Balance & Equilibrium

Chapter 56

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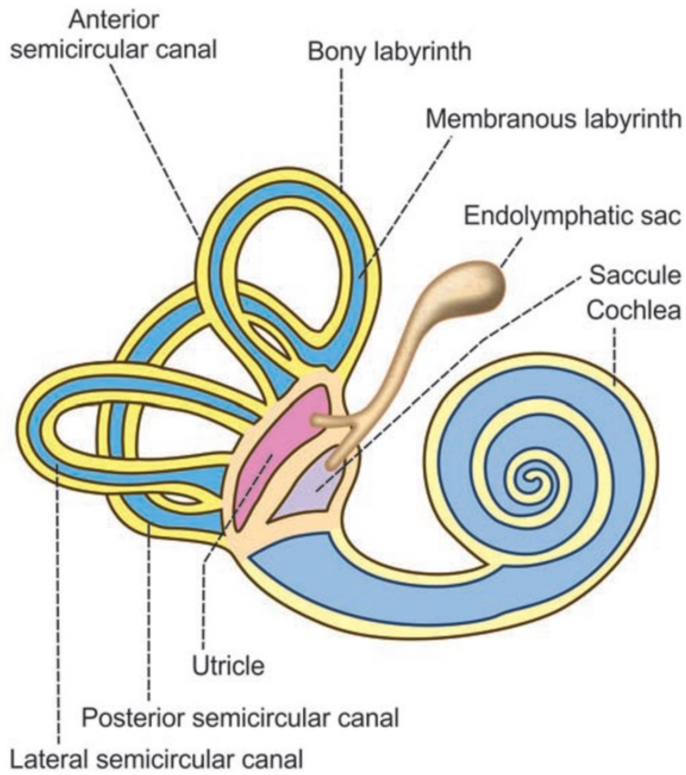
VESTIBULAR APPARATUS

- sensory organ for equilibrium
- In bony labyrinth
- functional part is membranous labyrinth

Components

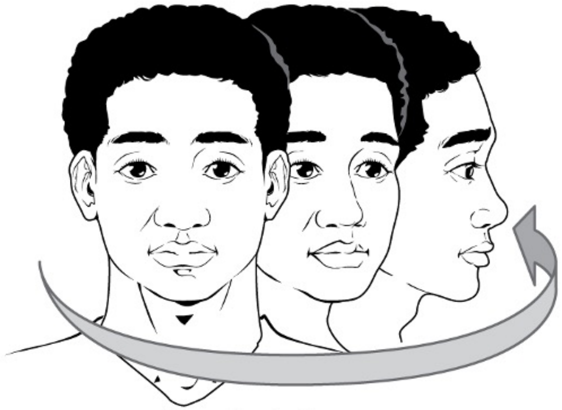
1- semicircular canals

2- otolith (utricle & saccule)



semicircular canals

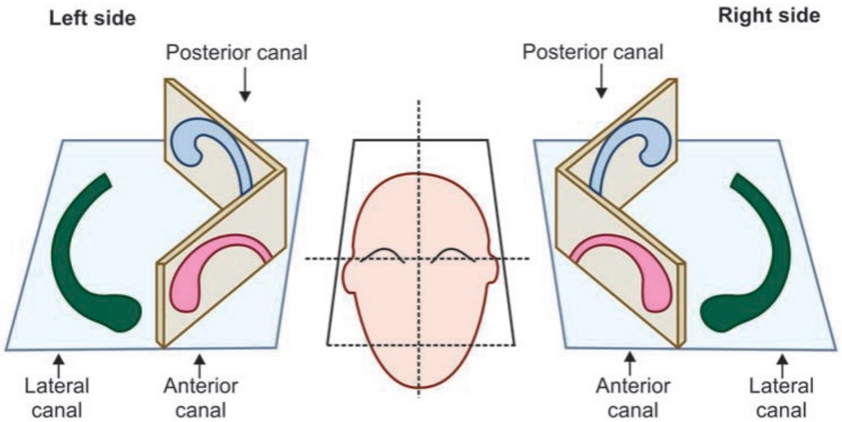
- semicircular canals →respond to **rotatory movements** or **angular acceleration** of the head.



Semicircular Ducts

__three semicircular ducts__

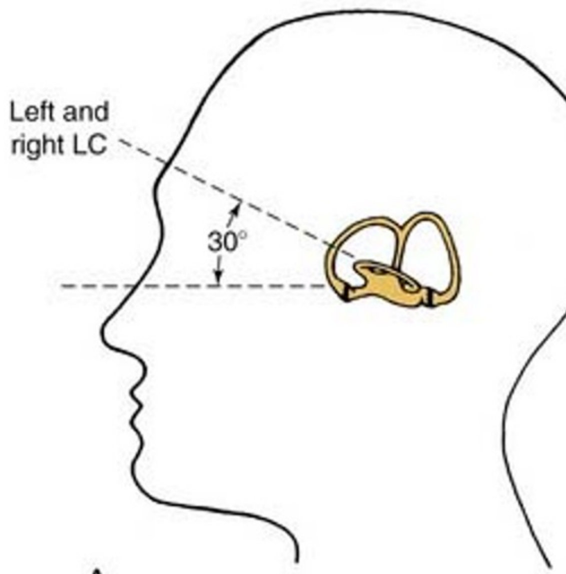
- A are in vertical planes project forward & 45 degrees outward
- P are in vertical planes project backward & 45 degrees outward.



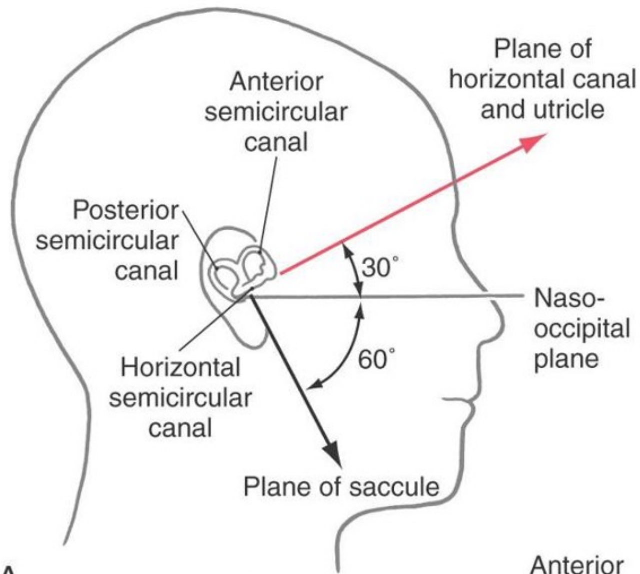
Semicircular Ducts

<u>three semicircular ducts</u>

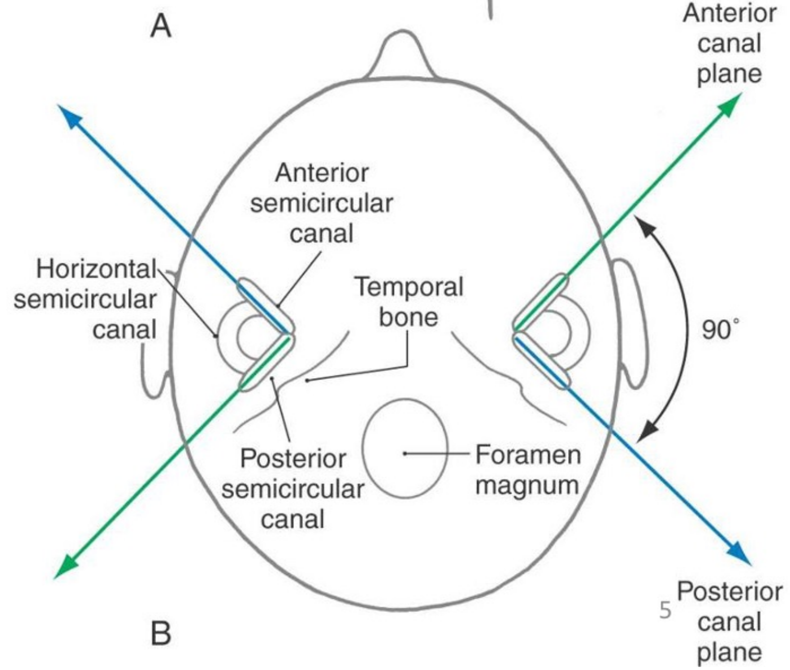
- anterior (A)→ respond to front to back movements (nodding)
- posterior (P)→ When head is rotated from shoulder to shoulder
- lateral/horizontal (H) → side to side movements (left to right or right to left-shaking the head while saying ‘no – no’.).



A



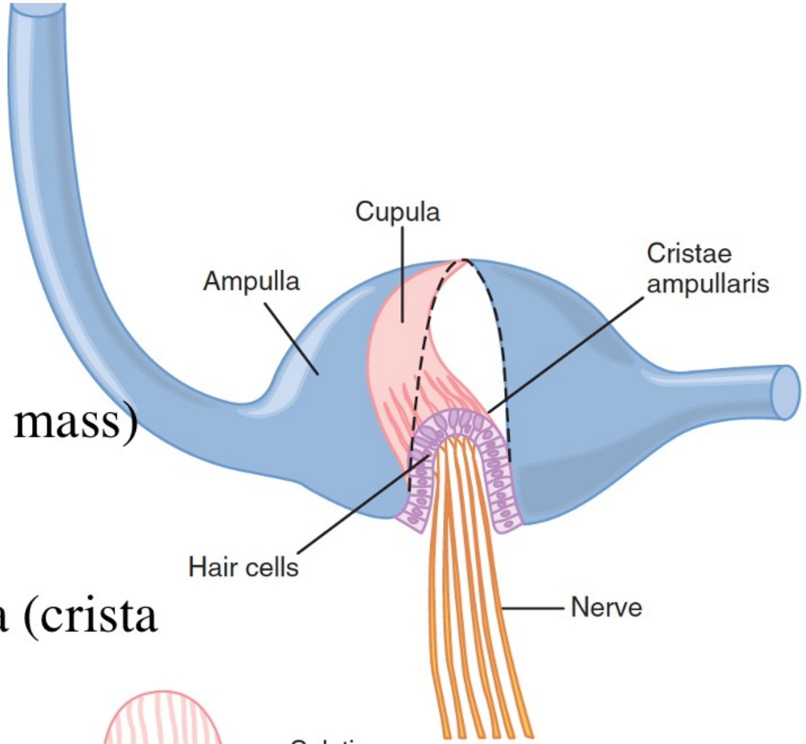
A

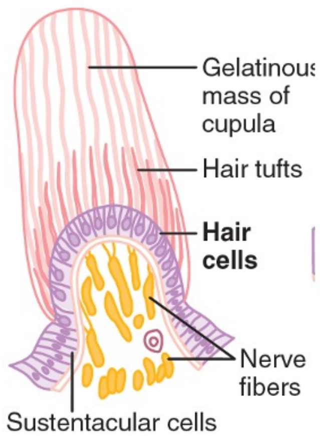


B

Semicircular Ducts

- enlargement at its ends: **ampulla**
- Receptor→ crista ampullaris→ **cupula** (gelatinous tissue mass) on top .
- ducts and ampulla are filled with endolymph.
- Flow of endolymph excites sensory organ of the ampulla (crista ampularis)





Hair Cells

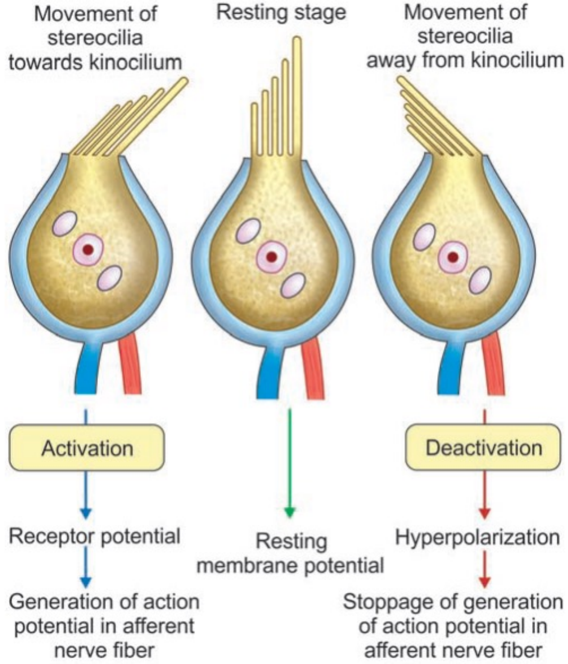
- 50-70 stereocilia: become progressively shorter toward other side of cell
- 1 kinocilium: located to one side
- filamentous attachments connect tips of stereocilia & kinocilium.

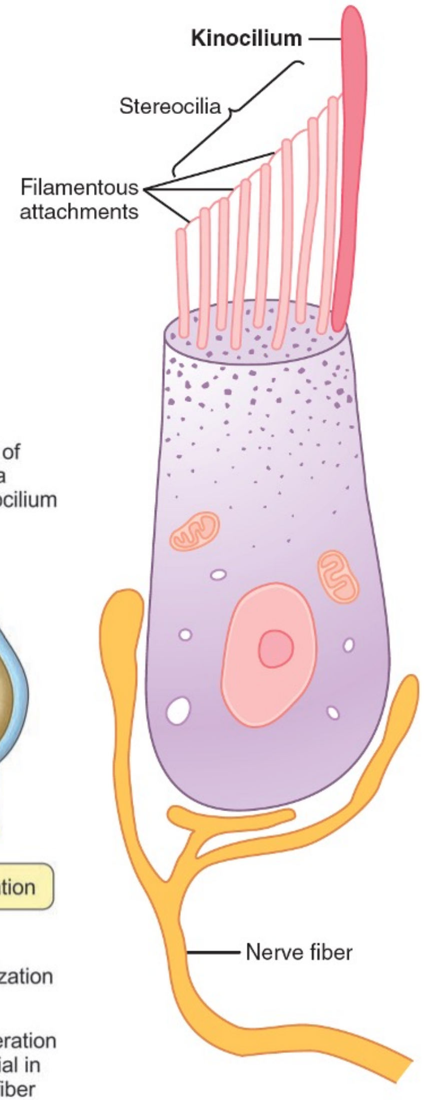
Under normal resting conditions →**continuous** nerve impulses.

Movement toward kinocilium→ **opens positive ions** channels in cell membrane→depolarization→ ↑impulse.

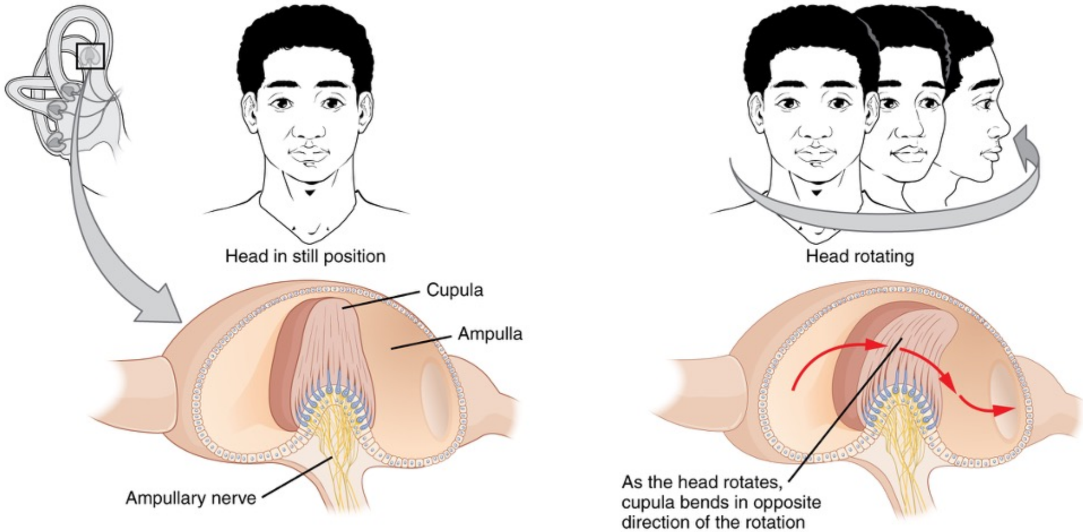
Opposite movement →closes ion channels→ receptor hyperpolarization→↓impulse

Changing head orientation →signals are transmitted via vestibular nerveto → to control equilibrium.



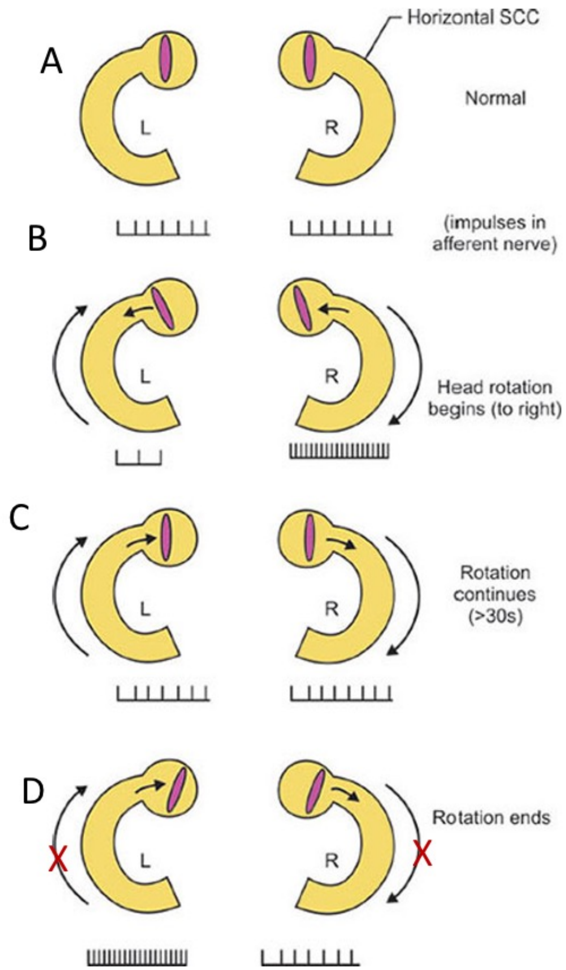


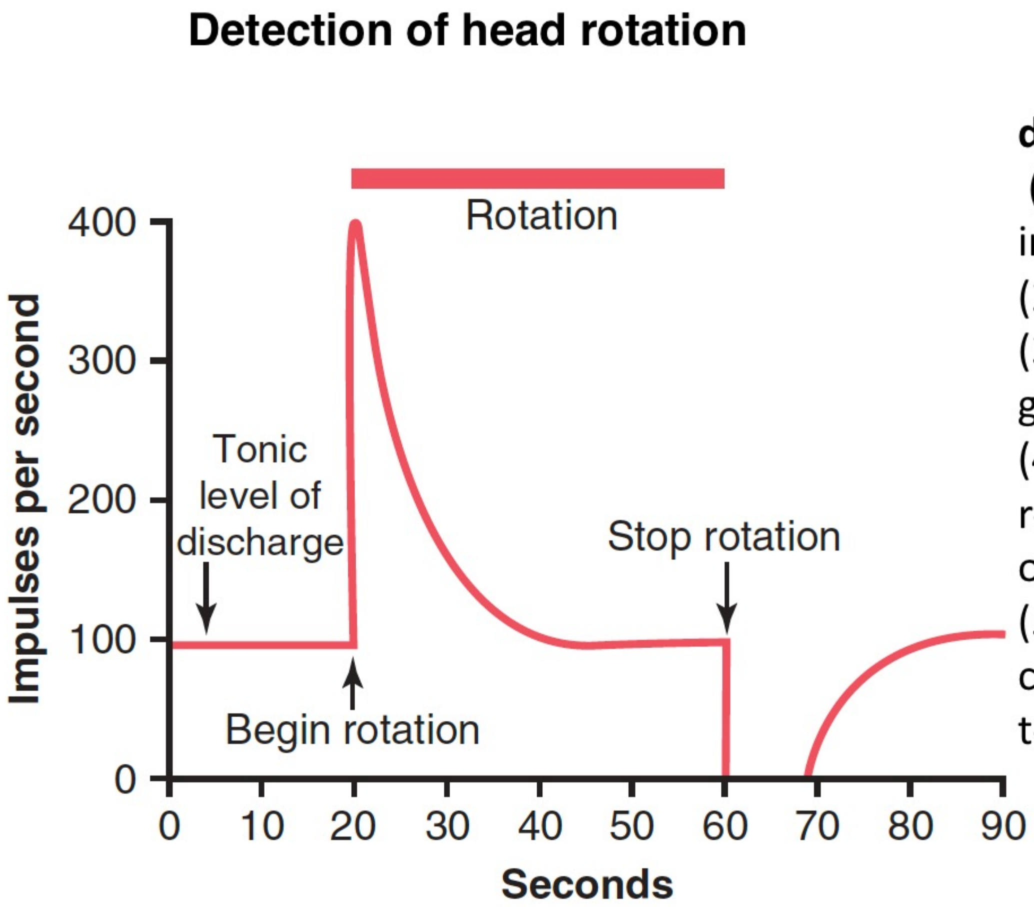
Responses to rotational acceleration



Mechanism of Stimulation of Receptor Cells in Semicircular Canal

Position	SSC movement direction	Endolymph movement direction	Cupula position In right	Crista position In left	sensation
A-Resting	-	-	midposition	midposition	No sensation of rotation
B-beginning of movement	To right	Left (inertia)	toward U-depolarization	Away from U-hyperpolarized	Rotation to right (true)
C-continuation of movement (constant speed)	To right	To right (inertia overcome)	midposition	midposition	No sensation of rotation
D-stop of movement	No movement	To right (momentum)	Away from U-hyperpolarized	toward U-depolarization	Rotation to left (false)=vertigo





discharge signal from hair cell on 40 sec rotation:

(1) cupula is in its resting position→ tonic discharge 100 impulses /sec

(2) Rotation begining →hairs bend → ↑rate of discharge

(3) continued rotation→ discharge of hair cell gradually↓ to resting.

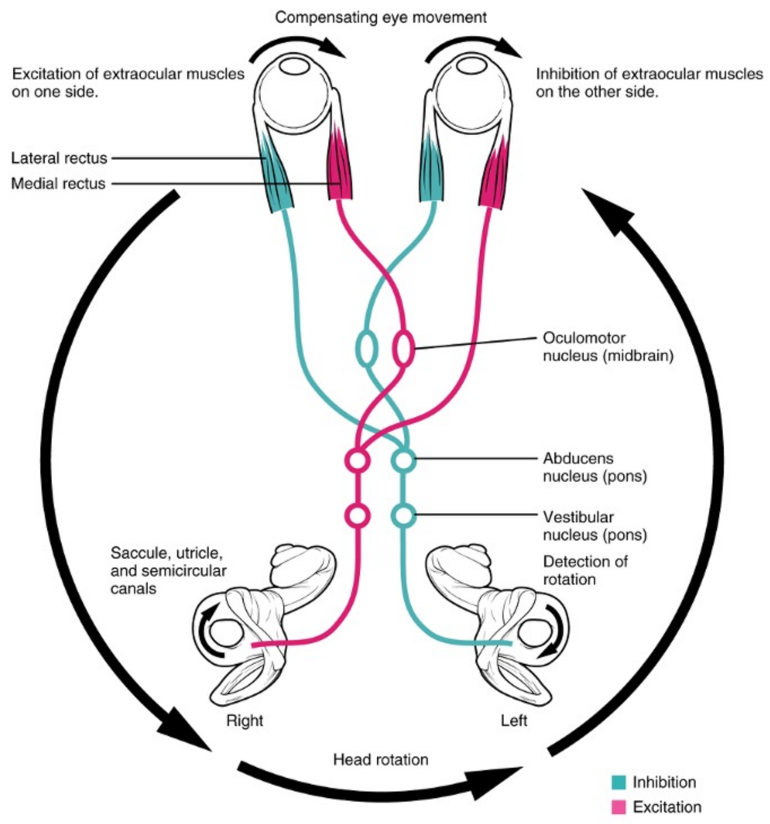
(4)rotation suddenly stops → endolymph continues to rotate but semicircular duct stops → Cupula bends in opposite direction → stop discharge

(5) After few seconds, endolymph stops moving → cupula gradually returns to its resting position → normal tonic level discharge

Vestibular Mechanisms for Stabilizing the Eyes

- Sudden head rotation →signals from **semicircular ducts** cause the eyes to rotate in direction equal and **opposite** to rotation of head.

- reflexes transmitted through vestibular nuclei & medial longitudinal fasciculus → oculomotor nuclei→ inhibition of extraocular muscles on <u>one side </u>and activation on the extraocular muscles <u>on the other side</u>.



Vestibulo-Ocular Reflexes

movement of head→ vestibular reflexes

<u>1-nystagmus</u>

in response to angular/rotational acceleration

initially → slow component of =nystagmus eyes move in **opposite direction** of the rotation to maintain a constant direction of gaze.

Followed by → rapid component of nystagmus= rapid eye movement in **same** direction as the head's rotation because eyes approach the limit of their lateral movement→ eyes fix on new position.

rotation is stopped→ postrotatory nystagmus= eyes move in opposite direction to rotation

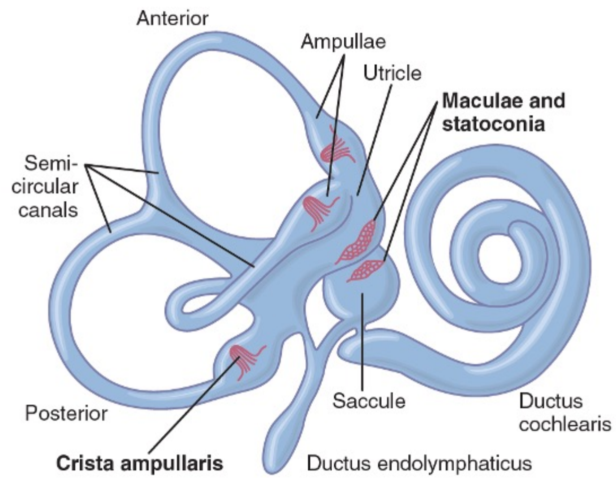
person tends to fall in **the direction** of the original rotation (due to stimulation of **contralateral extensor muscles**) because the person thinks he or she is **spinning in the opposite direction**.

RECEPTOR ORGAN IN OTOLITH ORGAN – MACULA

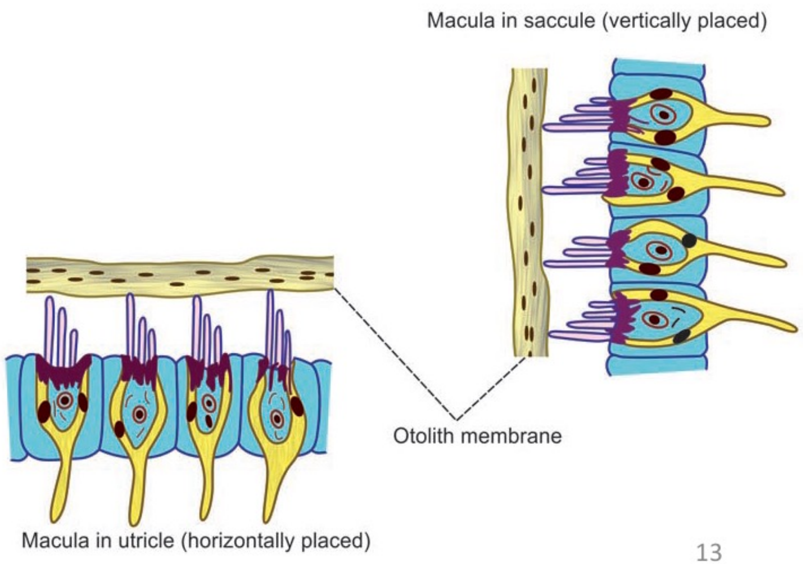
Located on the inside surface of each utricle and saccule

<u>macula of utricle</u>
Horizontal plane
determines orientation of head when the head is **upright**

<u>macula of saccule</u>
Vertical plane
determines orientation when person is **lying down**

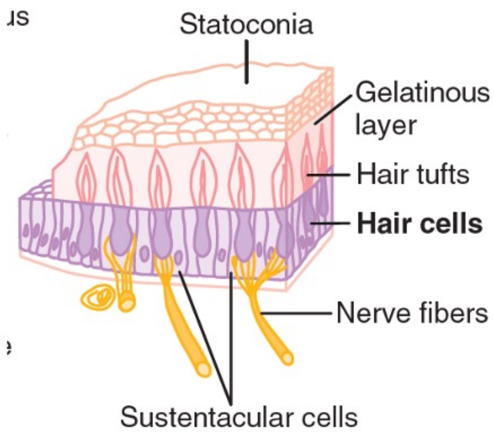


MEMBRANOUS LABYRINTH



Maculae

- covered by gelatinous layer rich in calcium carbonate crystals (statoconia)
- cilia of hair cells project up into gelatinous layer.
- hair cells synapse with sensory endings of vestibular nerve.
- weight of statoconia bends cilia in the direction of gravitational pull.



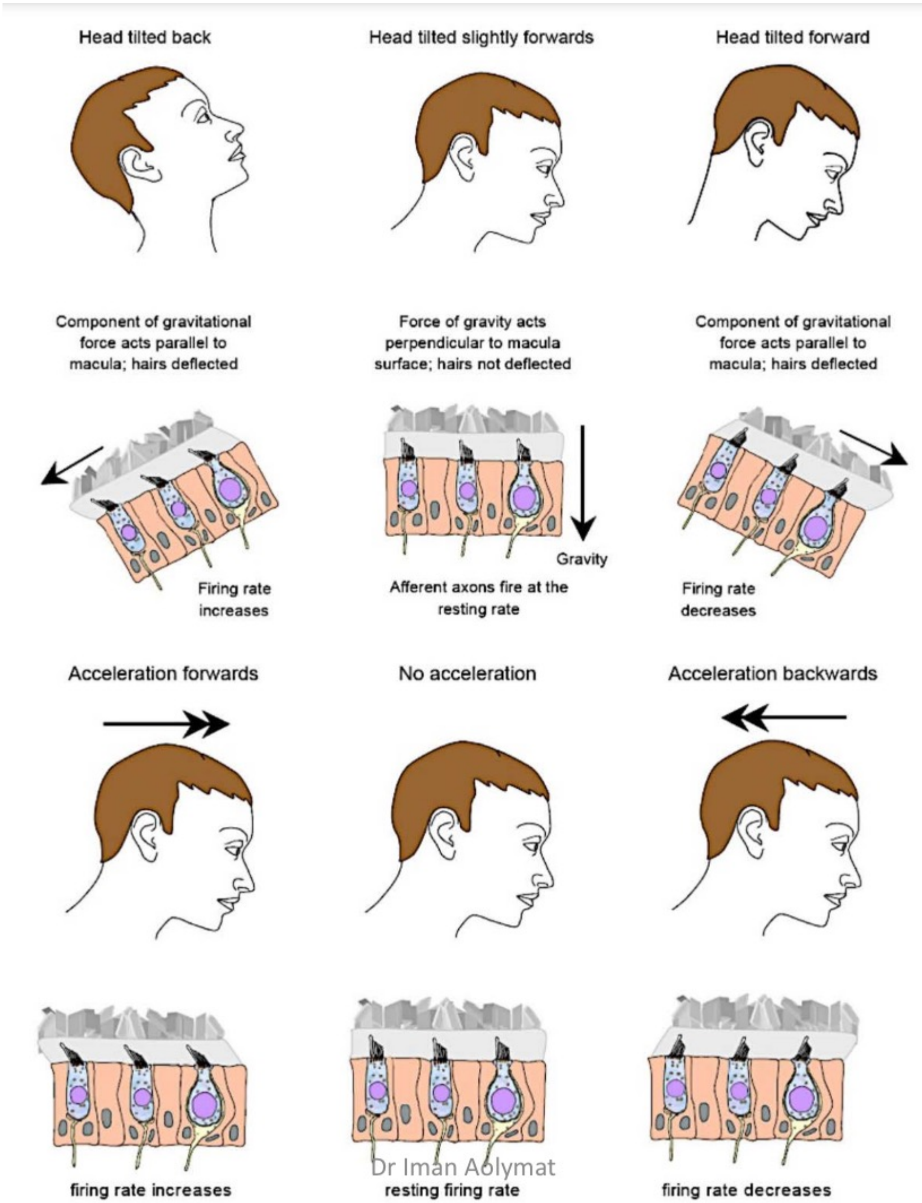
FUNCTIONS OF VESTIBULAR APPARATUS

- utricle & saccule →respond to **linear acceleration** of head.

Detection of linear acceleration by the utricle and saccule

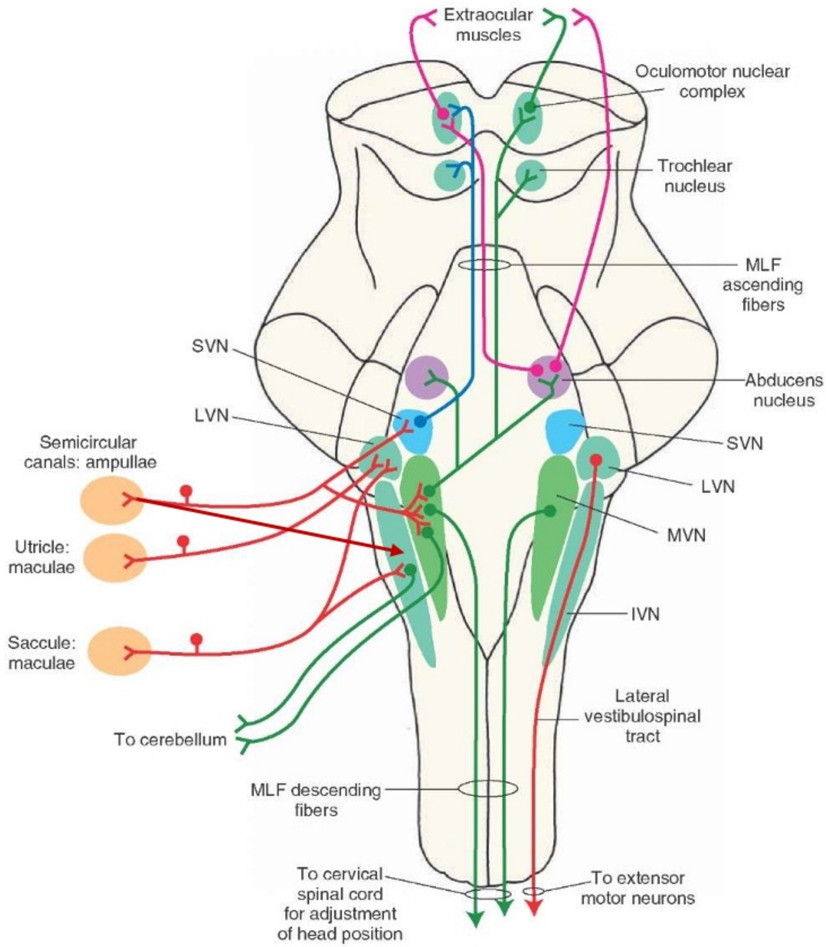
- Utricle for horizontal acceleration
- Saccule for vertical acceleration

- Forward acceleration of the body →statoconia fall backward → information of disequilibrium is sent into brain → **leaning forward** response until anterior shift of statoconia exactly matches the backward shift because of acceleration.


Head tilted back
Head tilted slightly forwards
Head tilted forward
Component of gravitational force acts parallel to macula; hairs deflected
Force of gravity acts perpendicular to macula surface; hairs not deflected
Component of gravitational force acts parallel to macula; hairs deflected
Gravity
Firing rate increases
Afferent axons fire at the resting rate
Firing rate decreases
Acceleration forwards
No acceleration
Acceleration backwards
firing rate increases
resting firing rate
firing rate decreases

vestibular, cerebellar & reticular motor nerve systems excite appropriate postural muscles to maintain proper **equilibrium**.

Neuronal Connections of the Vestibular Apparatus With the Central Nervous System

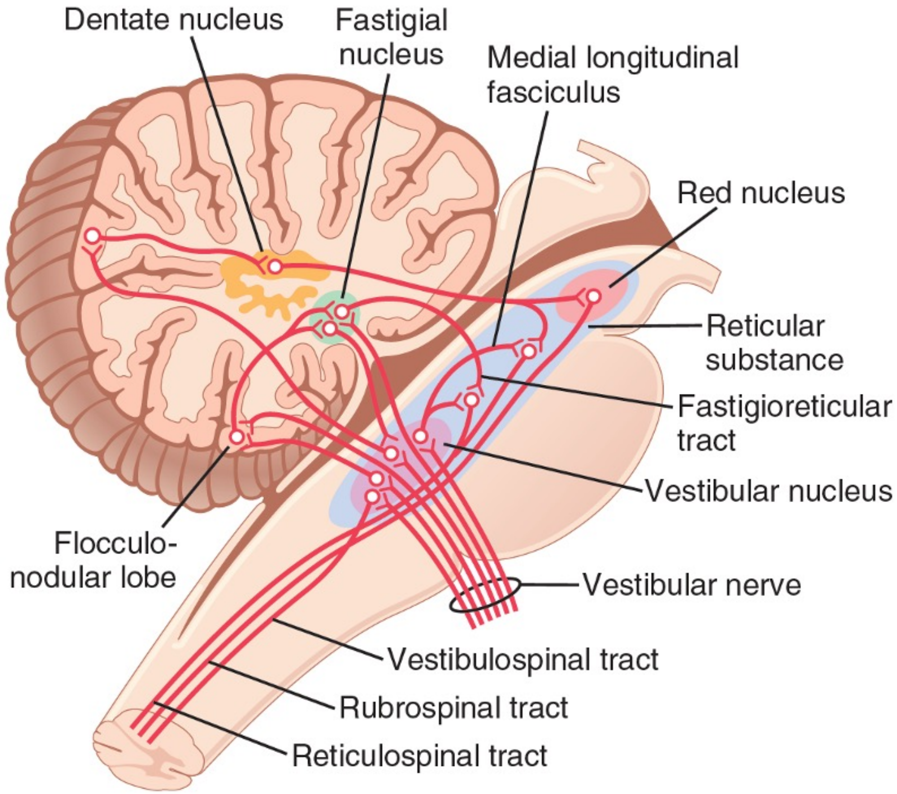


Most of vestibular nerve fibers terminate in **ipsilateral** vestibular nuclei

four vestibular nuclei in medulla→superior, inferior, lateral & medial

Superior & medial →from **crista ampullaris** of semicircular canals.
Lateral →from **maculae** of otolith organ
inferior → from both crista ampullaris and maculae.

Neuronal Connections of the Vestibular Apparatus With the Central Nervous System

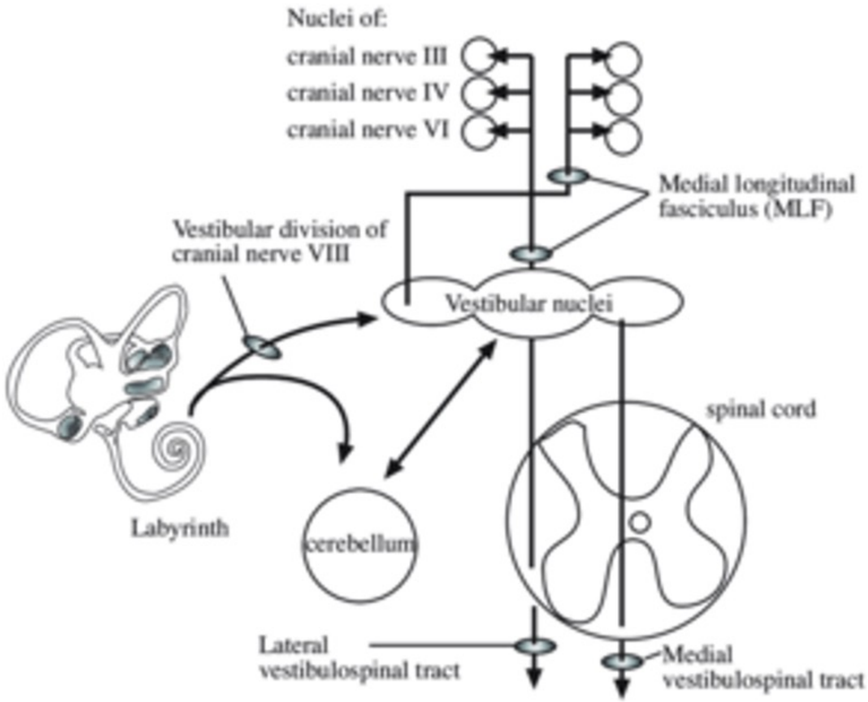


From vestibular nuclei→ synapse with
1-cerebellum
2-vestibulospinal tracts
3-medial longitudinal fasciculus
4-reticular nuclei

Some fibers pass directly to reticular nuclei/ cerebellar, fastigial, uvular, and flocculonodular lobe nuclei **without** synapsing.

Tracts form vestibular nuclei

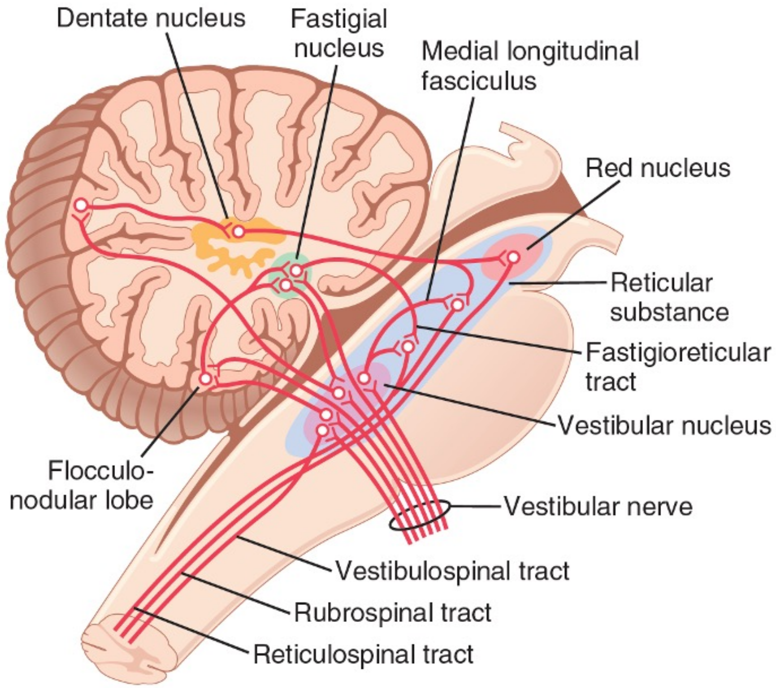
1. **<u>Vestibulo-ocular Tract</u>**
- through *<u>medial longitudinal fasciculus</u>* → nuclei of III, IV and VI cranial nerves.
- concerned with eye movements in relation to the position of the head.



Tracts form vestibular nuclei

2. **Vestibulospinal Tract**

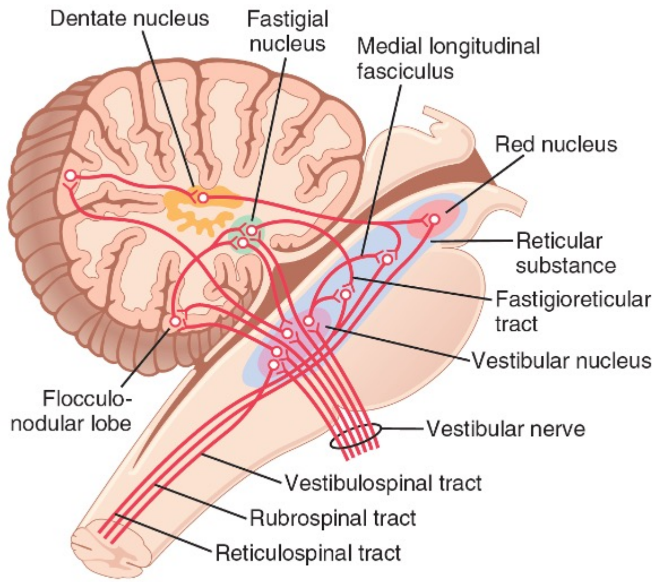
- from **lateral** nucleus→ descend downwards and form the vestibulospinal tract/ascend upward and join medial longitudinal fasciculus.
- Involved in **reflex movements of head and body** during postural changes.



Tracts form vestibular nuclei

3. **<u>Vestibuloreticular Tract</u>**
- vestibular nuclei →reticular formation of brainstem.
- concerned with the **facilitation of muscle tone**.

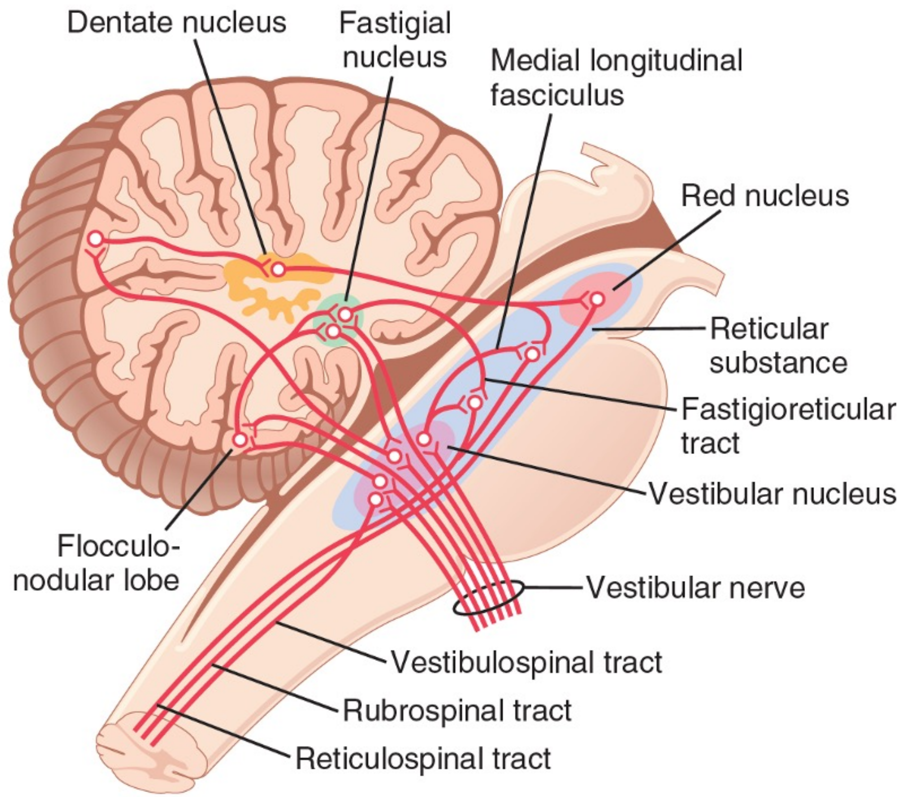
4. **<u>Vestibulocerebellar Tract</u>**
- Fibers rom all four vestibular nuclei and terminate in flocculonodular lobe and fastigial nuclei of cerebellum.
- involved in **coordination of movements** according to body position.



equilibrium reflexes

equilibrium reflexes pathways begins in
vestibular nerves →
vestibular nuclei & cerebellum →
reticular nuclei & spinal cord by
vestibulospinal & reticulospinal tracts.

signals to cord control antigravity
muscles→controlling equilibrium.



Vestibular disorders

1-**unilateral lesion in the vestibular pathway**→ **nystagmus** is reduced or absent on the side of the lesion

2-**Benign paroxysmal positional vertigo**
- the most common vestibular disorder
- characterized by episodes of vertigo that occur with particular changes in body.

3- **Ménière disease**
- abnormality of the inner ear that causes vertigo, tinnitus, hearing loss, and sensation of pressure or pain in the affected ear.

4- **motion sickness**
- nausea, sweating, pallor, and vomiting
- occur when conflicting information is fed into the vestibular and other sensory systems.

The End

Chemical senses-Smell

Smell

- least understood of all senses.
- poorly developed in humans.

Importance of smell

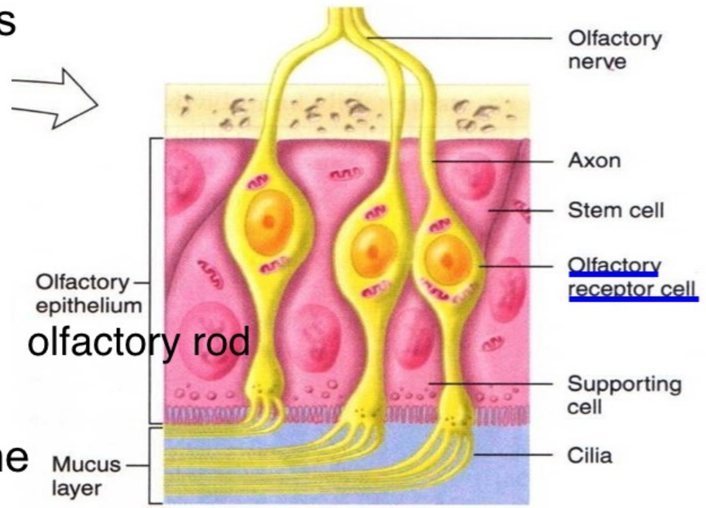
- Enjoyment & selection of food .
- Flavours are combinations of taste and smell (smell contribution about 80%)
- Gives warning of harmful substances or places

OLFACTORY MEMBRANE

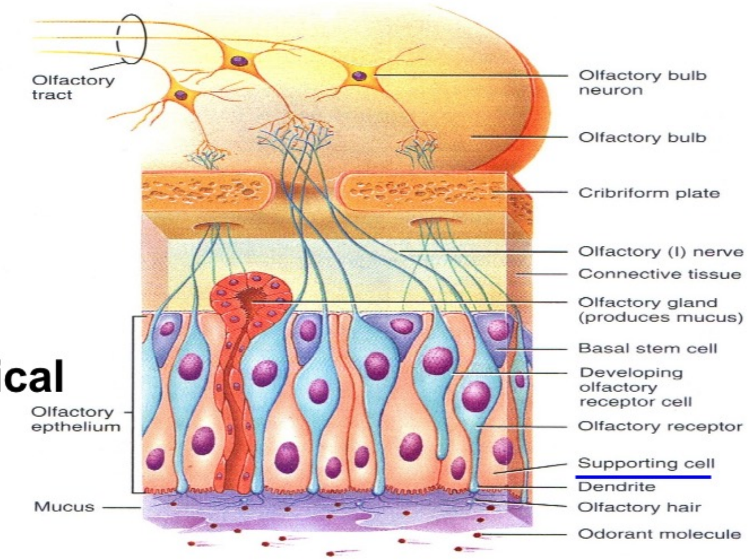
- located on superior part of each nostril.
- The olfactory epithelium consists of three kinds of cells:
  - olfactory receptors
  - supporting cells / sustentacular cells
  - basal cells

Olfactory receptors

- The **receptor cells** for the smell sensation are the olfactory cells
- They are actually **bipolar nerve cells** derived from the CNS
- There are about 100 M of these cells in the olfactory epithelium.
- The mucosal end of the olfactory cell forms a knob .
- From knob 4 to 25 olfactory hairs (olfactory cilia), project into the mucus that coats the inner surface of the nasal cavity.
- These projecting olfactory cilia form a dense mat in the mucus.
- These cilia react to odours in the air and stimulate the olfactory cells



Supporting cells/sustentacular cells



- The receptor cells in the olfactory epithelium are interspersed among sustentacular cells or supporting cells.

- They provide **physical support**, **nourishment and electrical insulation** for the olfactory receptors

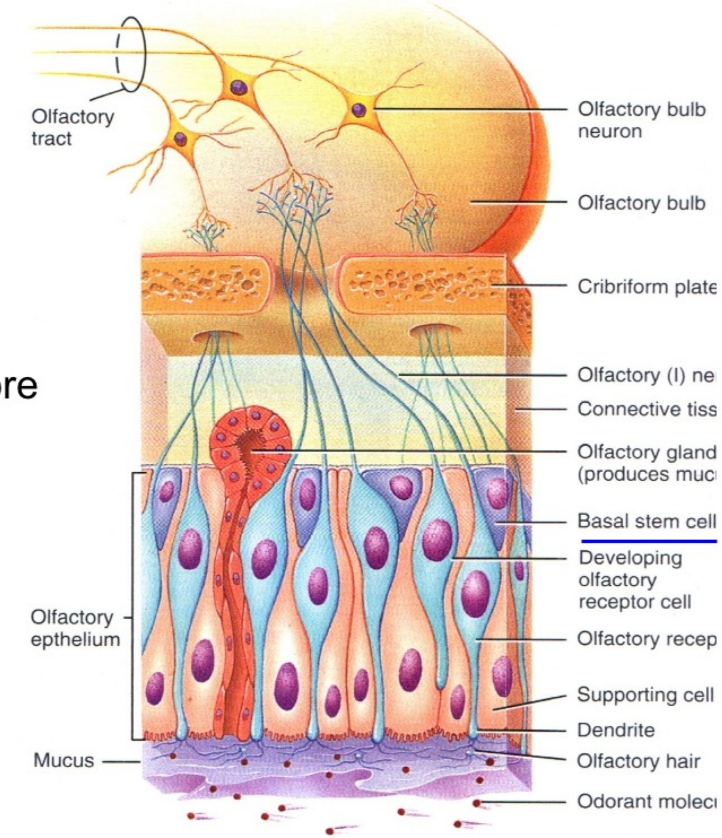
- They help detoxify chemicals that come in contact with the olfactory epithelium.

Basal cells

- **Basal cells** are stem cells located between the bases of the supporting cells.

- They continually undergo cell division to **produce new olfactory receptors,** which live for only a month or so before being replaced.

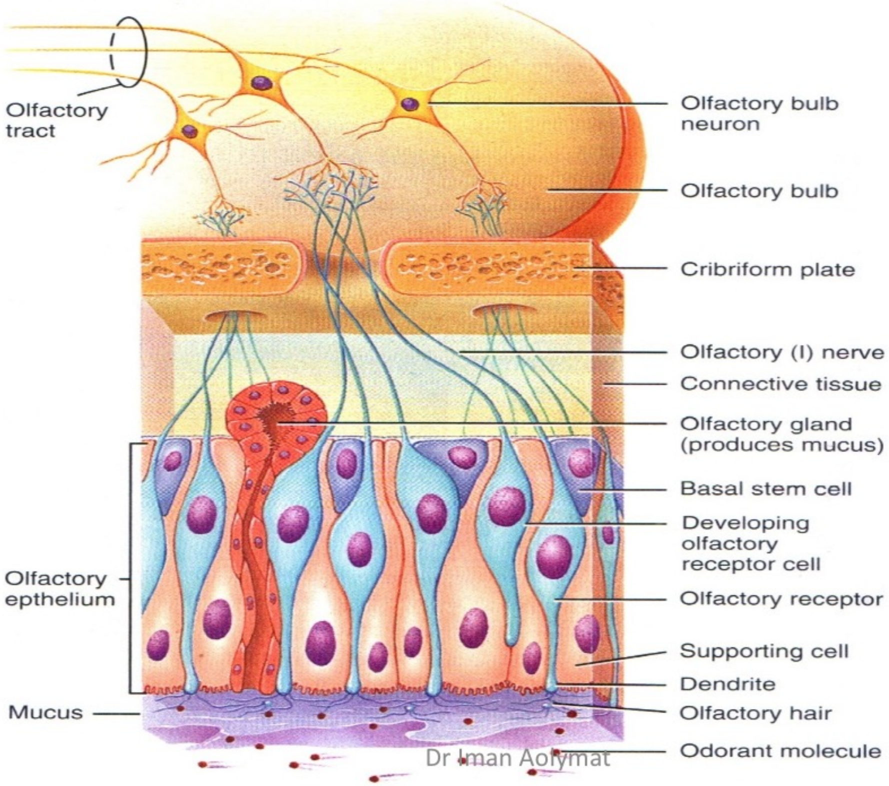
- The olfactory renewal process is carefully regulated - a bone morphogenic protein (BMP) exerts an inhibitory effect.



➢Spaced among the olfactory cells in the olfactory membrane are many small Bowman's glands that secrete **mucus** onto the surface of the olfactory membrane

➢mucus is carried to the surface of the epithelium by ducts.

➢The secretion **moistens** the surface of the olfactory epithelium and **dissolves odourants** so that transduction can occur.



MECHANISM OF EXCITATION OF OLFACTORY CELLS.

on the cilia are odorant-binding proteins

binding of odorant to protein induces a G-protein (G_{olf}) transduced formation of cAMP which opens ion channels.

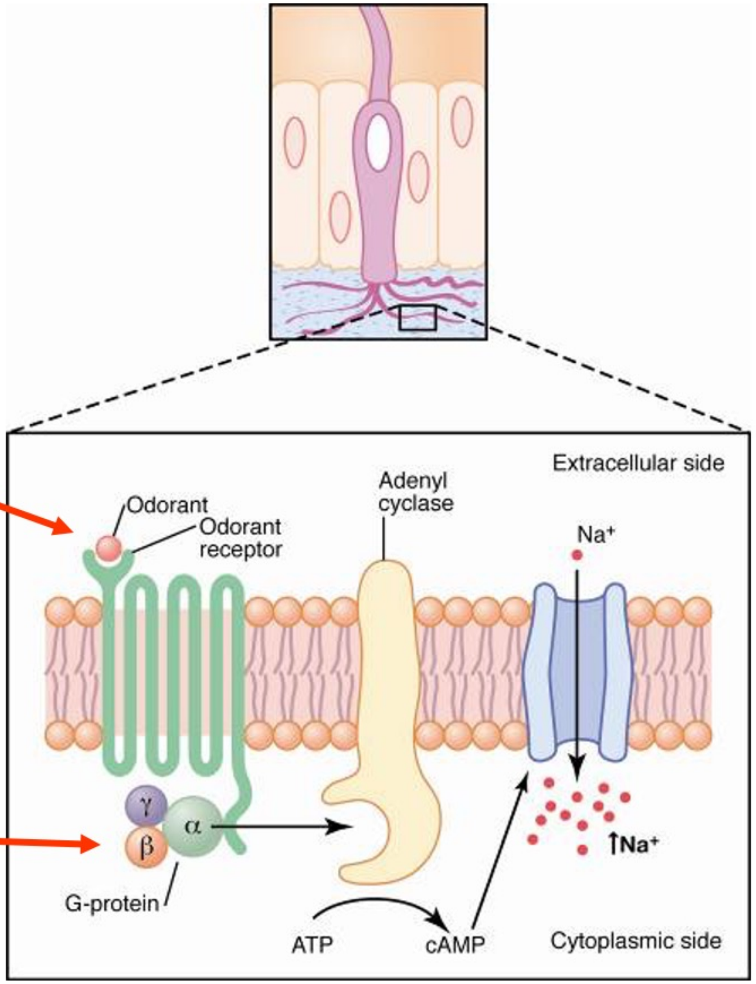


Figure 53-4

Na influx → receptor potential
Depolarization (-30mV → AP

RMP -55mV

Mechanism of olfactory cell stimulation

Odourant + receptor protein

↓

Activation of G protein

↓

Activation of adenylate cyclase

↓

ATP → cAMP

↓

Opening of Na^+ channels

↓

Na^+ influx

↓

depolarization

To Be Smelled

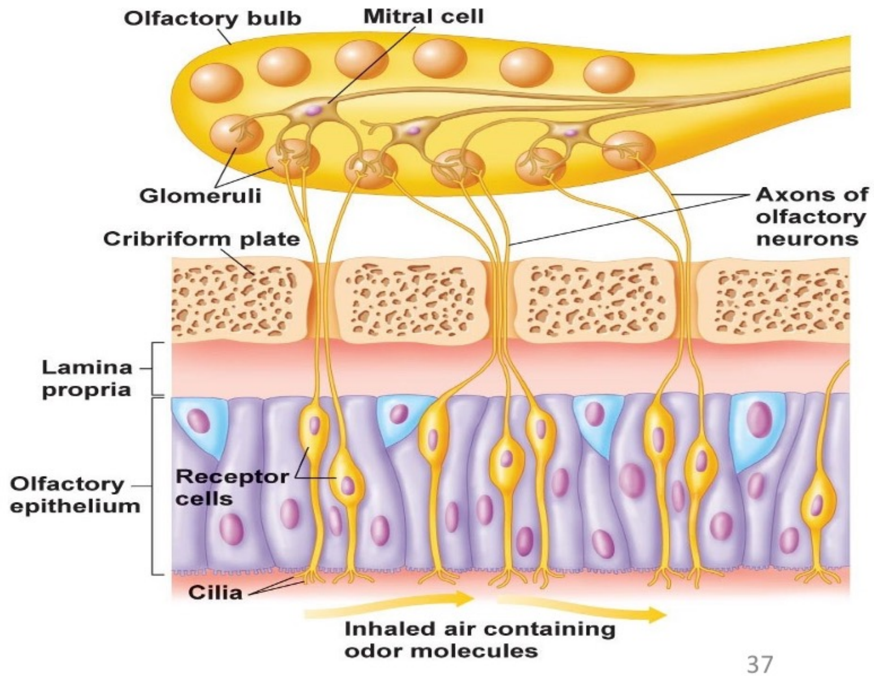
- substance must be **volatile** so that it can be sniffed into the nostrils.
- substance must be at least **slightly water soluble** to penetrate the mucus to reach the olfactory cells.
- substance must be at least **slightly lipid soluble** to interact with the membrane.
- olfactory receptors adapt very slowly.
- olfactory sensation itself adapts rather rapidly.
- must involve a central mechanism.

OLFACTORY PATHWAY

- Axons of olfactory neurons pass through perforations in the cribiform plate to enter olfactory bulb in the cranial cavity.

- Short axons from the olfactory cells terminate in multiple globular structures within the olfactory bulb called glomeruli.

- Each bulb has several thousand such glomeruli, each of which is the terminus for about 25,000 axons from olfactory cells.



OLFACTORY PATHWAY

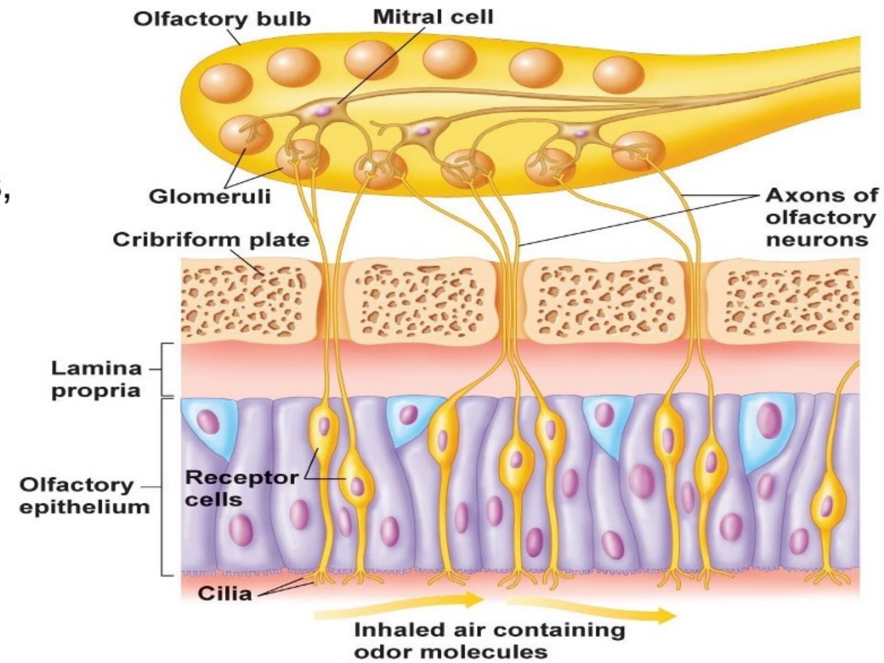
- Each glomerulus also is the terminus for dendrites from about 25 large mitral cells and about 60 smaller tufted cells, the cell bodies of which lie in the olfactory bulb superior to the glomeruli.

- These dendrites receive synapses from the olfactory cell neurons,

- the mitral and tufted cells send axons through the olfactory tract to transmit olfactory signals to higher levels in the central nervous system.

- Some research has suggested that different glomeruli respond to different odours.

- Olfactory nerve fibers leading from olf.bulb are called Cranial nerve I or olf. Tract.



Olfactory pathways into the Central Nervous System

- The olfactory tract enters the brain at the **anterior junction** between the mesencephalon and cerebrum

- there, the tract divides into two pathways, one passing medially into the medial olfactory area (primitive olfactory system) of the brain stem, and the other passing laterally into the lateral olfactory area.

- The medial olfactory area represents a very old olfactory system, whereas the lateral olfactory area is the input to

(1) A less old olfactory system and (2) a newer system

olfactory nerve is
the first cranial nerve

medial (old)
and lateral (new)
olfactory area

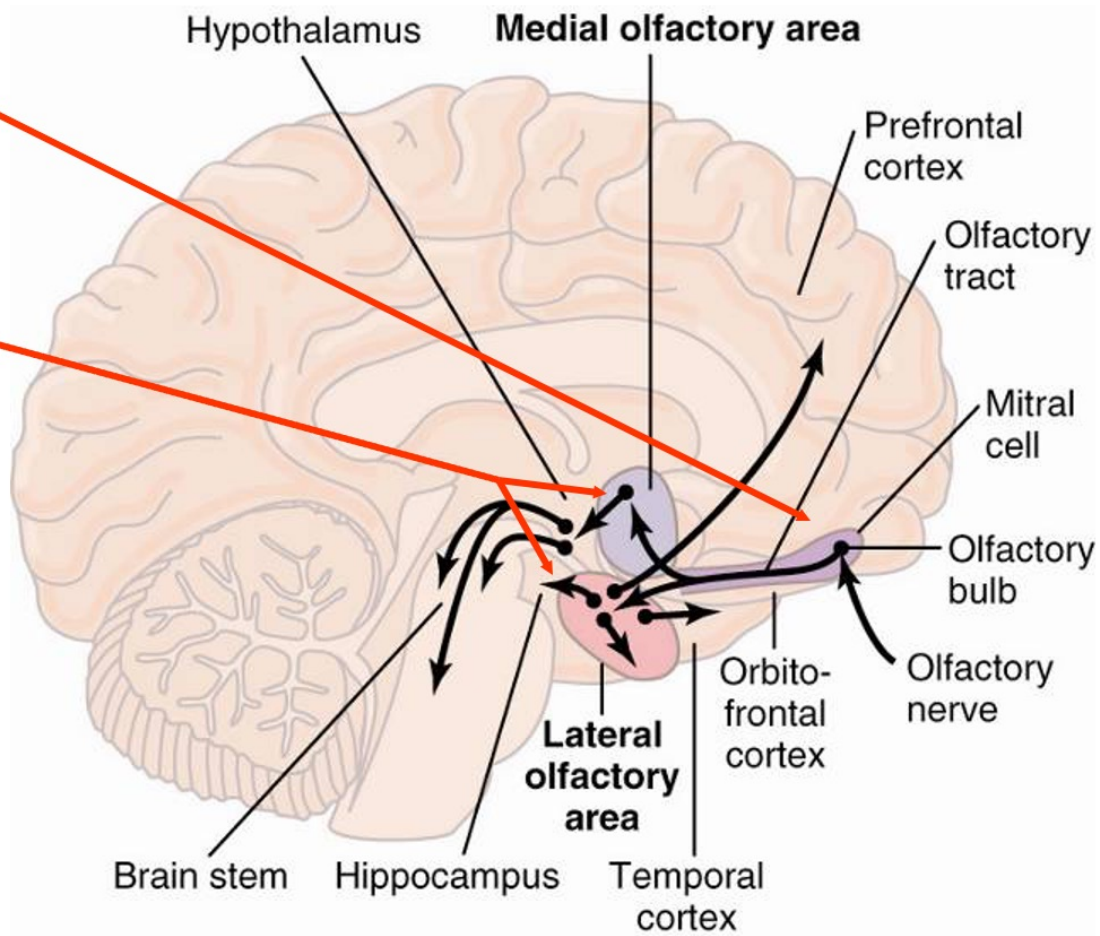
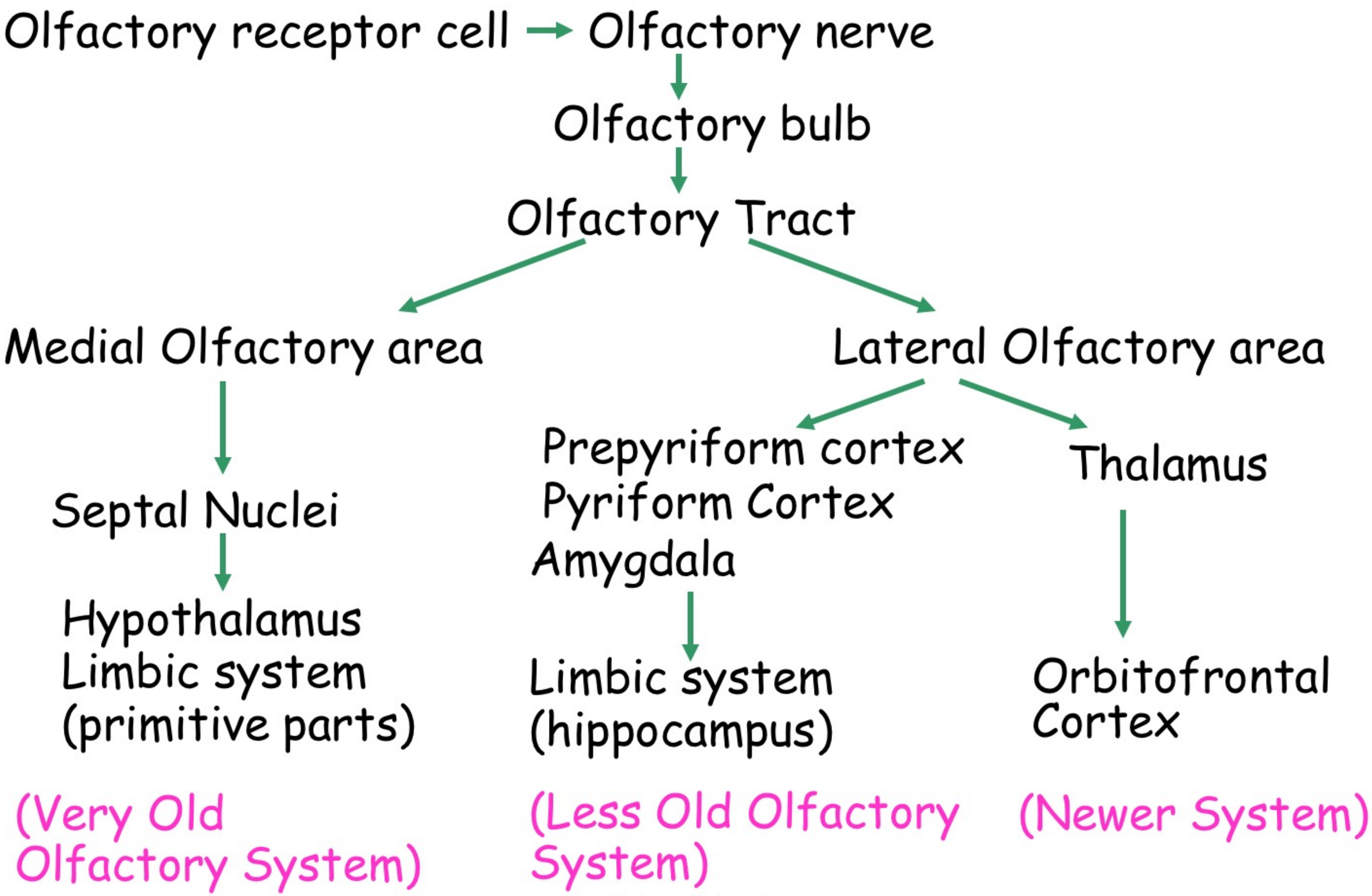


Figure 53-5

Olfactory pathway



Very Old Olfactory System

- More primitive responses to olfaction

  - salivation, liking lips and primitive emotional drives to smell=basic olfactory reflexes

Less Old Olfactory System

- Learned control of food intake

  - Aversion to food that have caused nausea and vomiting.

Newer System

- Conscious perception & analysis of odour

  - Odour discrimination

ABNORMALITIES OF OLFACTORY SENSATION

- ANOSMIA

total loss of smell sensation
Temporary anosmia
obstruction of nose- common cold, nasal sinus and allergic conditions.
Permanent anosmia –olfactory tract lesion, meningitis and ND

- HYPOSMIA

reduced ability to recognize and to detect any odor.
the most common disorder of smell.

- HYPEROSMIA=olfactory hyperesthesia

increased or exaggerated olfactory sensation.
brain injury, epilepsy and neurotic conditions.

The End