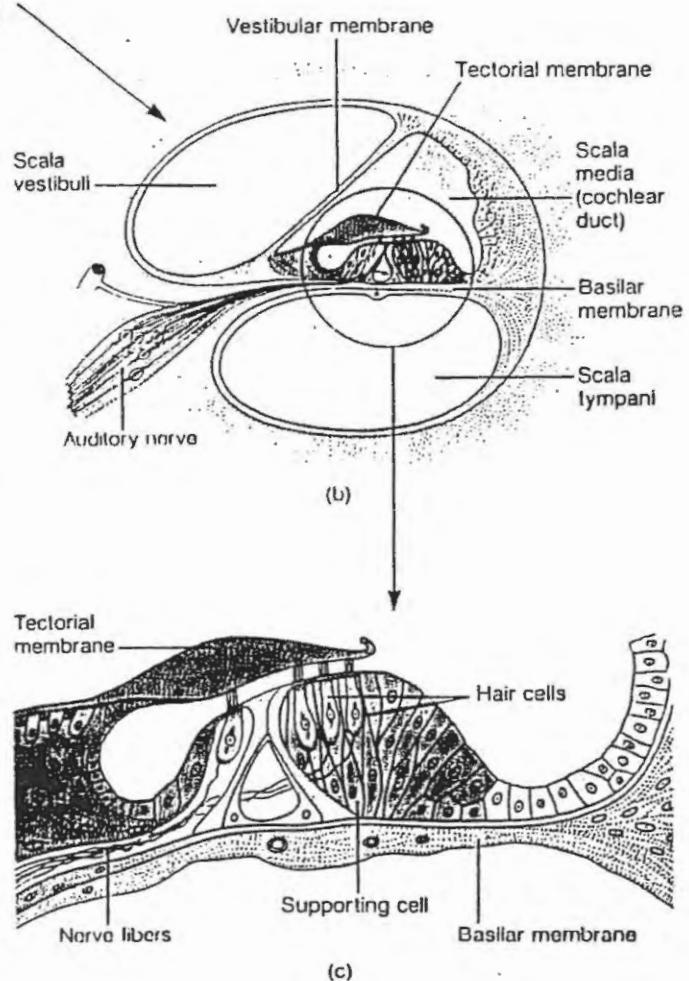
Figure 70 : The membranous labyrinth.





(a)

FIGURE 6-35 Middle Ear and Cochlea (a) Gross anatomy of the middle ear and cochlea, with the cochlea "unrolled." (b) Cross section of cochlea. (c) Enlargement of organ of Corti.



(b)

(c)

fluid-filled cochlea. As the tympanic membrane vibrates in response to sound waves, the chain of bones is set into motion at the same frequency, transmitting this frequency of movement from the tympanic membrane to the oval window. The resultant pressure on the oval window with each vibration produces wavelike movements in the inner ear fluid at the same frequency as the original sound waves. However, as noted earlier, greater pressure is required to set fluid in motion. Two mechanisms related to the ossicular system amplify the pressure of the airborne sound waves to set up fluid vibrations in the cochlea. First, because the surface area of the tympanic membrane is much larger than that of the oval window, pressure is increased as force exerted on the tympanic membrane is conveyed to the oval window ($\text{pressure} = \text{force}/\text{unit area}$). Second, the lever action of the ossicles provides an additional mechanical advantage. Together, these mechanisms increase the force exerted on the oval window by twenty times what it would be if the sound wave struck the oval window directly. This additional pressure is sufficient to set the cochlear fluid in motion.

Several tiny muscles in the middle ear contract reflexly in response to loud sounds (over 70 dB), causing the tympanic membrane to tighten and limit movement of the ossicular chain. This reduced movement of middle ear structures diminishes the transmission of loud sound waves to the inner ear to protect the delicate sensory apparatus from damage. This reflex response is relatively slow, however, happening at least 40 msec after exposure to a loud sound. It thus provides protection only from prolonged loud sounds, not from sudden loud sounds like an explosion.

Hair cells in the organ of Corti transduce fluid movements into neural signals.

The snail-shaped cochlear portion of the **inner ear** is a coiled tubular system lying deep within the temporal bone (Fig. 6-32). It is easier to understand the functional components of the **cochlea** by "unrolling" it, as shown in Figure 6-35a. The cochlea is divided throughout most of its length into three fluid-filled longitudinal compartments. A blind-ended **cochlear duct**, which is also known as the **scala media**, constitutes the middle compartment. It tunnels lengthwise

20 ~~24~~

ت تكون الا موجات الصوتية
منطقة ضغط تبادر
مع مناطق تخلخل لجزيئات الهواء

أي جزء تادر على اهتزاز
اضطراب في جزيئات الهواء بالشكل
ان بعد يكون مصدر الصوت

الاهتزاز الشوكة الرنانة ينزل
منطقة ضغط لجزيئات الهواء امام
شوكة من طرف تخلخل لجزيئات الهواء
يلف الشوكة وبالتالي تحدث اهتزازات
صوت

يمكن لامواج الصوت أن تنتقل
في أي طرف عن الهواء (مثل الماء)

يمتاز الصوت بـ:

(1) نبرة أو نغمة الصوت (لون الصوت)
Pitch (tone)

(2) علو الصوت
intensity (loudness)

(3) طابع (رقة) الصوت
Timbre (quality)

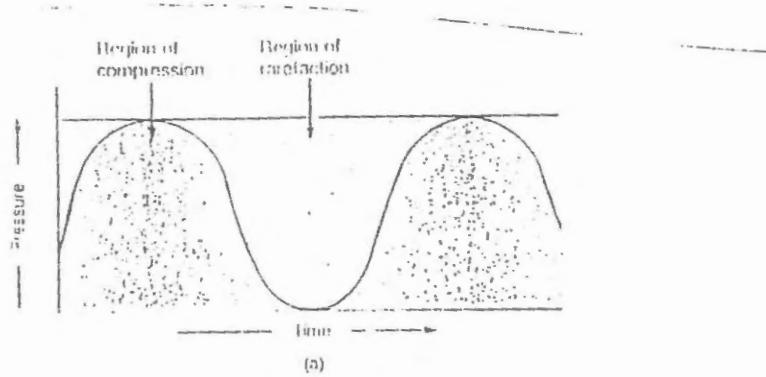
Pitch نغمة الصوت وتحدد على

Frequency of vibrations زردد الاهتزازات
كلما زاد التردد زادت نغمة الصوت

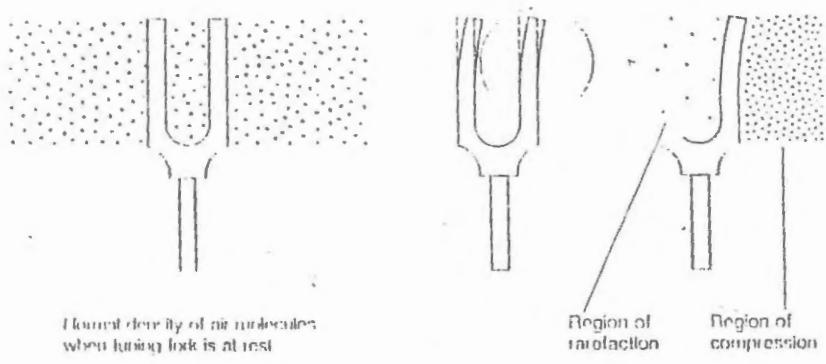
تنبع أذن اهتز أن تحيي أسماع جزيئات
ان تردد يتراوح بين 20 - 20,000 دورة
الثانية ولكن تكون أقل حساسية للتغيرات
ترابع بين 1,000 - 4,000 دورة في الثانية

علو الصوت أو حدة الصوت
intensity or loudness
تحدد على حجم امون الصوت

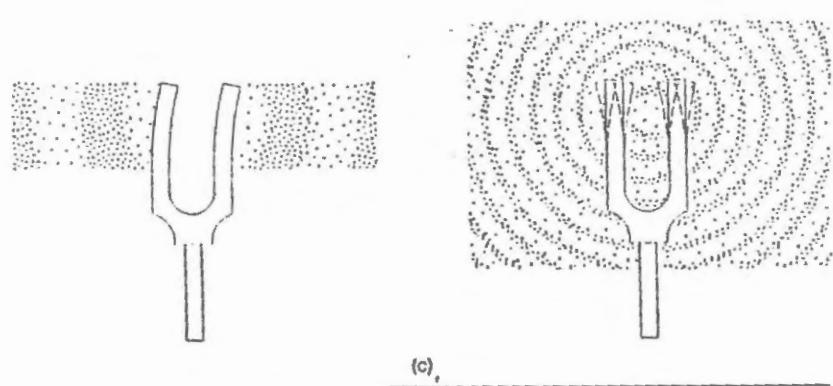
الفرق في الفنط بين نفق ضغط على جزيئات الهواء
وهي من سرع السفع لأنها تتمسان كلما ازداد حجم امون الصوت غالباً
تنبع أذن إلأن ان تحيي بين ملدي راسع لـ 20 - علو الصوت من درجة الحرارة
لي صوت اقل من الطامة النفاذه.



(a)

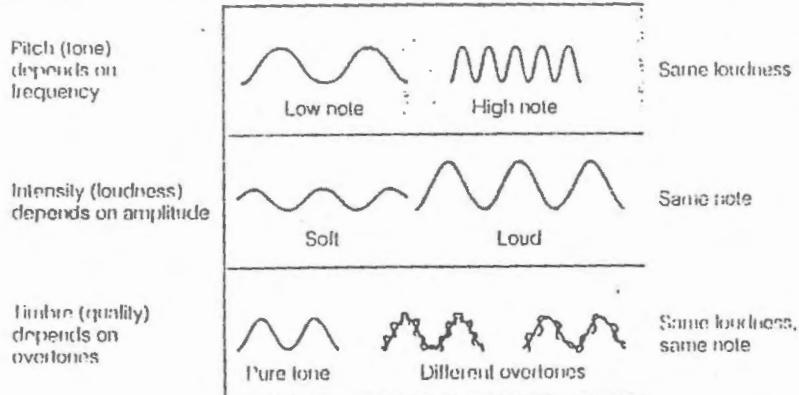


(b)



(c)

FIGURE 6-34 Properties of Sound Waves



الفرق في الفنط بين نفق ضغط على جزيئات الهواء
وهي من سرع السفع لأنها تتمسان كلما ازداد حجم امون الصوت غالباً
تنبع أذن إلأن ان تحيي بين ملدي راسع لـ 20 - علو الصوت من درجة الحرارة
لي صوت اقل من الطامة النفاذه.

FIGURE 25.6 The Weber and Rinne tuning fork tests. (a) The Weber test to evaluate whether the sound remains centralized (normal) or lateralizes to one side or the other (indicative of some degree of conduction or sensorineural deafness). (b and c) The Rinne test to compare bone conduction and air conduction.



(a) Weber Test



(b)



(c) Rinne test

Weber Test to Determine Conduction and Sensorineural Deafness (Nerve deafness)

Strike a tuning fork and place the handle of the tuning fork medially on your partner's head (see Figure 25.6a). Is the tone equally loud in both ears, or is it louder in one ear?

* If it is equally loud in both ears → You have EQUAL HEARING or EQUAL LOSS OF HEARING in both ears

* If nerve deafness is present in the Rt. ear → the tone will be heard in the Lt. ear but not the Rt. ear

* If conduction deafness is present in the Rt. ear → the sound will be heard more strongly in the Rt. ear due to sound conduction by the bone of skull.

* Rinne test for comparing Bone- and Air-conduction hearing

1. Strike the tuning fork, and place its handle on your partner's mastoid process (Figure 25.6b).

2. When your partner indicates that the sound is no longer audible, hold the still-vibrating prongs close to his auditory canal (Figure 25.6c). If your partner hears the fork again (by air conduction) when it is moved to that position, hearing is not impaired and the test result is to be recorded as positive (+). (Record below step 5.)

3. Repeat the test on the same ear, but this time test air-conduction hearing first.

4. After the tone is no longer heard by air conduction, hold the handle of the tuning fork on the bony mastoid process. If the subject hears the tone again by bone conduction after hearing by air conduction is lost, there is some conduction deafness and the result is recorded as negative (-).

5. Repeat the sequence for the opposite ear.

Right ear: _____ Left ear: _____

Does the subject hear better by bone or by air conduction?

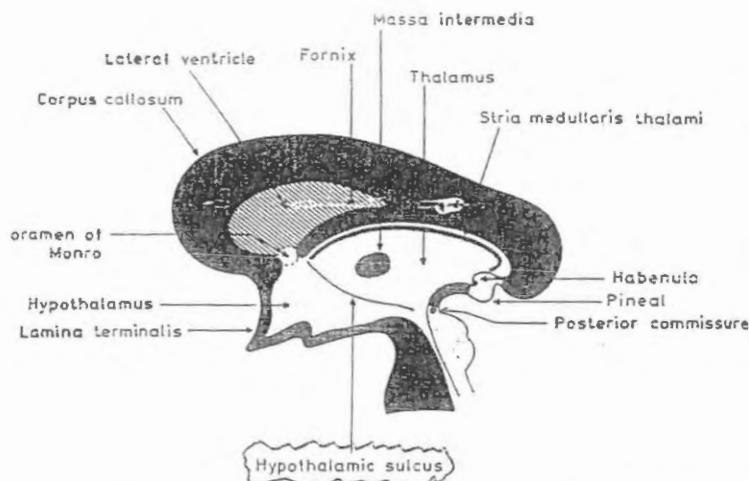


Figure 9.1. Schematic diagram showing the major subdivisions of the diencephalon as seen in a midsagittal view.

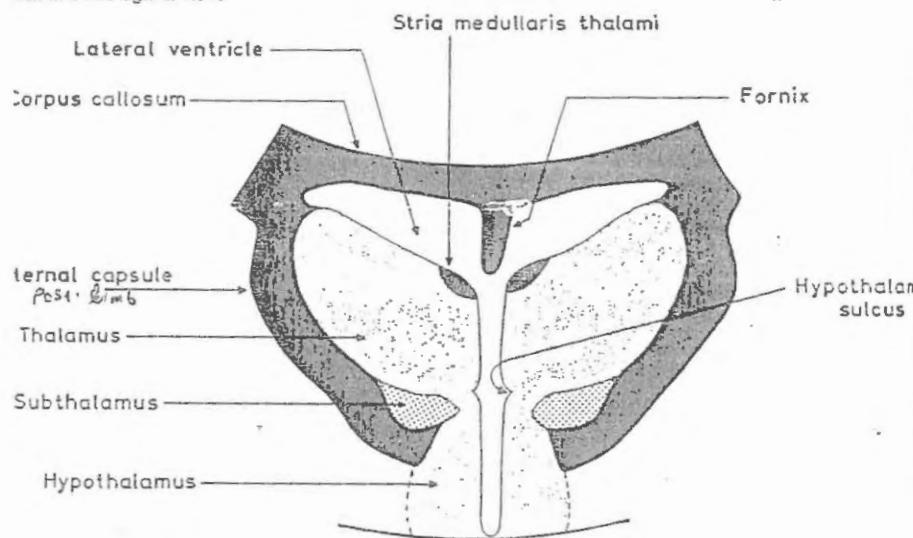


Figure 9.2. Schematic diagram showing the subdivisions of the diencephalon as seen in a composite coronal section.

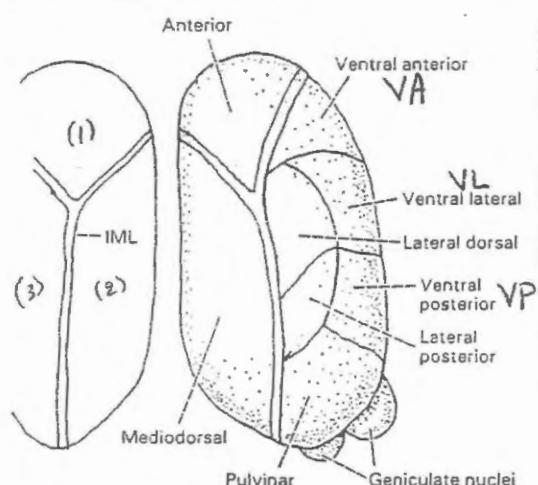


Fig. 17-1 Thalamus from above, with nuclear subdivisions. IML, internal medullary lamina.

Anatomical Subdivisions of thalamus:

The Y-shaped internal medullary lamina divides the thalamus into anterior, mediadorsal, and lateral groups. The lateral group has dorsal and ventral tiers, each containing three nuclei. Below the hindmost member of the dorsal tier (the pulvinar) lie the medial and lateral geniculate nuclei.

Olfactory sulcus

A groove extending between the foramen of Monro and the cerebral aqueduct → the hypothalamic sulcus divides the diencephalon into a dorsal portion the thalamus and a ventral portion, the hypothalamus.

Diencephalon "inbetween brain" is completely surrounded by the cerebral hemispheres Except at its ventral surface.

Medially → 3rd ventricle
Laterally → post. limb of internal capsule
* dorsal surface → forms the floor of the lateral ventricle

Medially → hypoth.
Subthalamus (lat.) → int. capsule
Dorsally → thalamus
Ventrally → int. capsule

Functional subdivisions of thalamus

1 Specific nuclei are reciprocally connected to localized areas of the cerebral cortex. They are said to be 'cortically dependent', because they degenerate when the target area of cortex is removed.

Anterior, VA, VL, VP, MGB, LGB

2 Non-specific nuclei project to wide areas of the cortex and influence their level of activity. They are not cortically dependent because they give abundant sustaining collaterals to one another.

Intralaminar, Reticular

3 Association nuclei have reciprocal linkages with association areas of the cerebral cortex (Table 17-1).

Mediodorsal, lateral dorsal, lateral posterior
Pulvinar

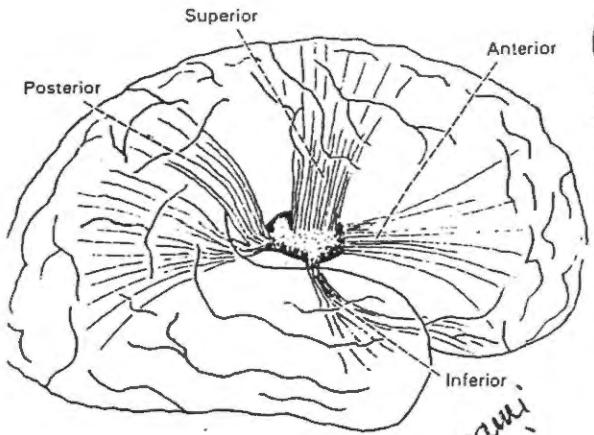


Fig. 17-6 Thalamic peduncles.

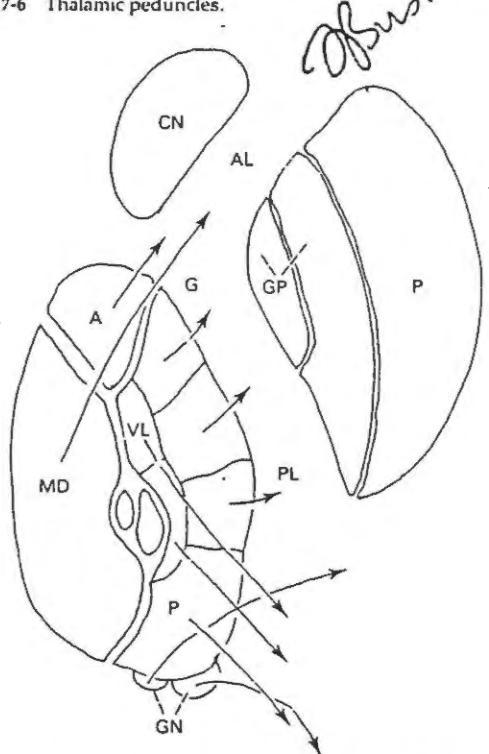
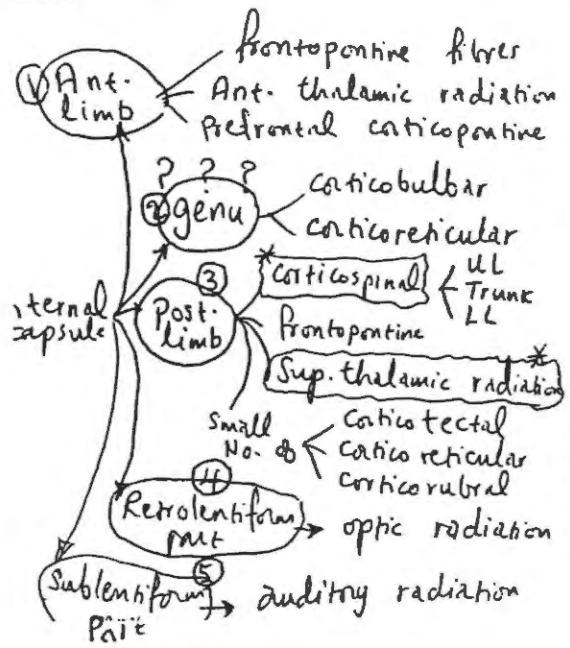


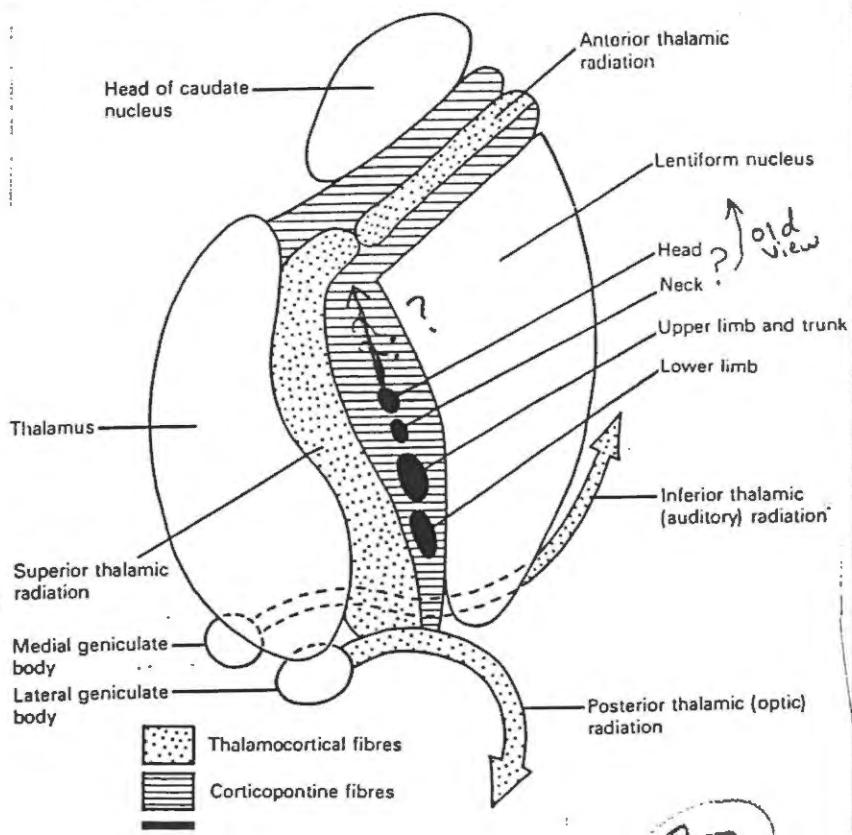
Fig. 17-7 Horizontal section through internal capsule. AL, anterior limb; G, genu; PL, posterior limb. Caudate nucleus (CN) & lentiform nuclei (P, putamen; GP, globus pallidus) are shown. Anterior nucleus; MD, mediodorsal nucleus; VL, ventral lateral nucleus; GN, geniculate nuclei. Arrows indicate thalamic radiations.



27 Thalamic radiations (Peduncles) 27

Fibres that RECIPROCITY (i.e App. & Eff.) connect the thalamus & cerebral cortex

- 1 Anterior (frontal) peduncle: passes through the anterior limb of the internal capsule and connects the frontal lobe with the medial and anterior thalamic nuclei.
- 2 Superior peduncle: passes through the posterior limb of the int. capsule and connects ^{Pre. → 4, 6}
^{Post central → 3, 1, 2}
the ventral thalamic nuclei.
VA
gryi
VL
VP
- 3 Posterior (occipital) peduncle passes through the retrolentiform part of int. capsule and connects occipital lobe and caudal portion of thalamus, includes also the optic radiation from LGB → calcarine cortex
- 4 Inf. or temporal peduncle passes through the sublentiform part of int. capsule. Includes auditory radiation from MGB → transverse temporal gyrus



27

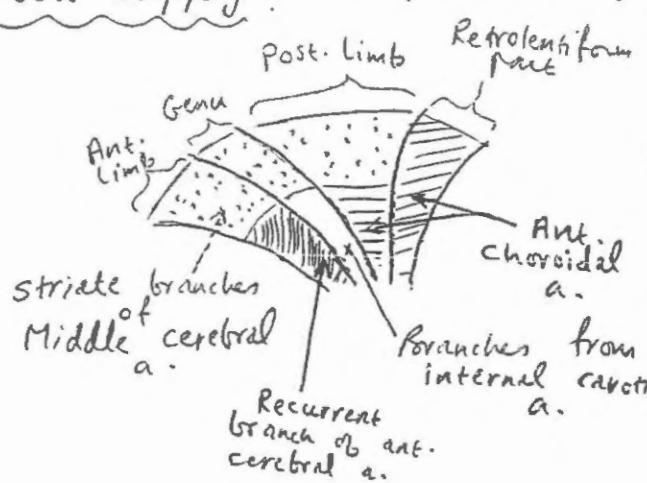
(23) (10) (24) Officiant (25)

The internal capsule → Composed of all the fibres Afferent & Efferent which go to or come from the cerebral cortex. A large part of it is formed of thalamic radiations; the rest of it is formed of efferent fibres i.e. corticofugal fibres which descend to lower portions of brainstem and spinal cord. These include corticospinal, corticobulbar, corticoreticular and corticopontine tracts. ↑
(Minimal)

↓

Thalamocortical & corticofugal fibres occupy a small compact area → Lesion in this area produce more widespread disturbances than lesions in any other region of the nervous system, and these include

- (a) Contralateral Hemiplegia or Hemiparesis (Corticospinal tract)
 - (b) Contralateral weakness of lower face (Corticobulbar)
 - (c) Temporary Contralateral (Hemianesthesia) (Sensory radiation)
 (After sometime there will be return of Pain sense.
 and Simple touch → perceived at thalamus i.e.
 Sensory cortex → is not needed to feel pain,
 temp. or simple touch; it is needed to feel
Stereognosis + discriminative touch. It
 is also needed to tell where the pain is
 - Localization-, the intensity and quality of stimulus)
 - (d) Contralateral Hemianopia (optic radiation at retroレンチ形 part)
- Blood supply: (e) Impaired hearing mainly in contralateral ear



- (1) Both ant. & post. limbs are supplied primarily by the lateral striate branches of the middle cerebral a.
- (2) The medial striate a. (recurrent a. of Heubner) supplies a rostromedial part of ant. limb
- (3) genu of int. capsule → receives some direct branches from int. carotid a.
- (4) the ventral part of post. limb
- (5) its entire retrolenticular part are supplied by branches of the anterior choroidal artery



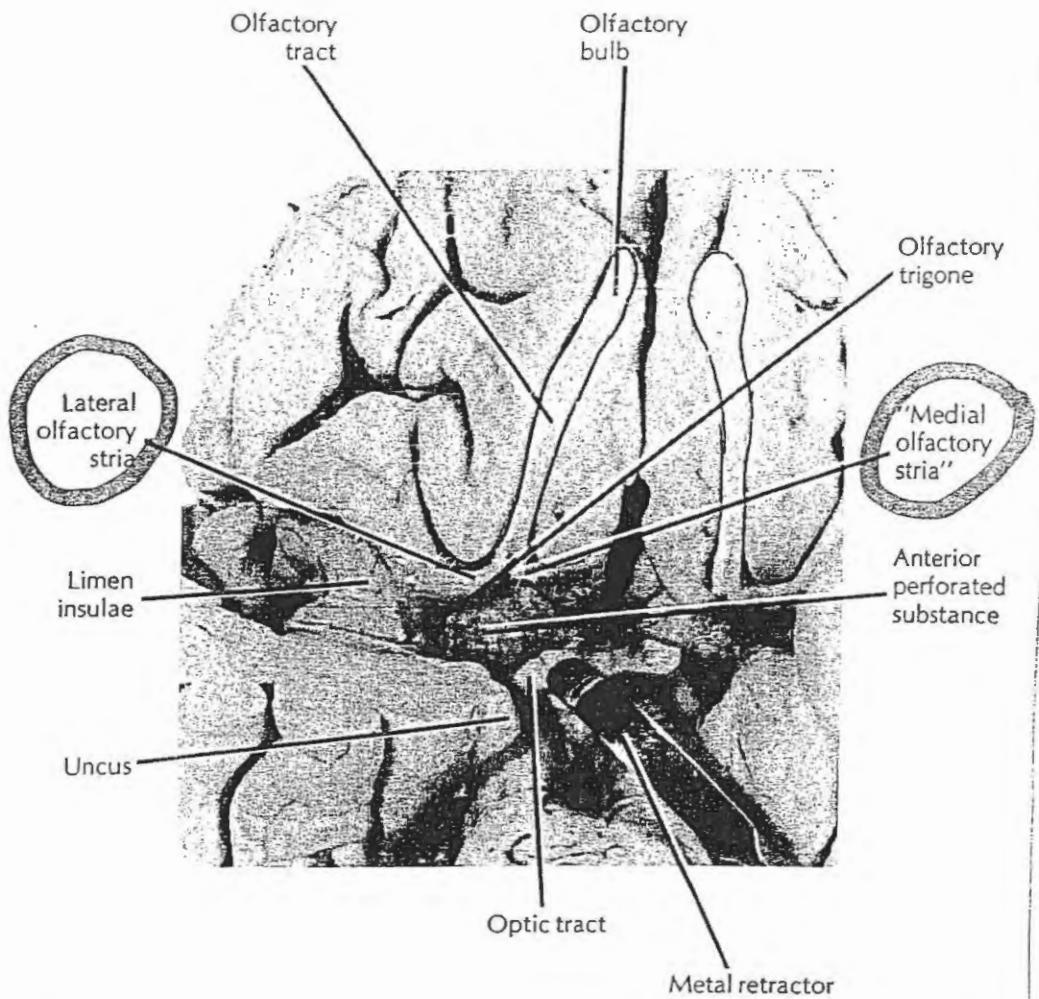
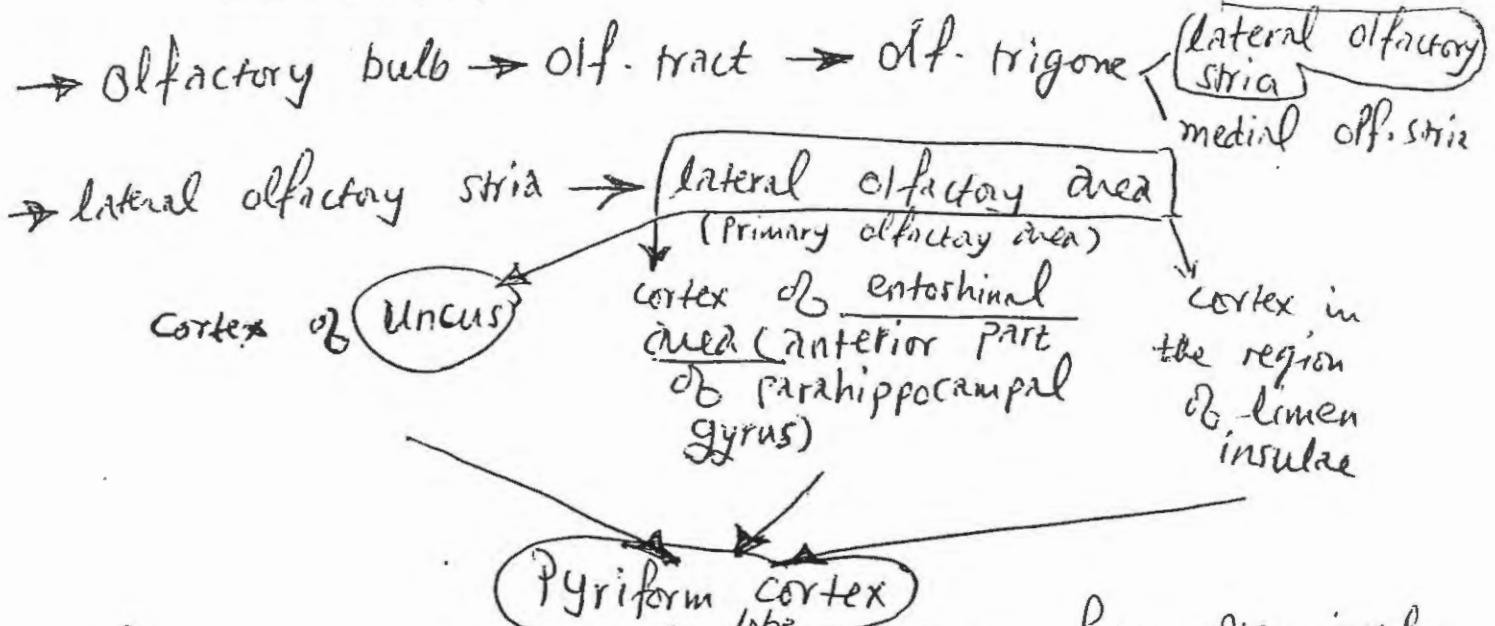


Figure 17-3. Some components of the olfactory system seen on the ventral surface of the brain. The right temporal pole has been cut away to give a clear view of the olfactory trigone, anterior perforated substance, and limen insulae. ($\times 1$)



* Fracture of the floor of the anterior fossa often involves the cribriform plate of ethmoid bone \rightarrow damaging the olfactory nerves and causing anosmia

The same injury may result in leakage of CSF from the Subarachnoid space into nasal cavity (CSF Rhinorrhea)

Bacteria * enters \rightarrow attack meninges + brain

26

Kristenau

TASTE

RECEPTOR ORGANS & PATHWAYS

Taste Buds

The taste buds, the sense organs for taste, are ovoid bodies measuring 50–70 μm . Each taste bud is made up of 4 types of cells (Fig 10–5): basal cells; type 1 and 2 cells, which are sustentacular cells; and type 3 cells, which are the gustatory receptor cells that make synaptic connections to sensory nerve fibers. The type 1, 2, and 3 cells have microvilli, which project into the taste pore, an opening in the lingual epithelium. The necks of all these cells are connected to each other and to the surrounding epithelial cells by tight junctions, so that the only part of the gustatory receptor exposed to the fluids in the oral cavity is its apical crown of microvilli. Each taste bud is innervated by about 50 nerve fibers, and conversely, each nerve fiber receives input from an average of 5 taste buds. The basal cells arise from the epithelial cells surrounding the taste bud. They differentiate into new receptor cells, and the old receptor cells are continuously replaced with a half time of about 10 days. If the sensory nerve is cut, the taste buds it innervates degenerate and eventually disappear. However, if the nerve regenerates, the cells in the neighborhood become organized into new taste buds, presumably as a result of some sort of chemical inductive effect from the regenerating fiber.

In humans, the taste buds are located in the mu-

cosa of the epiglottis, palate, and pharynx and in the walls of the fungiform and vallate papillae of the tongue. The fungiform papillae are rounded structures most numerous near the tip of the tongue; the vallate papillae are prominent structures arranged in a V on the back of the tongue. There are up to 5 taste buds per fungiform papilla, and they are usually located at the top of the papilla (Fig 10–5). The larger vallate papillae each contain up to 100 taste buds, usually located along the sides of the papillae. The small conical filiform papillae that cover the dorsum of the tongue do not usually contain taste buds. There are a total of about 10,000 taste buds.

Taste Pathways

The sensory nerve fibers from the taste buds on the anterior two-thirds of the tongue travel in the chorda tympani branch of the facial nerve, and those from the posterior third of the tongue reach the brain stem via the glossopharyngeal nerve (Fig 10–6). The fibers from areas other than the tongue reach the brain stem via the vagus nerve. On each side, the myelinated but relatively slow-conducting taste fibers in these 3 nerves unite in the medulla oblongata to enter the nucleus of the tractus solitarius (Fig 10–7). There they synapse on second-order neurons, the axons of which cross the midline and join the medial lemniscus, ending with the fibers for touch, pain, and temperature sensibility in the specific sensory relay nuclei of the thalamus. Impulses are relayed from there to the taste projection area in the cerebral cortex at the foot of the postcentral gyrus. Taste does not have a separate cortical projection area but is represented in the portion of the postcentral gyrus that subserves cutaneous sensation from the face.

OBristow

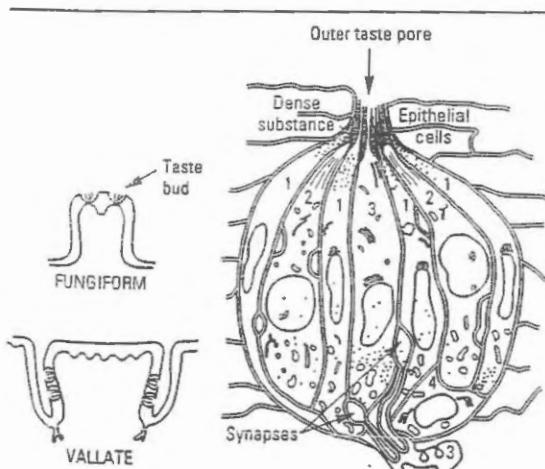


Figure 10–5. Taste bud, showing type 1, 2, and 3 cells. (Modified and reproduced, with permission, from Shepherd GM: *Neurobiology*, 2nd ed. Oxford Univ Press, 1988.)

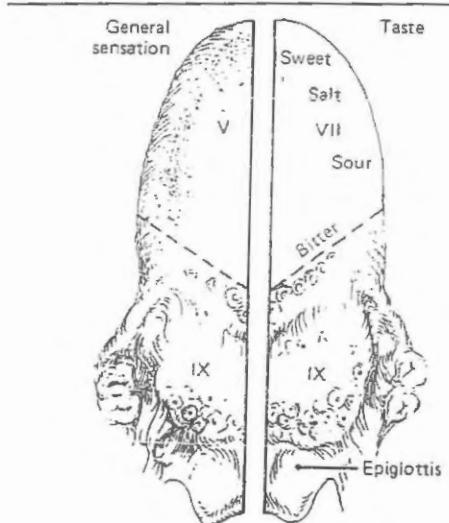


Figure 10–6. Sensory innervation of the tongue. The numbers refer to cranial nerves.

(27)

Osseous

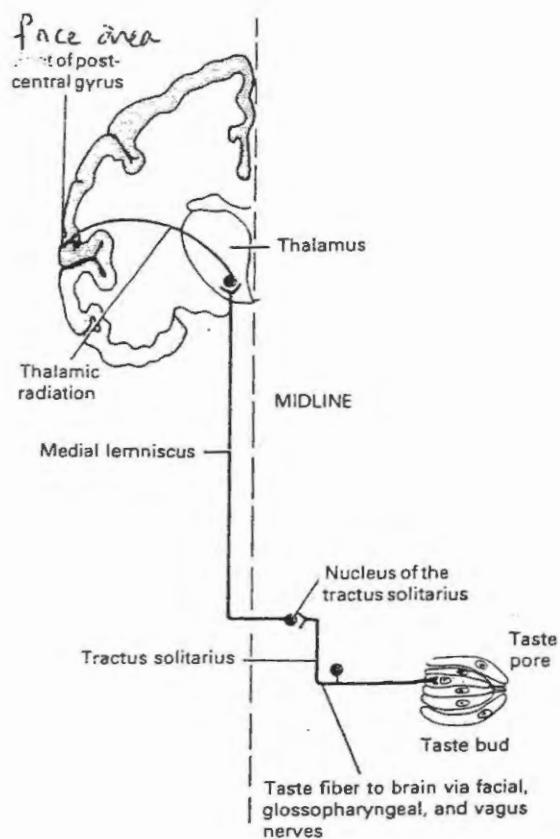
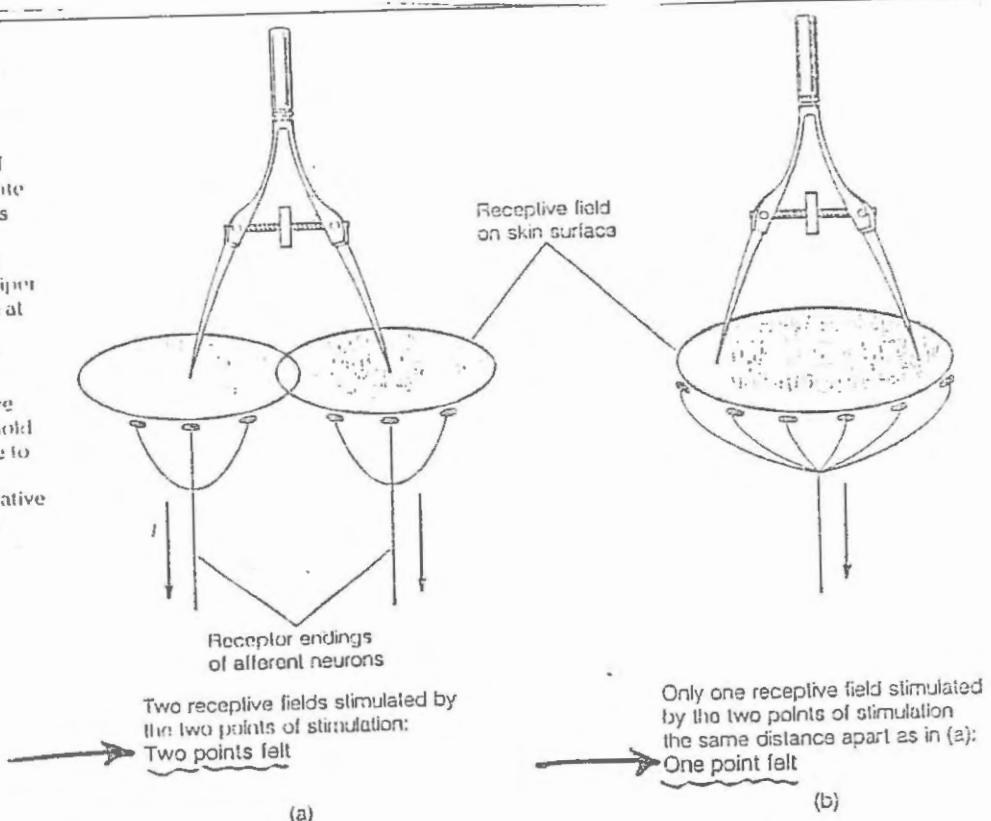


Figure 10-7. Diagram of taste pathways.

11/1
EOB

FIGURE 6-6 Comparison of Discriminative Ability of Regions with Small versus Large Receptive Fields
 The relative tactile acuity of a given region can be determined by the two-point threshold of discrimination test. If the two points of a pair of calipers applied to the surface of the skin stimulate two different receptive fields, two separate points will be felt. If the two points touch the same receptive field, they will be perceived as only one point. By adjusting the distance between the caliper points, one can determine the minimal distance at which the two points can be recognized as two rather than one, which is a reflection of the size of the receptive fields in the region. With this technique, it is possible to plot the discriminative ability of the body surface. The two-point threshold ranges from 2 mm in the fingertip (enabling one to read Braille, where the raised dots are spaced 2.5 mm apart) to 48 mm in the poorly discriminative skin of the calf. (a) Region with small receptive fields. (b) Region with large receptive fields.

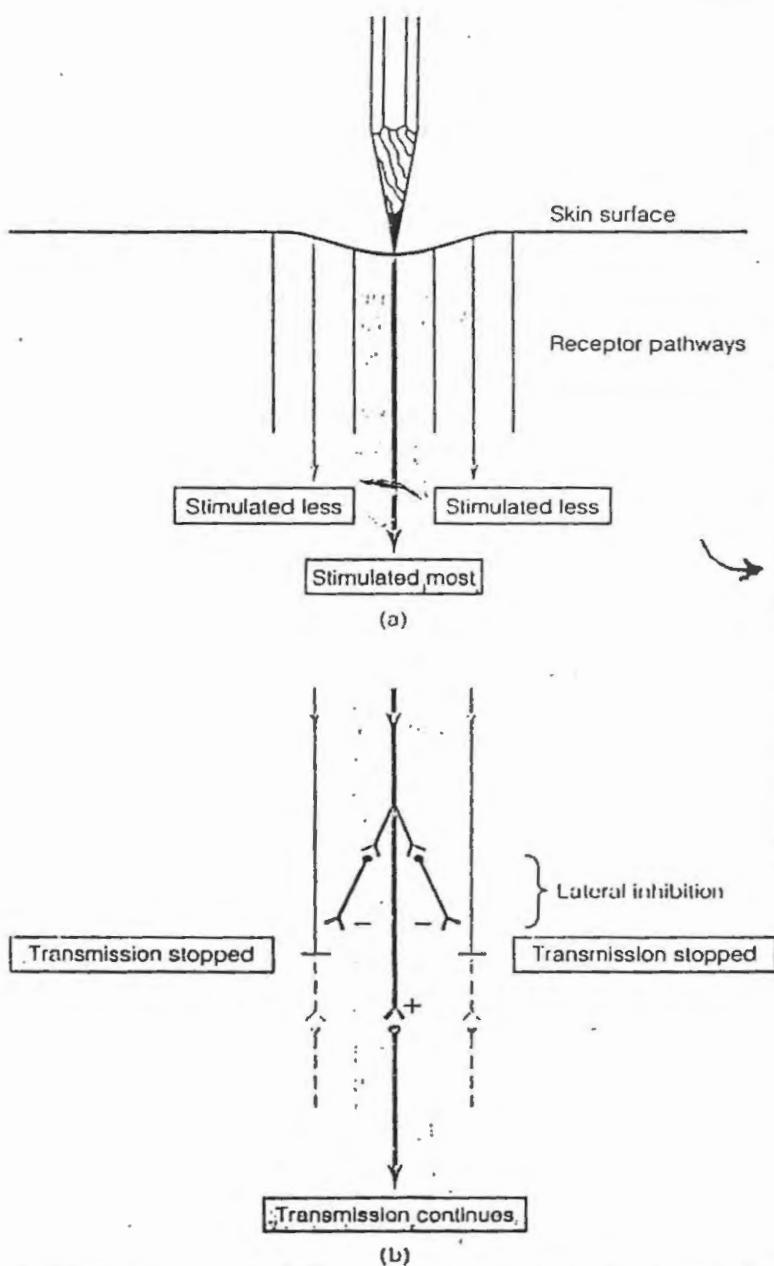


Acuity is Influenced by receptive field size and lateral inhibition.

Each sensory neuron responds to stimulus information only within a circumscribed region of the skin surface surrounding it; this region is known as its **receptive field**. The size of a receptive field varies inversely with the density of receptors in the region; the more closely receptors of a particular type are spaced, the smaller the area of skin each monitors. The smaller the receptive field in a region, the greater its **acuity** or **discriminative ability**. Compare the tactile (touch) discrimination in your fingertips with that in your elbow by "feeling"

the same object with both. You are able to discern more precise information about the object with your richly innervated fingertips because the receptive fields there are small; as a result, each neuron signals information about small, discrete portions of the object's surface. In contrast, the skin over the elbow is served by relatively few sensory endings with larger

receptive fields. Subtle differences within each large receptive field cannot be detected (• Fig. 6-6). The distorted cortical representation of various body parts in the sensory homunculus (see p. 119) corresponds precisely with the (innervation density) more cortical space is allotted for sensory reception from areas with smaller receptive fields and, accordingly, greater tactile discriminative ability.



• 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.

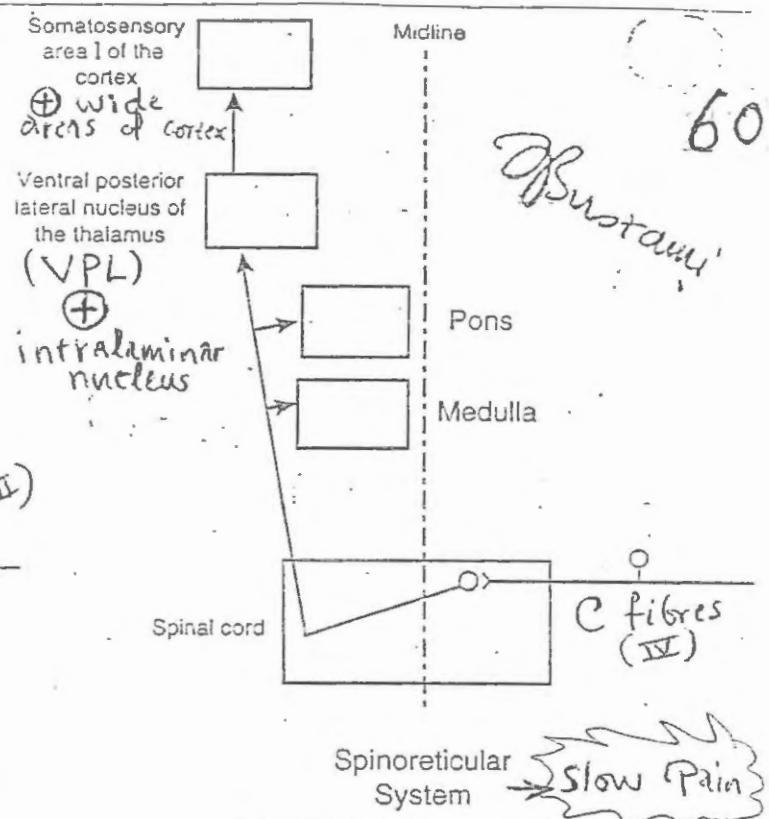
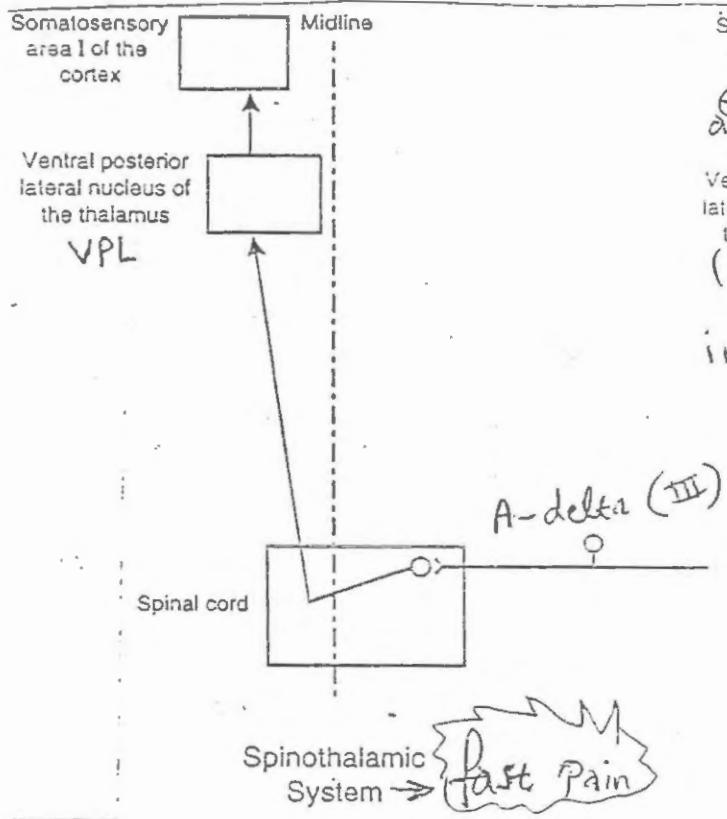
Properties of receptors

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 non-responsive 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.



* Spinoreticular tract: C(IV) afferent fibres → cells of origin are located in laminae I & II → ascend to terminate in both reticular formation & thalamus (VPL & intralaminar nuclei). The intralaminar nuclei are part of the Reticular activating system (RAS) which projects to wide areas of cerebral cortex → Thus they AROUSE one from sleep, create a sense of urgency and promote defence reactions to rid the person of pain.

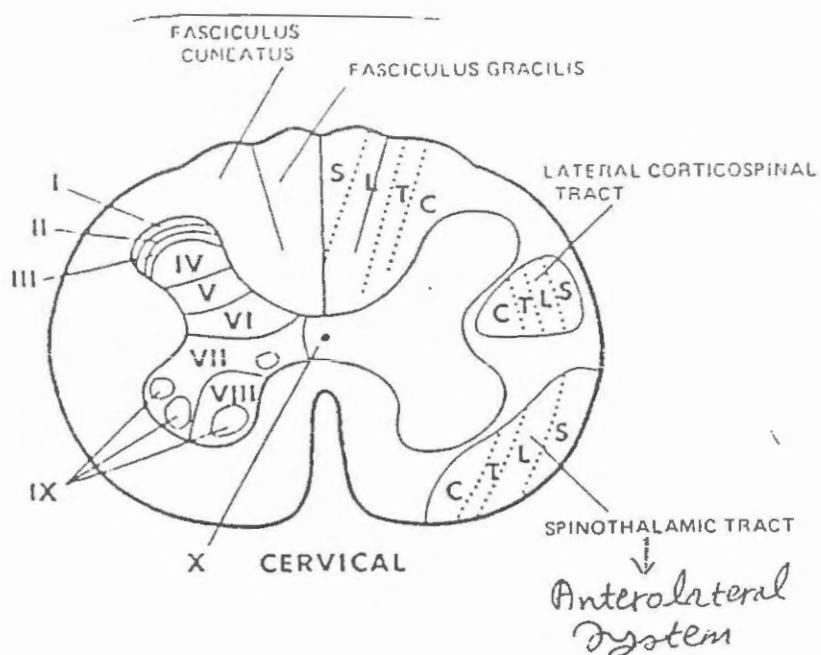
QUALITIES OF PAIN

Classically, the sensation of pain is subdivided into two components: fast (Pricking p.) & slow (Aching p.)

1 Pricking pain. This is often referred to as first pain. It is a fast acute sensation, which occurs within 0.1 s after application of a painful stimulus. It is usually well localized, the kind of sensation felt when a pin is stuck into the skin or the skin is cut with a knife. Pricking pain is usually superficial and is not felt in most of the deeper tissues. It is transmitted via type A_δ fibres.

2 Burning or aching pain. This is often referred to as second pain. It is a slow pain, which increases slowly over a period of many seconds or minutes. This component is the type that is difficult to endure and can occur both in the skin and in the deeper tissues. A good example is intestinal colic, toothache or a burn. Slow pain is transmitted by unmyelinated type C fibres.

The two qualities reflect not only the dual nature of the input (i.e. A_δ and C fibres), but also the two sets of connections within the nervous



Spinal

Spinal arteries

(Branches of vertebral arteries)

Two anterior

form one spinal artery

runs in the anterior median sulcus of spinal cord

Supplies blood to

anterior horns

lateral spinothalamic tract

pyramidal tracts (& extrapyr.)

* Thrombosis of ant spinal artery in cervical region

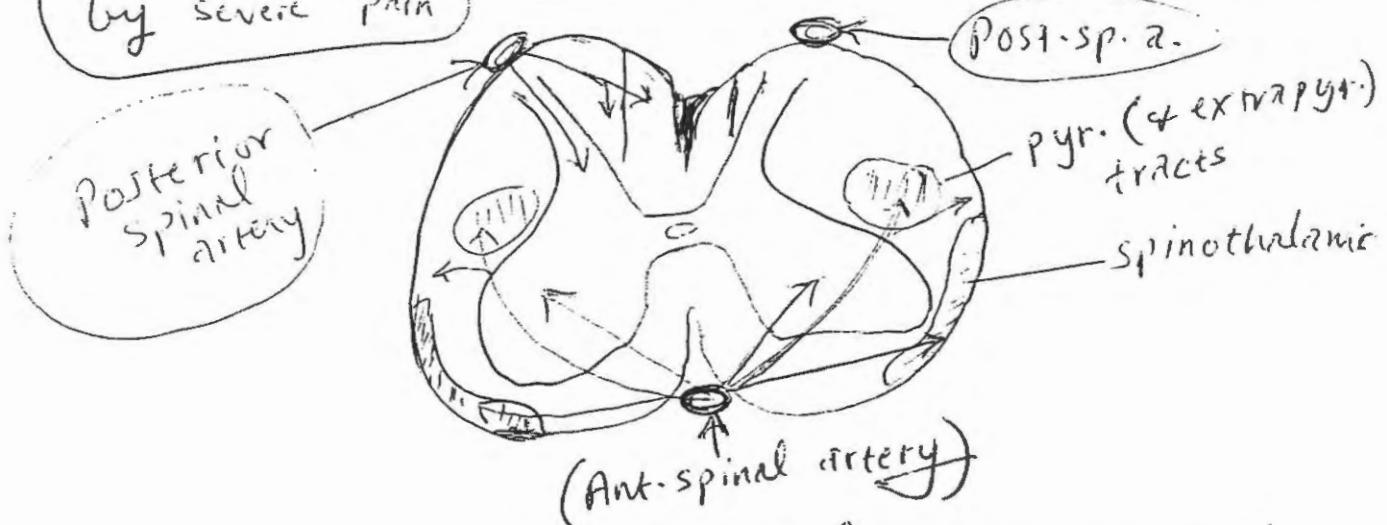
→ flaccid paralysis + fasciculation + atrophy at the level of the lesion due to destruction

of anterior horn cells

→ spastic paraparesis from involvement of pyramidal & extrapyramidal tracts

→ loss of pain & temperature below the lesion due to involvement of lateral spinothalamic tract

* The onset of symptoms is abrupt & is often accompanied by severe pain



* The posterior column + Post-horns are supplied independently by Post-spinal artery

* Remember → Radicular arteries? → branches from posterior intercostal arteries, lumbar arteries ---

→ enter through intervertebral foramina & contribute blood supply to the spinal cord → The largest arteria radicularis magna (of AdamKiewicz) at T10 or T11