Systems Neuroscience
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Vestibular system & chemical senses

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http: www.ini.unizh.ch/~kiper/system_neurosci.html

VESTIBULAR SYSTEM

A central role in the maintenance of equilibrium and gaze stability.

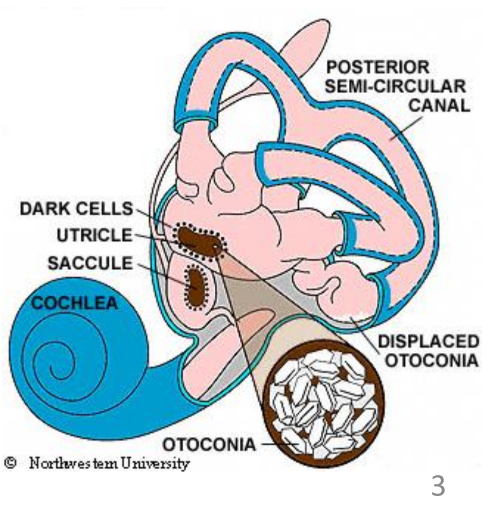
The vestibular system, by means of its receptors for the perception of linear and angular acceleration, plays a central role in orientation.

Designed to answer two basic questions:

Which way is up?
In which direction am I moving?

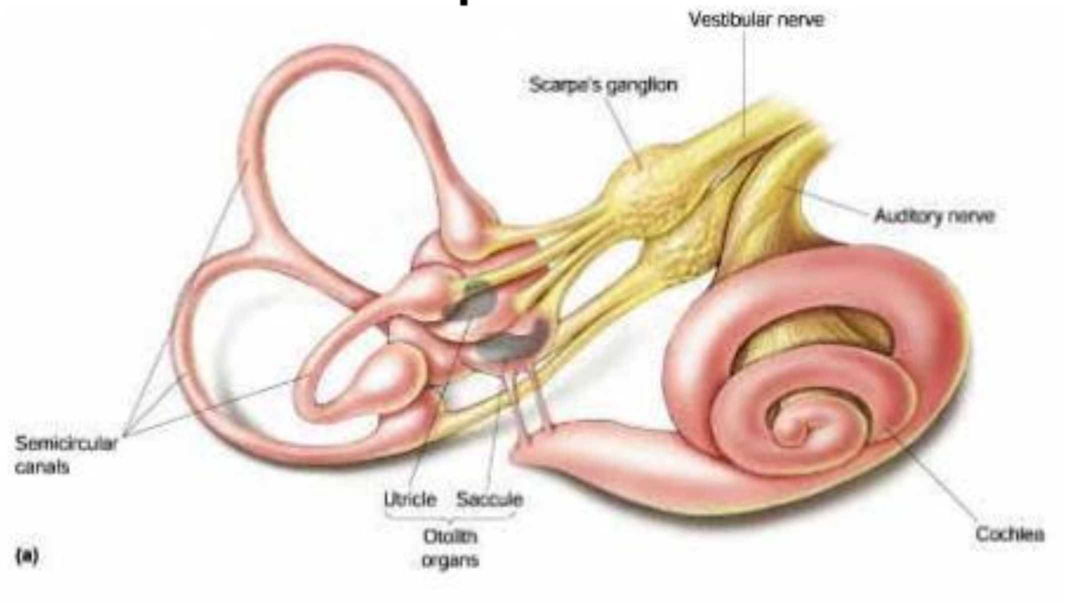
VESTIBULAR SYSTEM

- Very elusive to test
- Five peripheral “receptors” (three semicircular canals, utricule, saccule)
- Nerve (sub-divisions)
- Central connections
- Cortical area



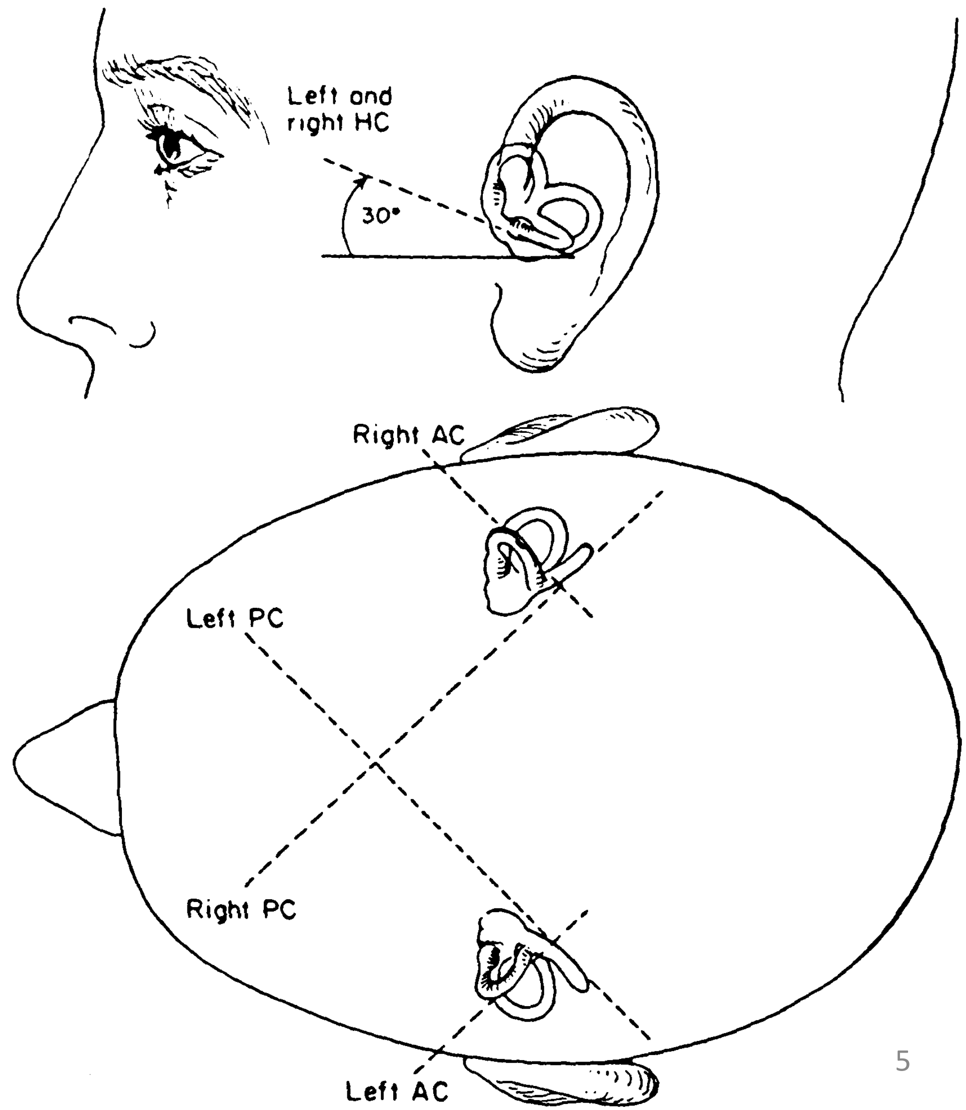
Vestibular system

- Semicircular canals: respond to rotation acceleration of the head
- Otolith organs: respond to linear acceleration and static position
  - Utricle
  - Saccule



The Semicircular Canals

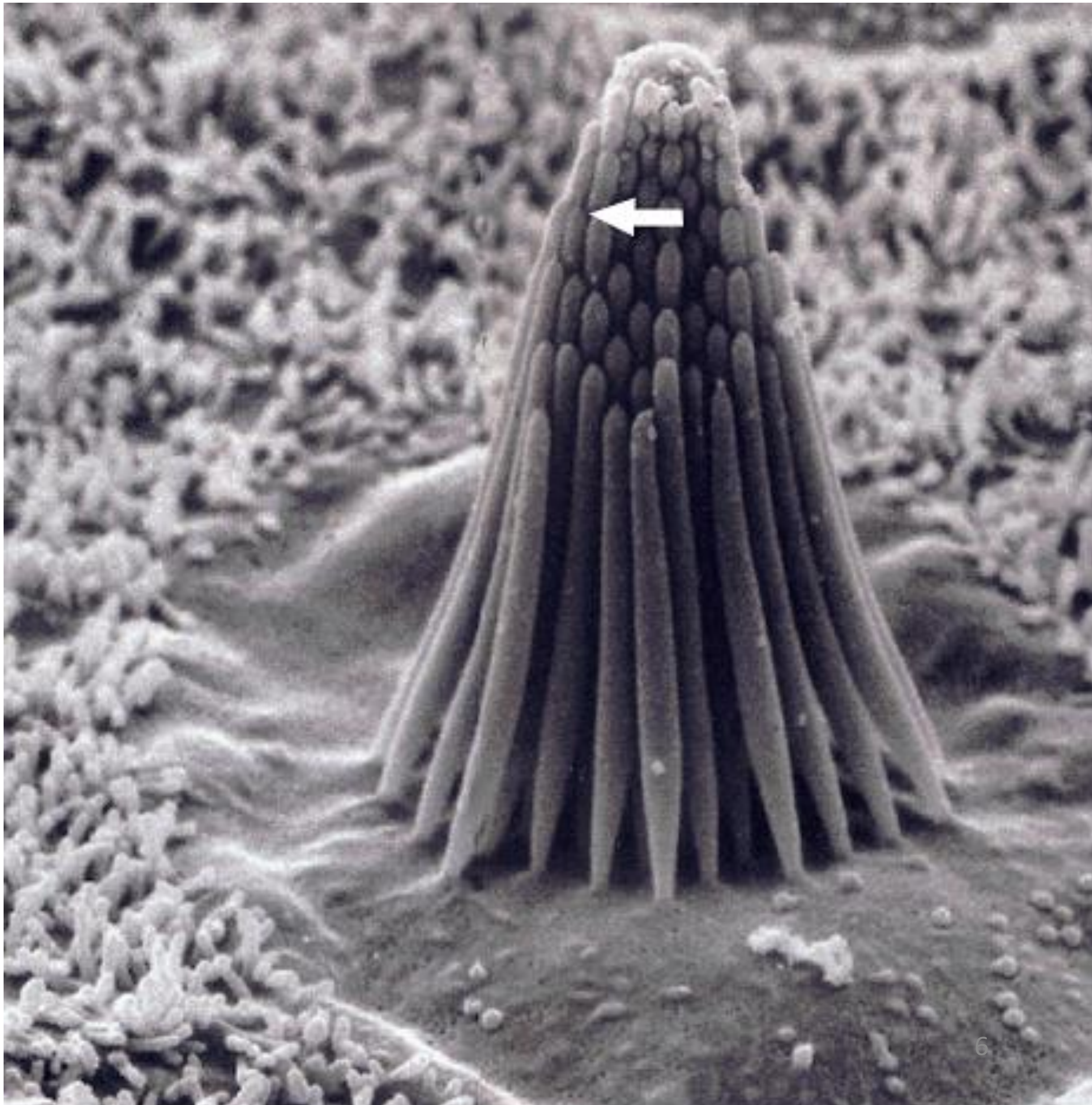
- posterior canal shares plane with contralateral anterior canal.
- horizontal canals share plane.

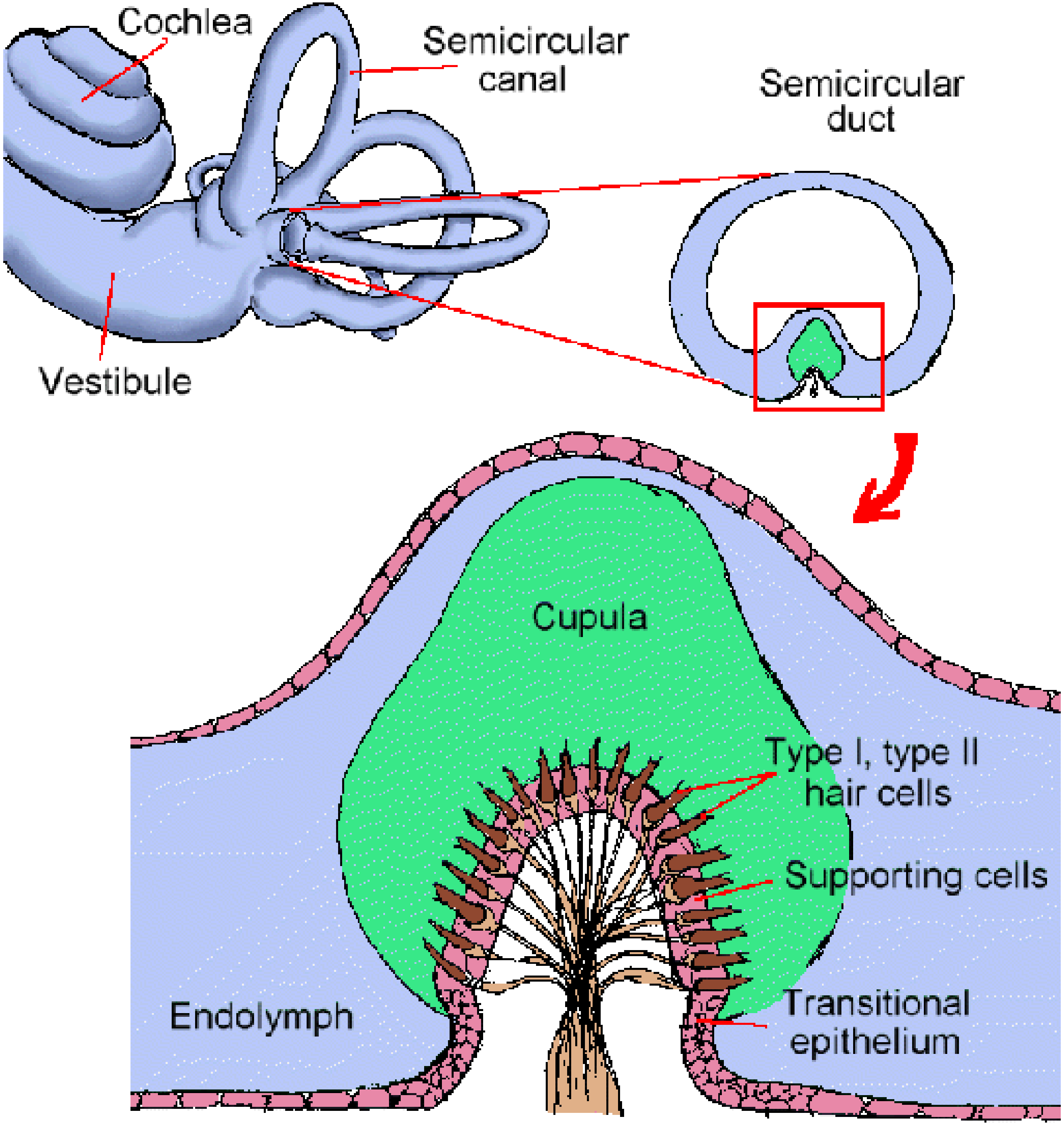


Vestibular Hair Cells

- Type I
  (aka inner)
- Type II
  (aka outer)

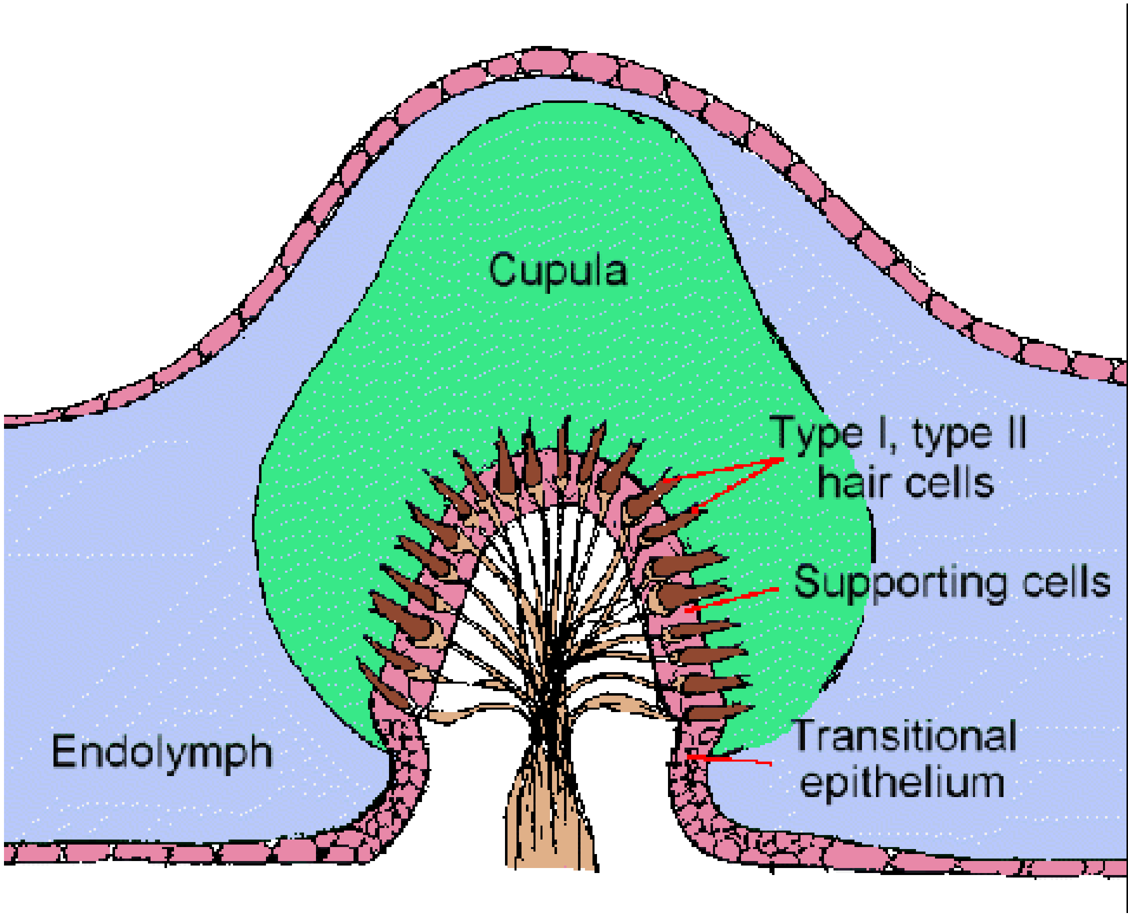
With
Kinocilium



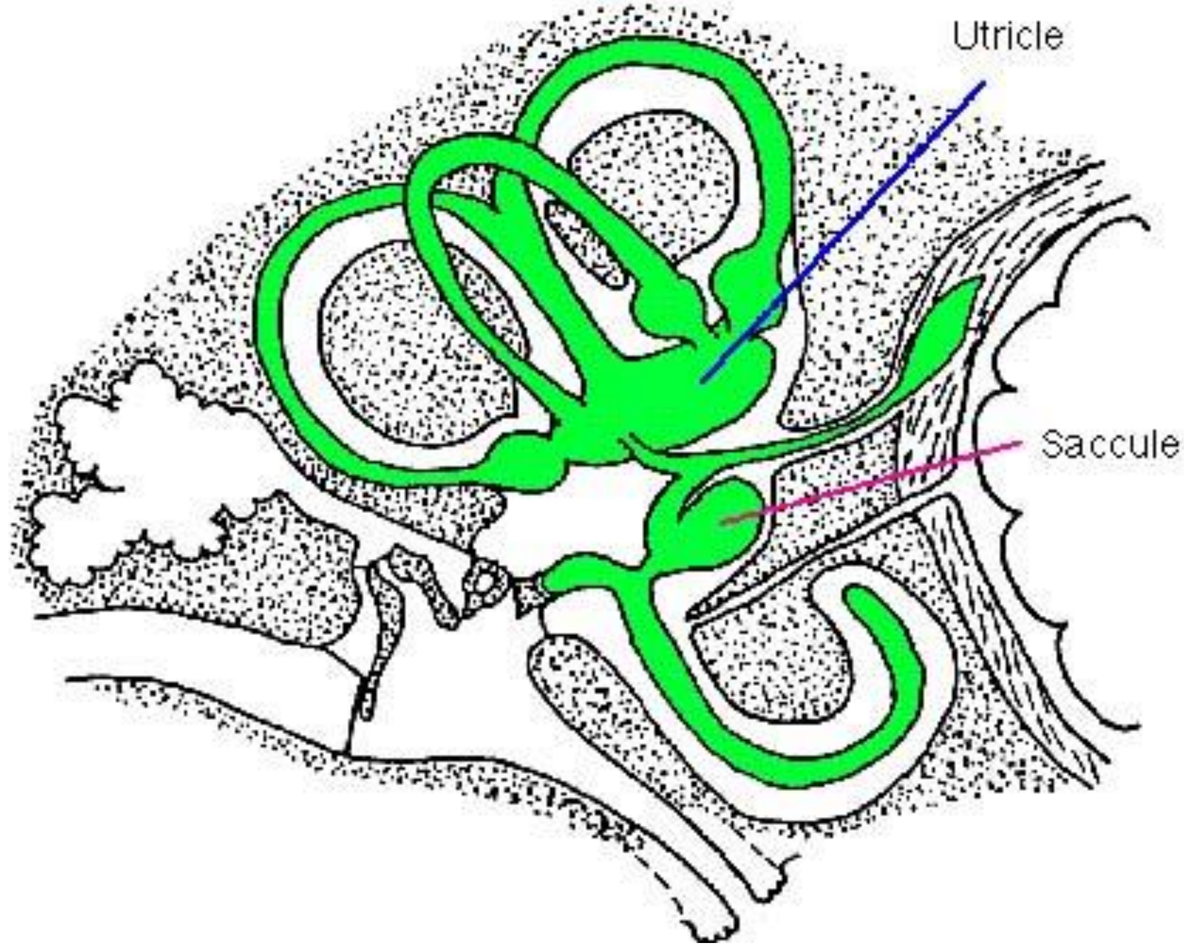

Cochlea
Semicircular canal
Semicircular duct
Vestibule
Cupula
Type I, type II hair cells
Supporting cells
Endolymph
Transitional epithelium

Responses of the Cristae

- All kinocilia are oriented in the same direction
- Crista in each pair of canals respond inversely to each other



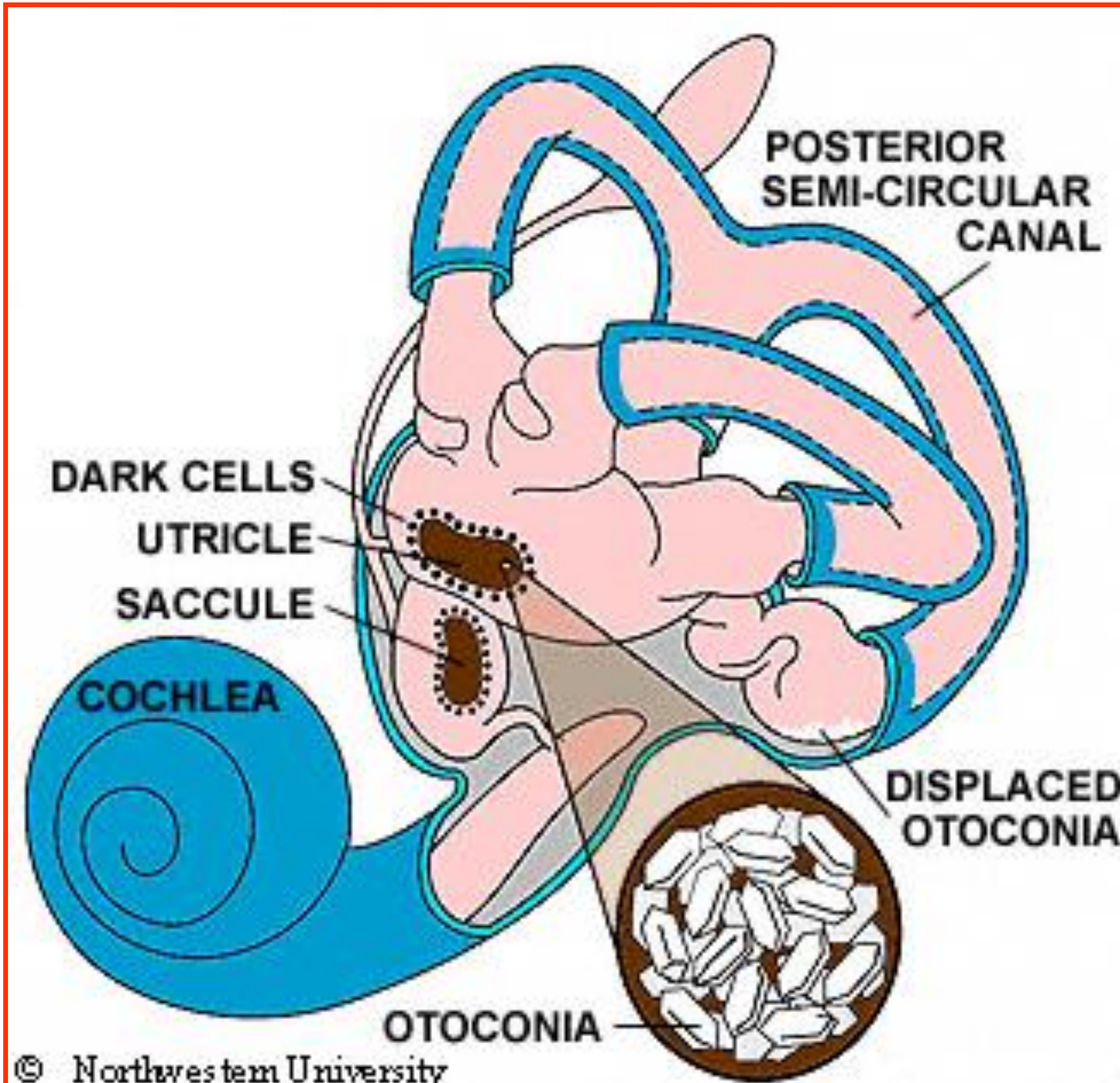
The Otolithic Organs

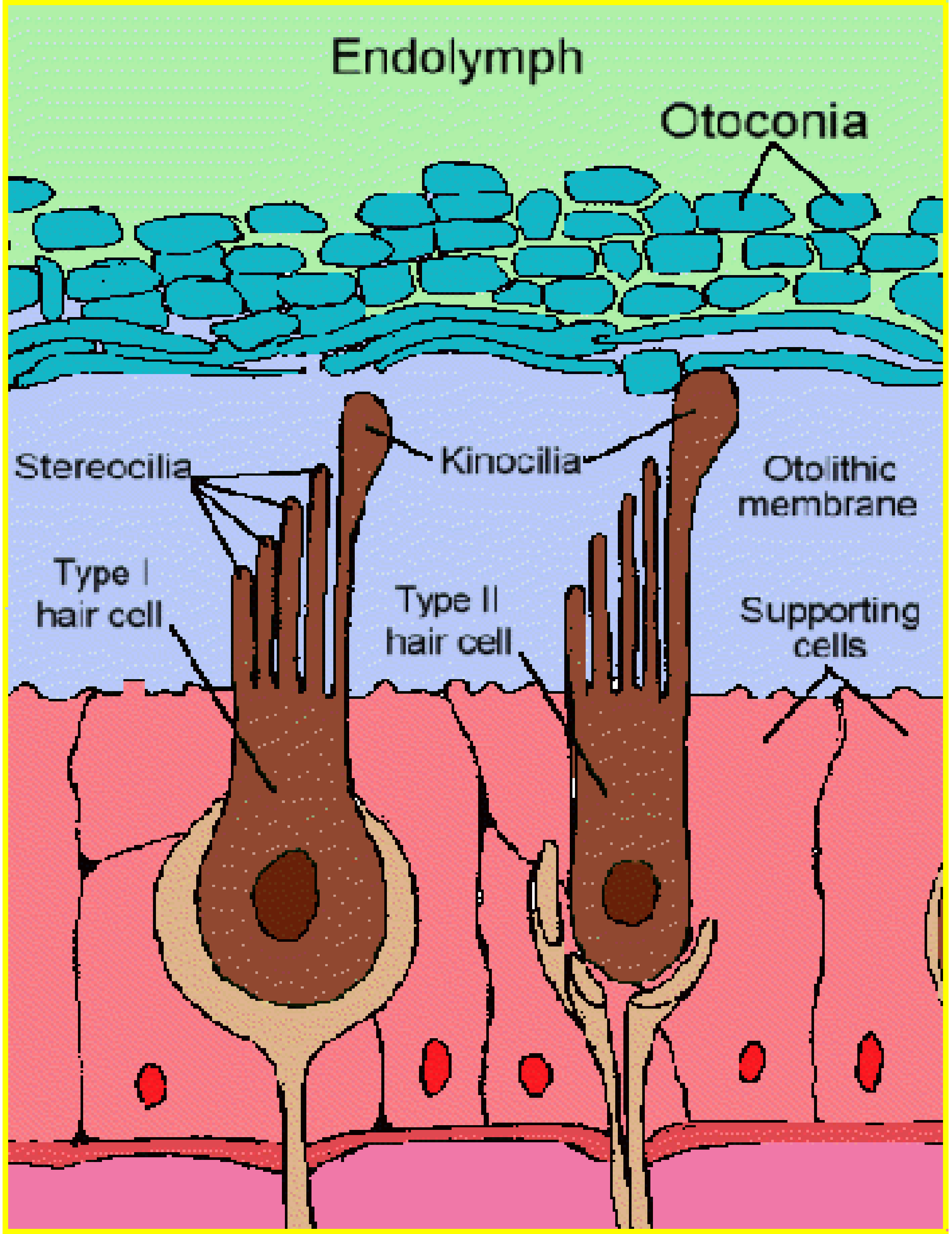


Saccule: roughly vertical orientation,

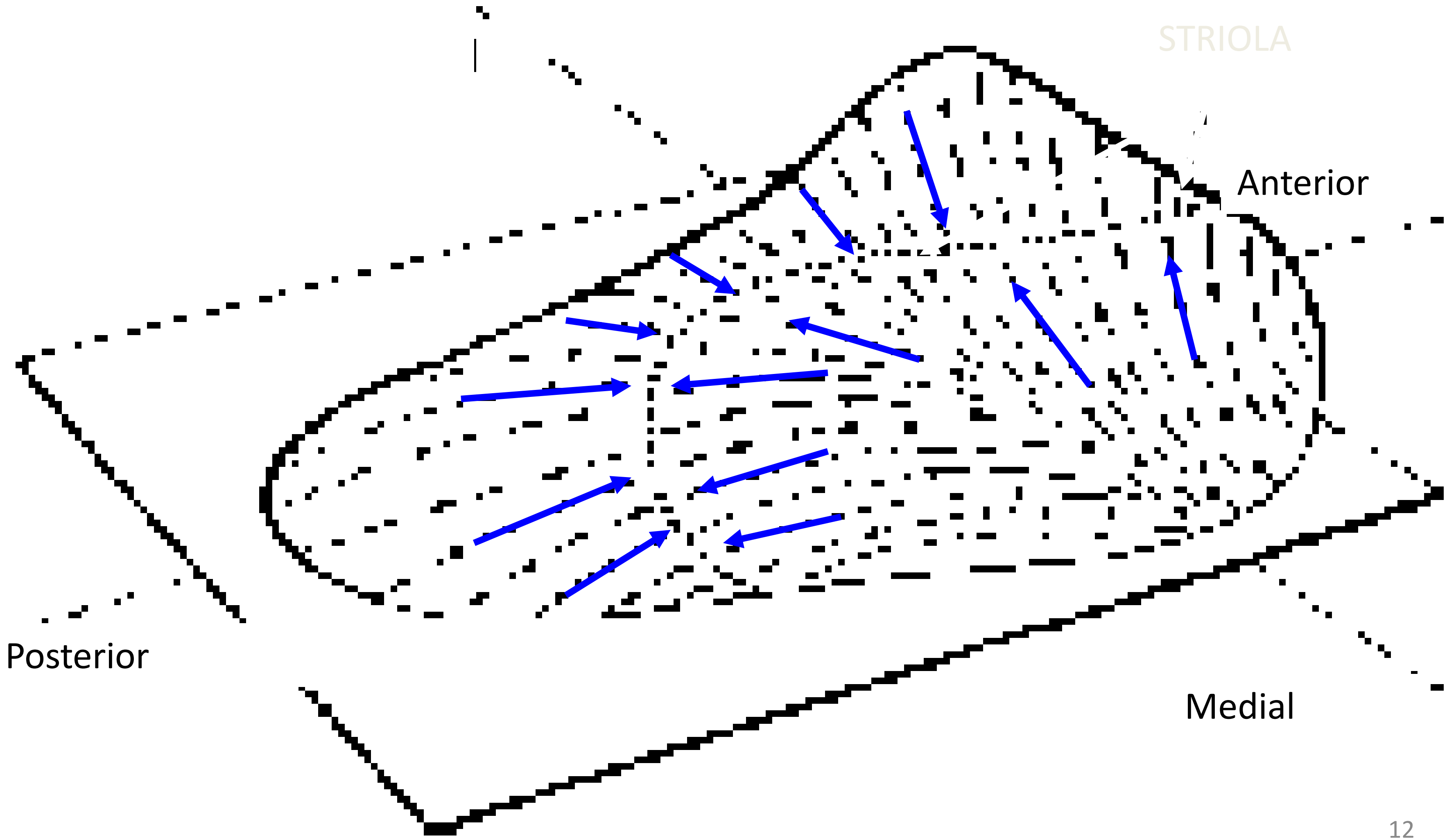
responds to acceleration components within saggital plane

Utricle: horizontal (+ 30 deg.) orientation

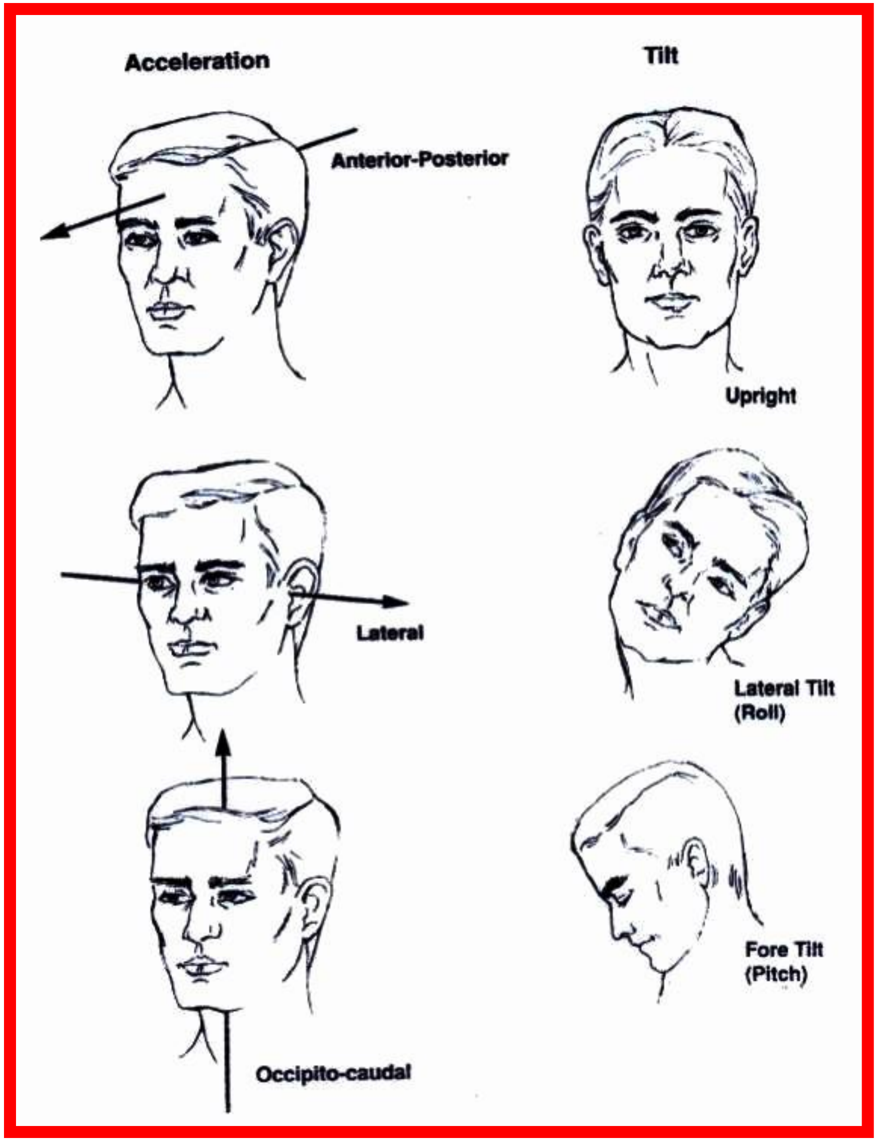

POSTERIOR
SEMI-CIRCULAR
CANAL
DARK CELLS
UTRICLE
SACCULE
COCHLEA
DISPLACED
OTOCONIA
OTOCONIA
© Northwestern University


Endolymph
Otoconia
Stereocilia
Kinocilia
Otolithic membrane
Type I hair cell
Type II hair cell
Supporting cells

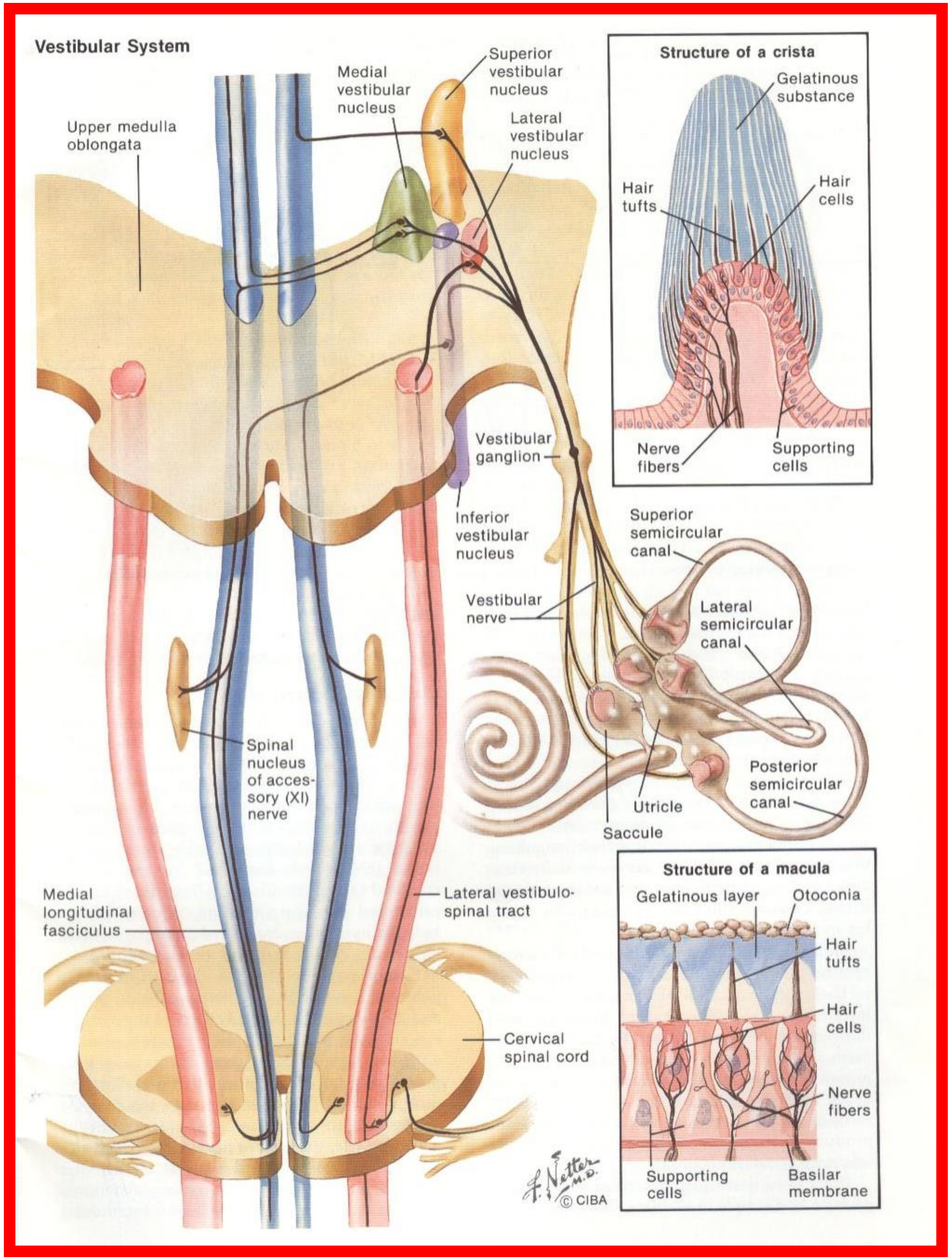
Excitation Patterns in the Utricle

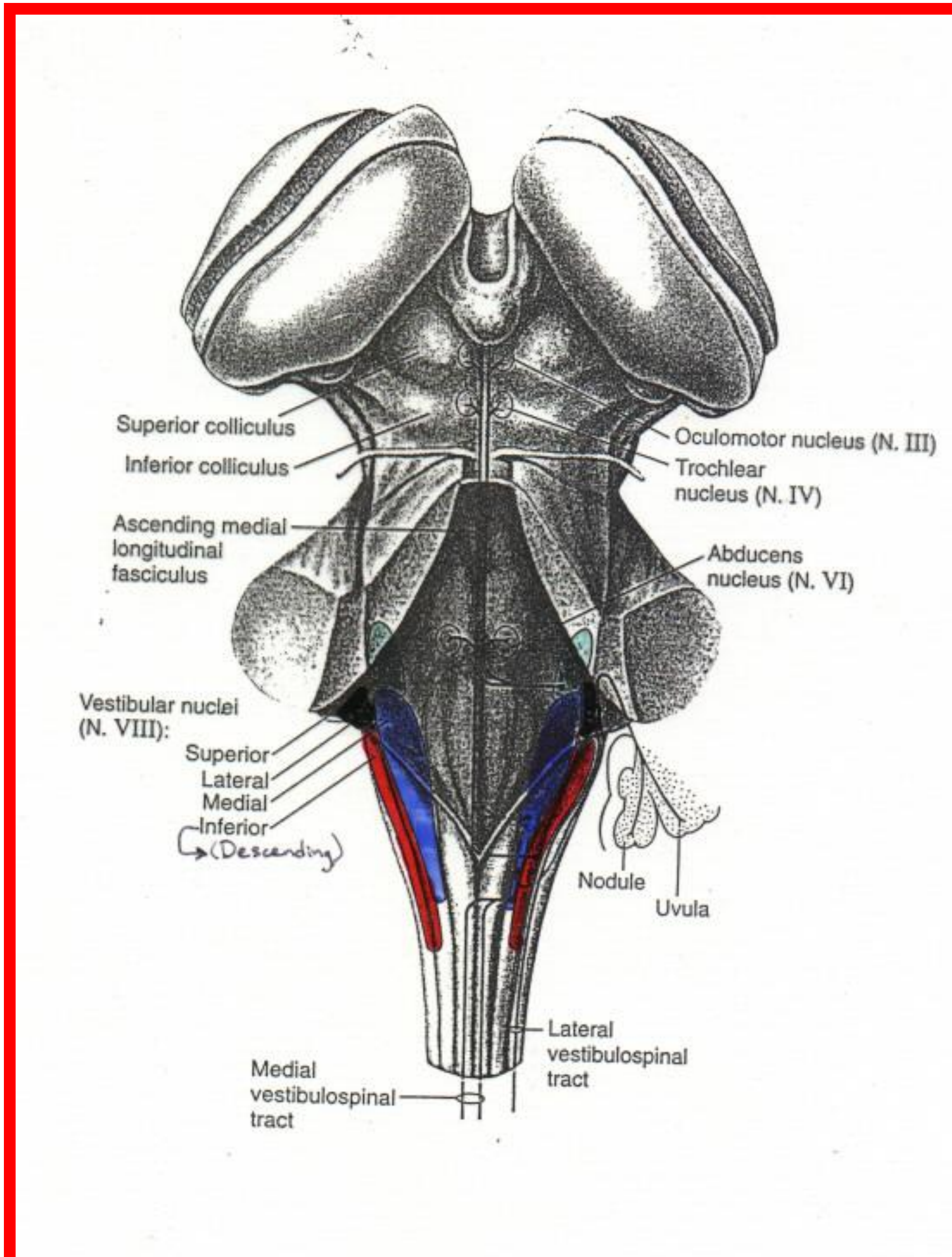


The otoliths register linear acceleration and static tilt

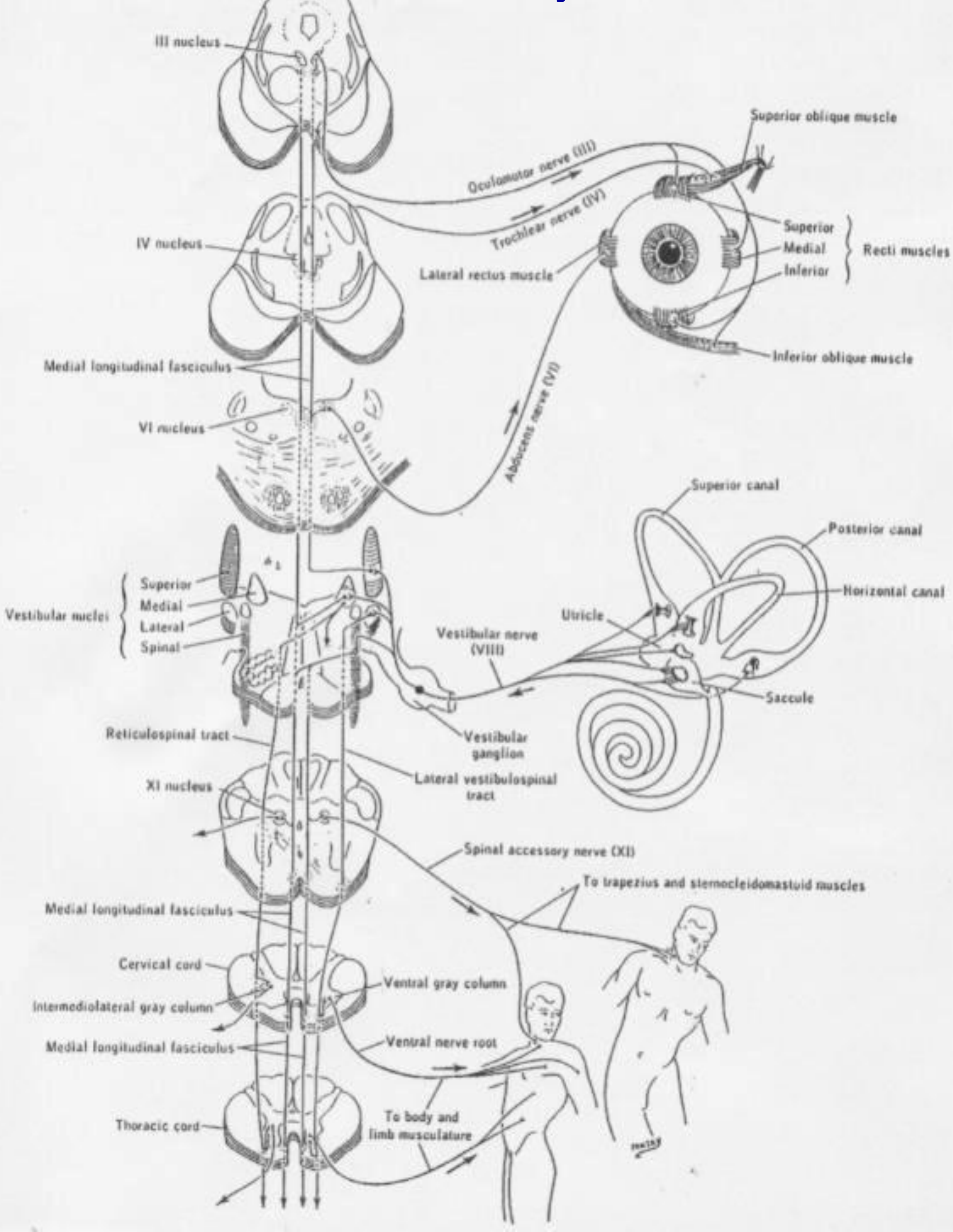


Vestibular system




Superior colliculus
Inferior colliculus
Ascending medial longitudinal fasciculus
Oculomotor nucleus (N. III)
Trochlear nucleus (N. IV)
Abducens nucleus (N. VI)
Vestibular nuclei (N. VIII):
Superior
Lateral
Medial
Inferior
(Descending)
Nodule
Uvula
Lateral vestibulospinal tract
Medial vestibulospinal tract

Vestibular System



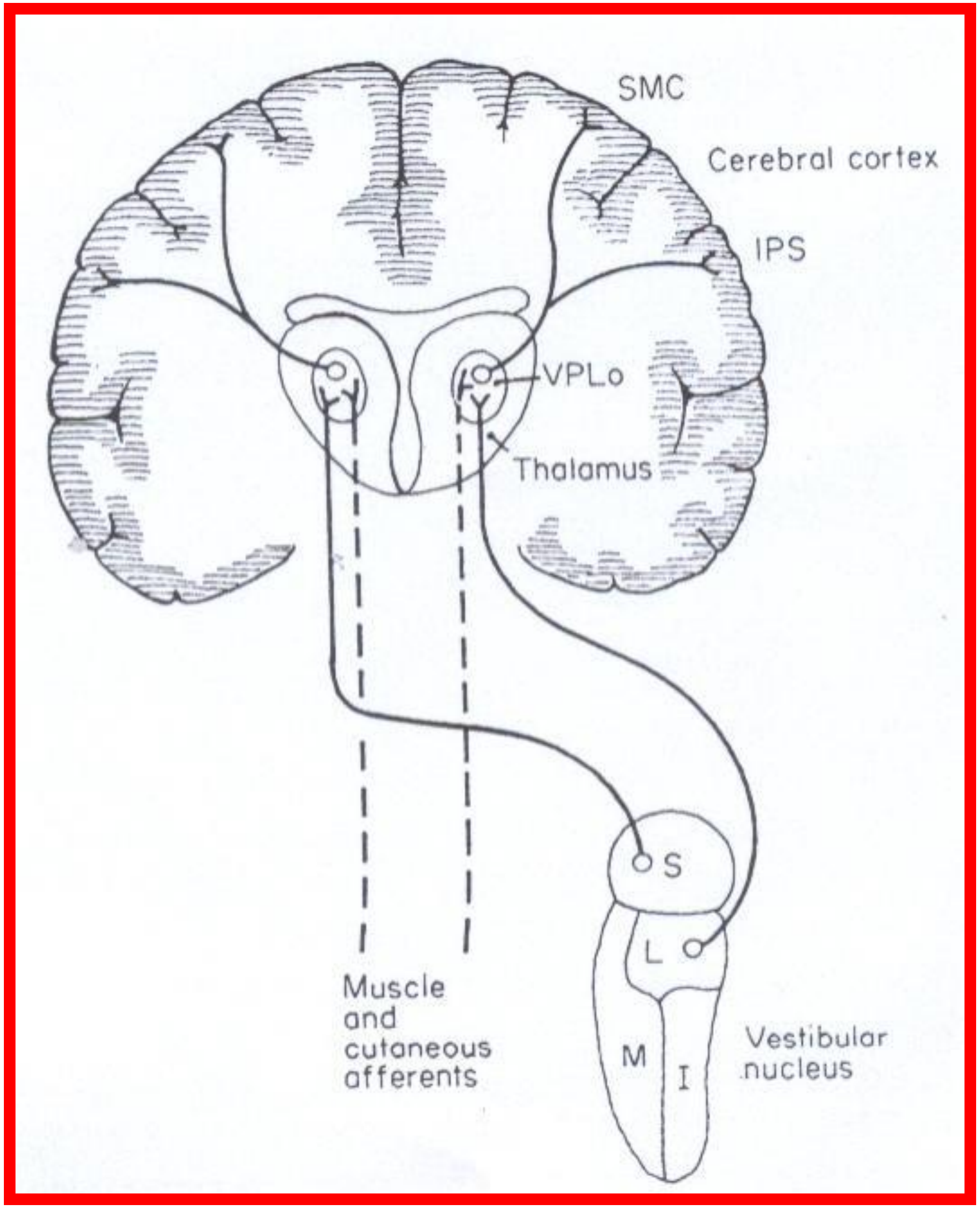
Vestibular Nuclei (VN)

Vestibular signals originating in the two labyrinths first interact with signals from other sensory systems in the VN.

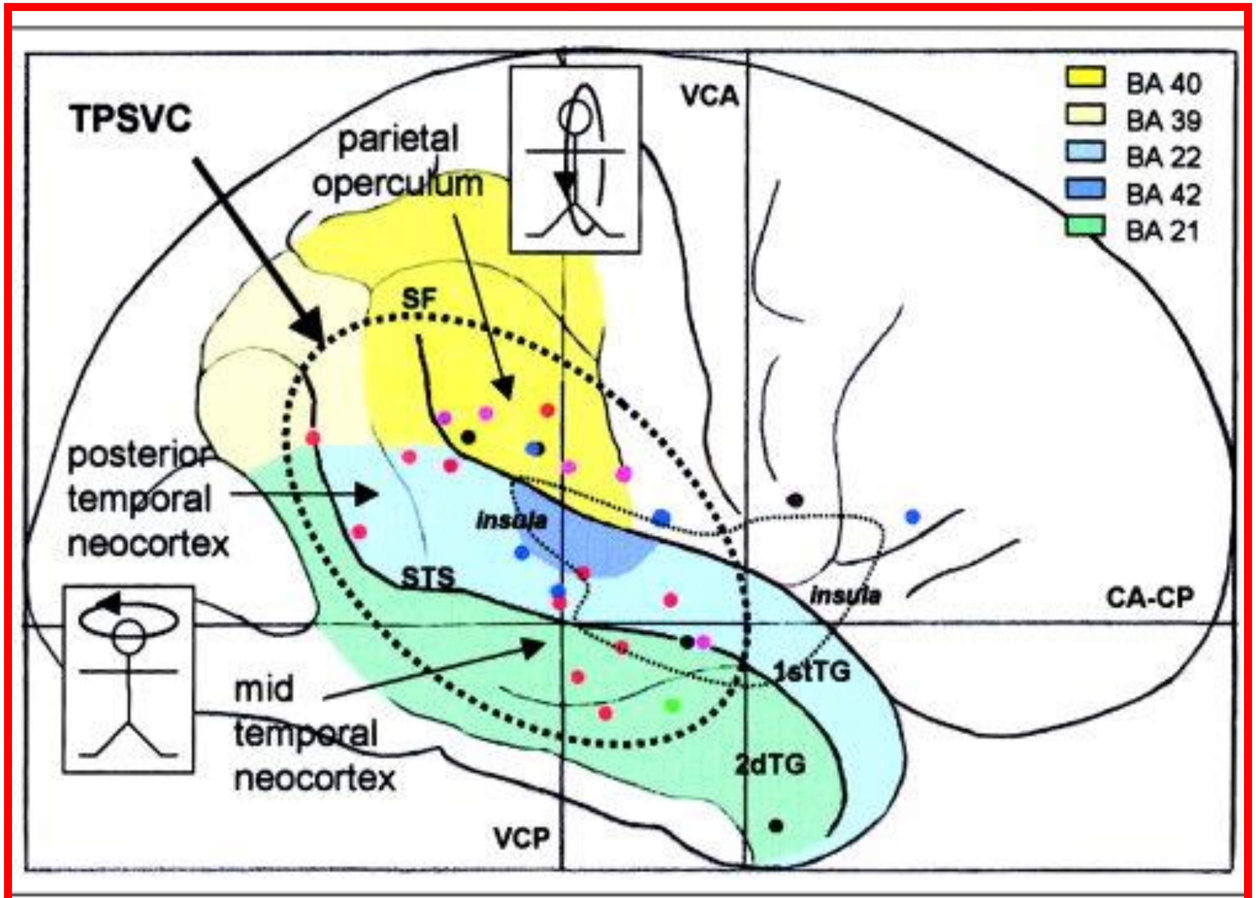
Only one fraction of the neurons in the VN receive direct vestibular input, and most neurons receive afferent input from other sensory systems (visual or proprioceptive) or regions of the CNS (cerebellum, reticular formation, spinal cord and contralateral VN).

Consequently the output of neurons from the VN reflect the interaction of many systems.

Vestibular Cortex

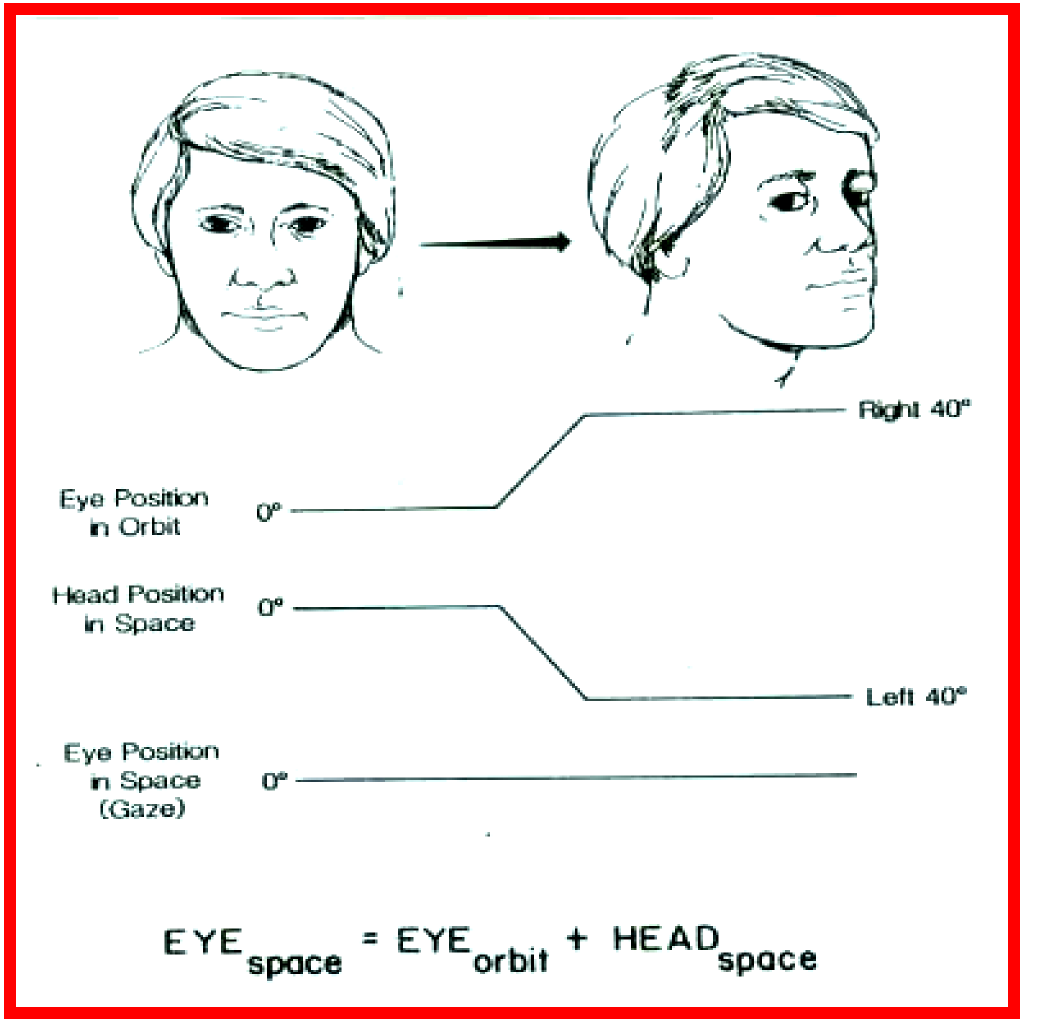


Vestibular Cortex



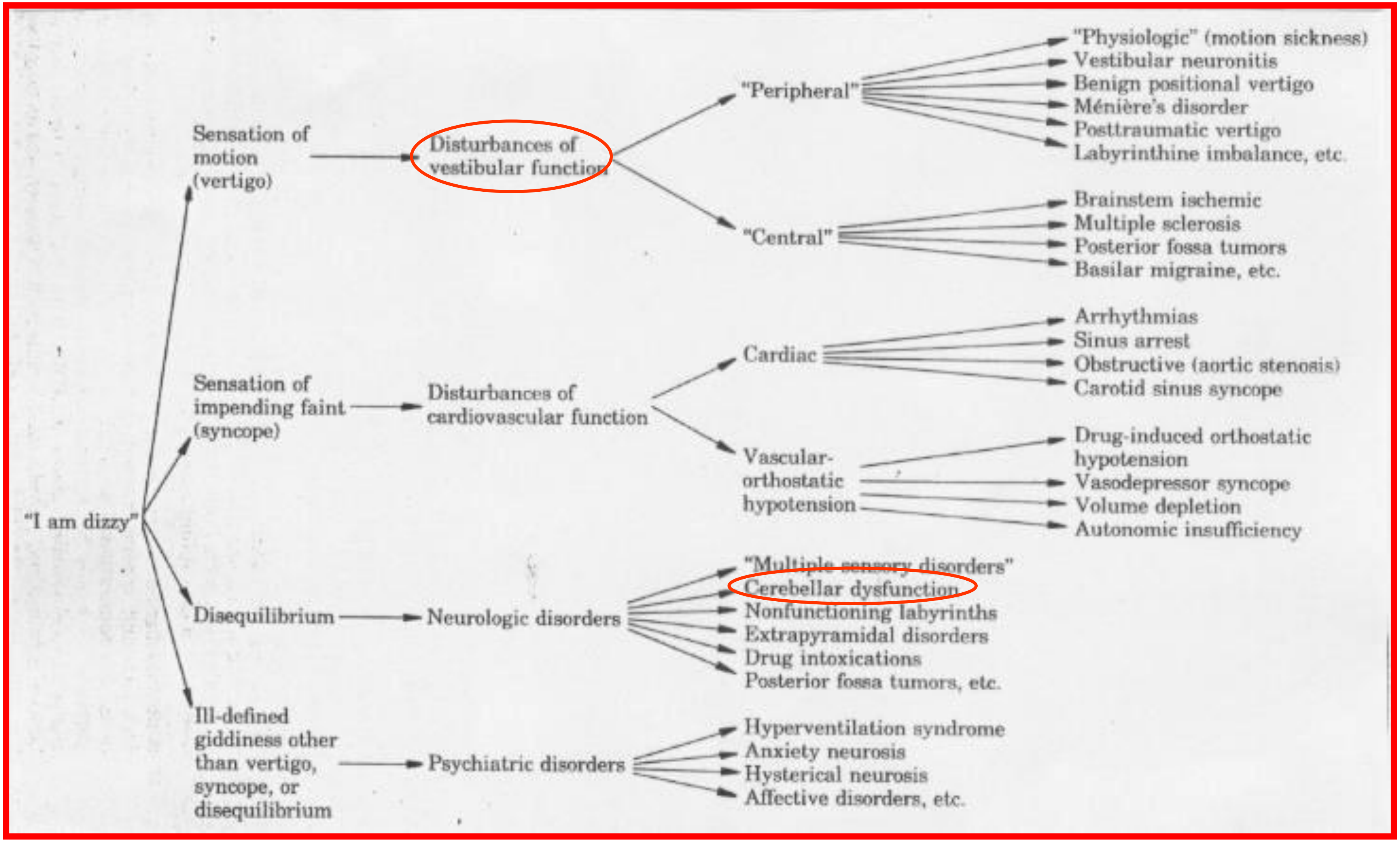
Schematic representation of the temporo-peri-Sylvian vestibular cortex (TPSVC). The vestibular sites located at the lateral aspect of the right or left hemispheres are projected on a lateral view of the right hemisphere normalized in the proportional stereotactic grid system of Talairach and Tournoux. BA = Brodmann area; CA-CP = anterior commissure-posterior commissure plane; VCA = vertical plane through CA; VCP = vertical plane through CP; SF = Sylvian fissure; STS = superior temporal sulcus; 1stTG = first (superior) temporal gyrus; 2dTG = second (mid) temporal gyrus. (*red dots*) Yaw plane illusions; (*pink dots*) pitch plane illusions; (*blue dots*) roll plane illusions; (*green dots*) translations; (*black dots*) indefinable sensations of body motion.

Vestibulo-Ocular Reflex (VOR)



To hold images of the seen world steady on the retina during brief head rotations

Dizziness – Vertigo - Disequilibrium



Brain Facts -- Taste/Smell

- Average number of human taste buds = 5,000
- Number of human olfactory receptor cells = 40 million
- Number of dog olfactory receptor cells = 1 billion

► **Sensitivity of Different Regions of the Tongue to Different Tastes**

*Most of the tongue is sensitive to all tastes

*The tongue is most sensitive to these basic tastes in certain regions

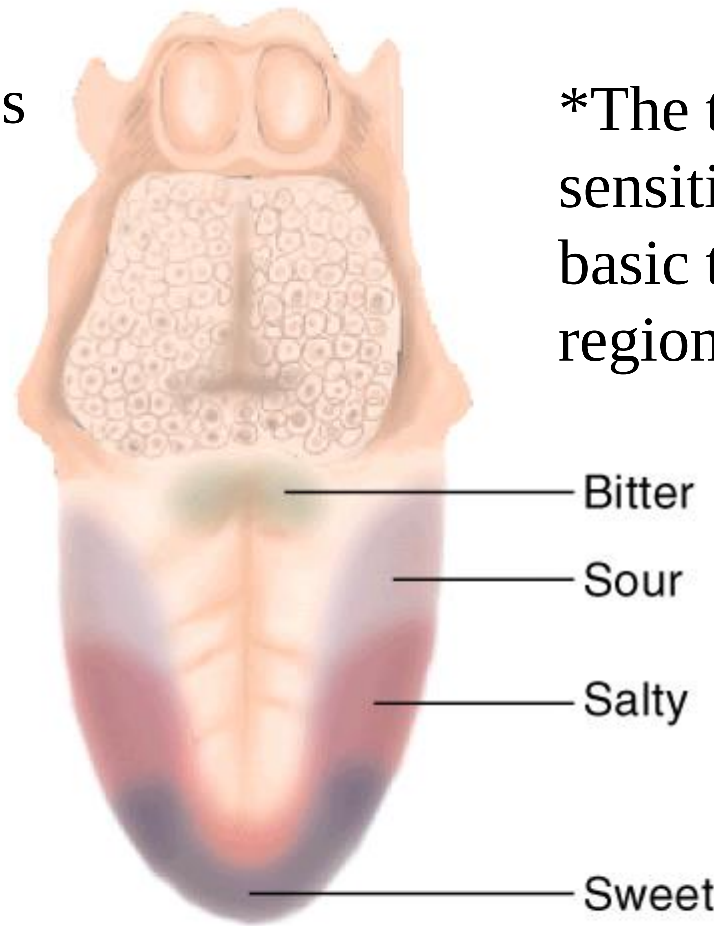
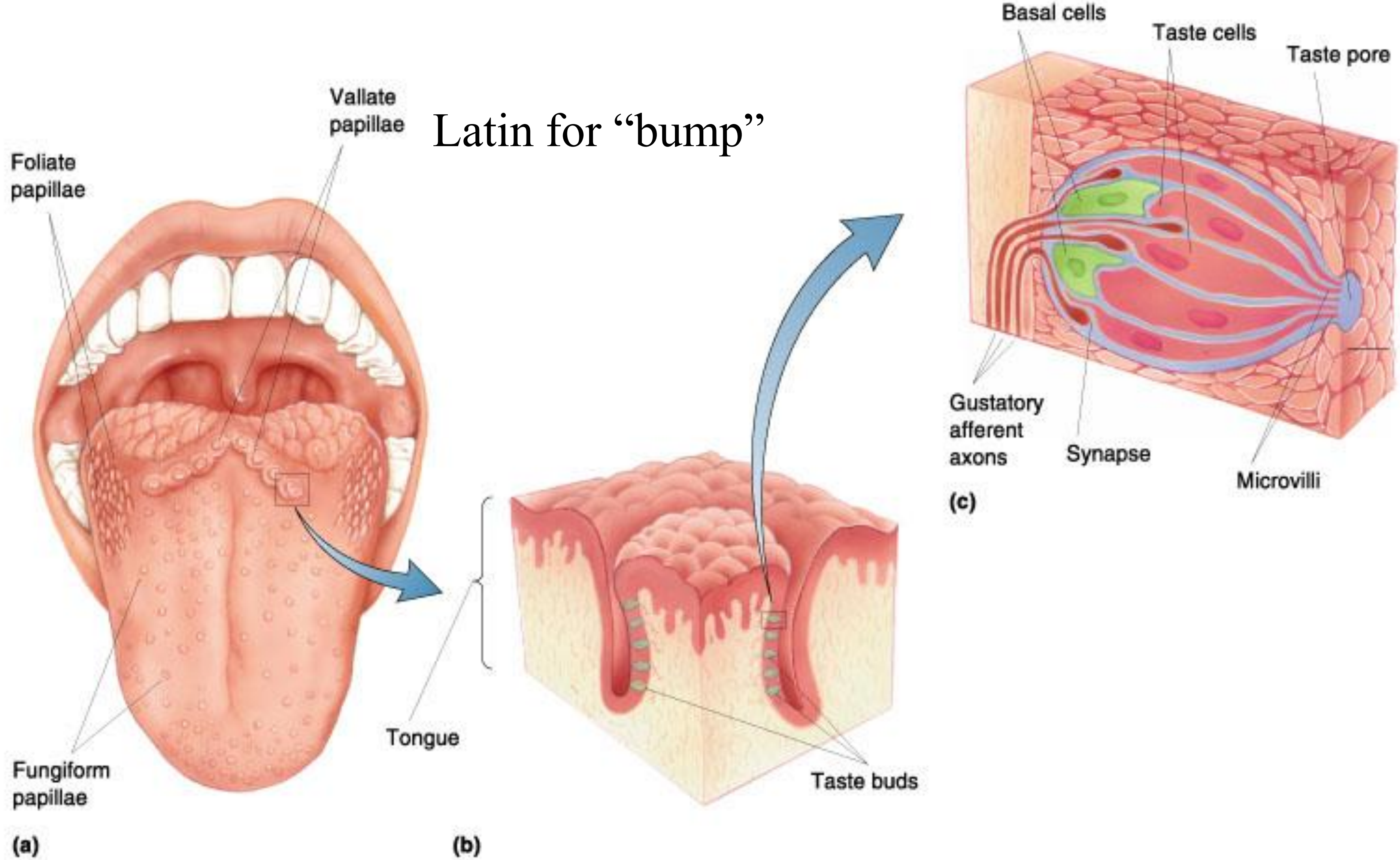


Figure 8.3
The tongue, its papillae, and its taste buds. (a) Papillae are the taste-sensitive structures. The largest and most posterior are the vallate papillae. Foliate papillae are elongated. Fungiform papillae are relatively large toward the back of the tongue and much smaller along the sides and tip. (b) Cross-sectional view of a vallate papilla showing the locations of taste buds. (c) A taste bud is a cluster of taste cells (receptor cells), gustatory afferent axons and their synapses with taste cells, and basal cells. Microvilli at the apical end of the taste cells extend into the taste pore, the site where chemicals dissolved in saliva can interact directly with taste cells.

Latin for "bump"



Taste

- Papillae—each one has several hundred taste buds—each having 50-150 receptor cells
- An average person has 2000-5000 taste buds, although super-tasters have as many as 20,000. and then there are the sorry bunch who only have 500

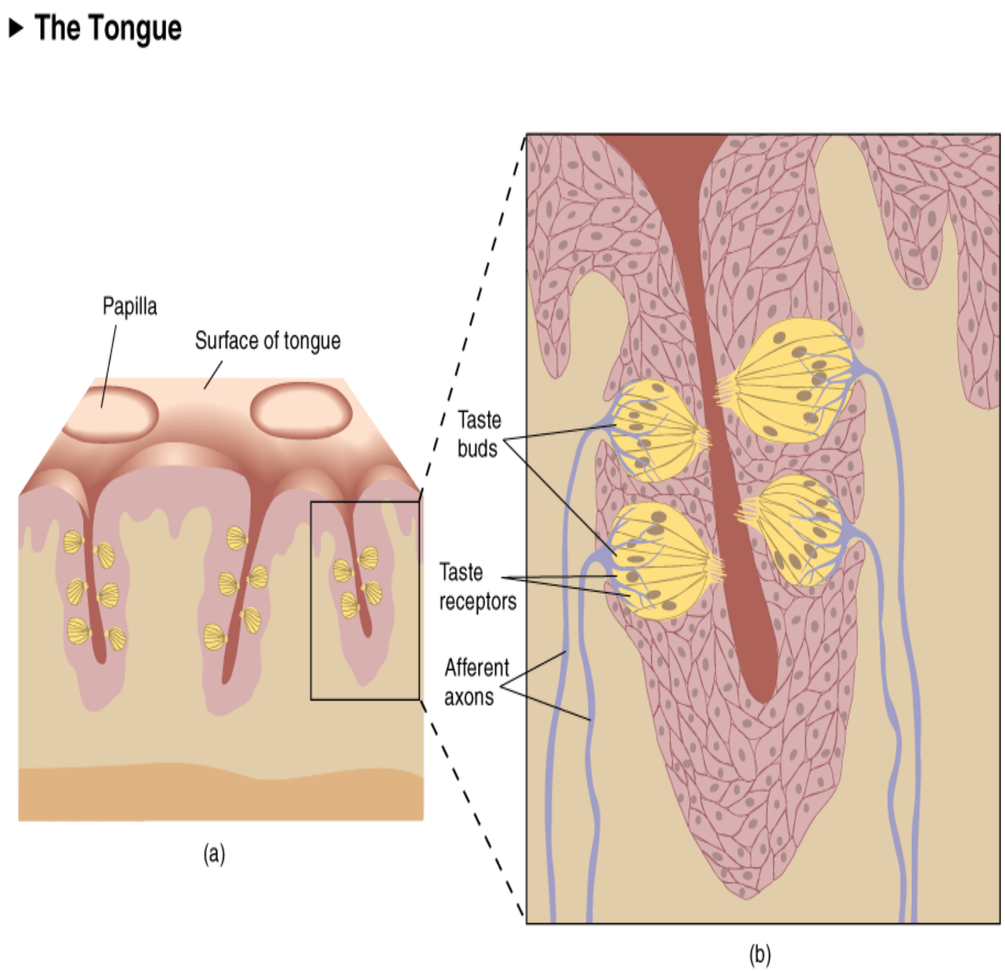


Figure 8.4

Responsiveness of taste cells and gustatory axons. (a) Two different cells were exposed to salt (NaCl), bitter (quinine), sour (HCl), and sweet (sucrose) stimuli, and their membrane potential was recorded with electrodes. Notice the different sensitivities of the two cells. (b) In this case, the action potential discharge of the sensory axons was recorded. This is an example of extracellular recording of action potentials. Each vertical deflection in the record is a single action potential.

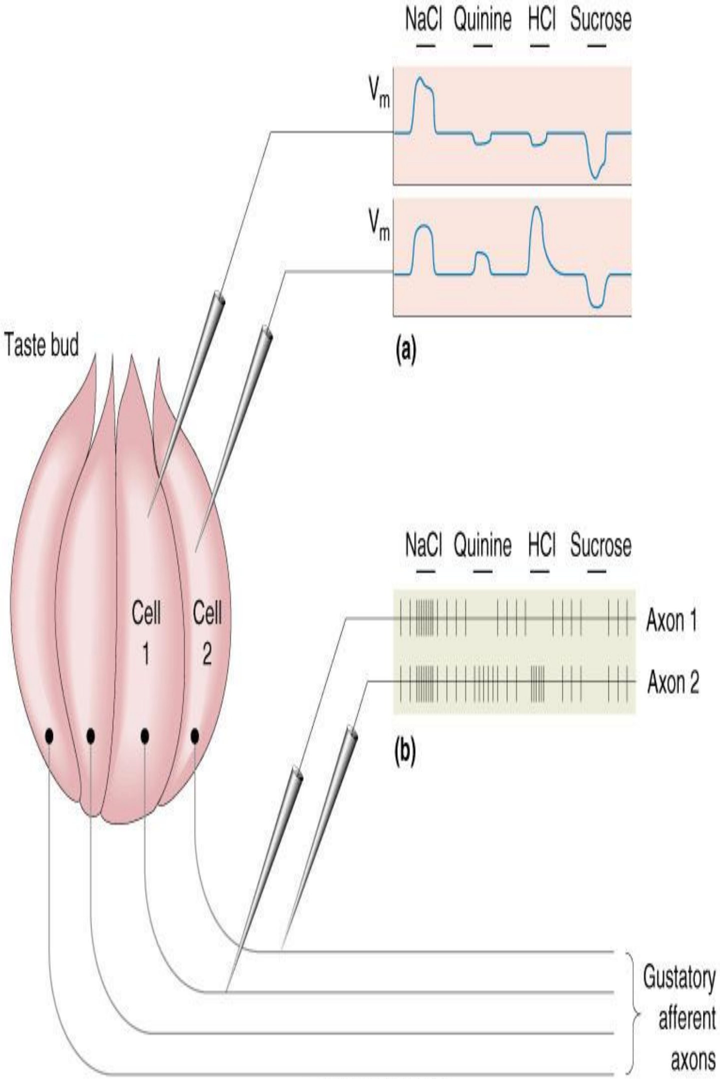


Figure 8.9

Transduction mechanisms for umami tastants (glutamate). Some amino acid tastants can bind to a cation-permeable channel, leading to a change in membrane current and potential, hence the direct entry of Ca^{2+}.

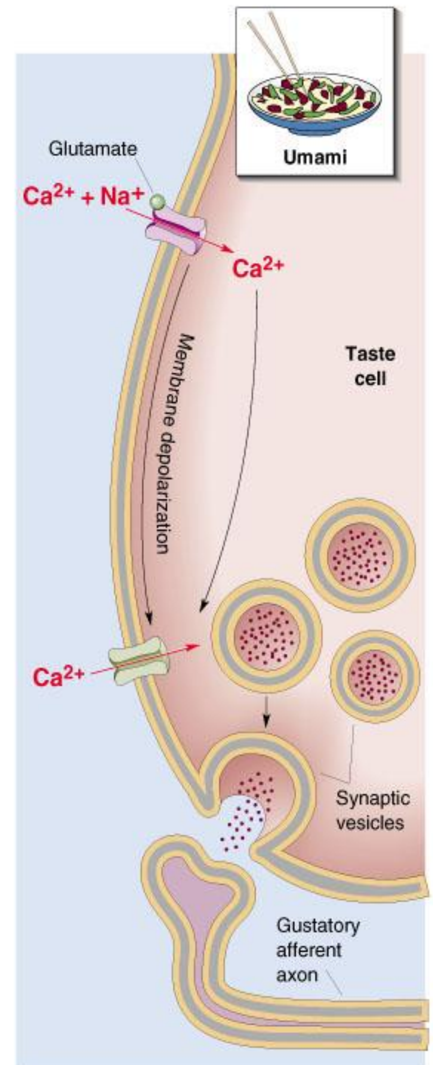
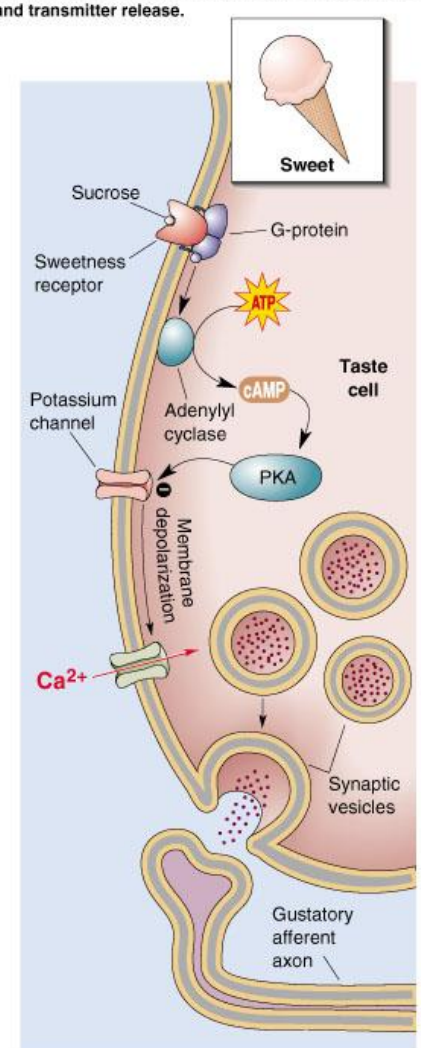


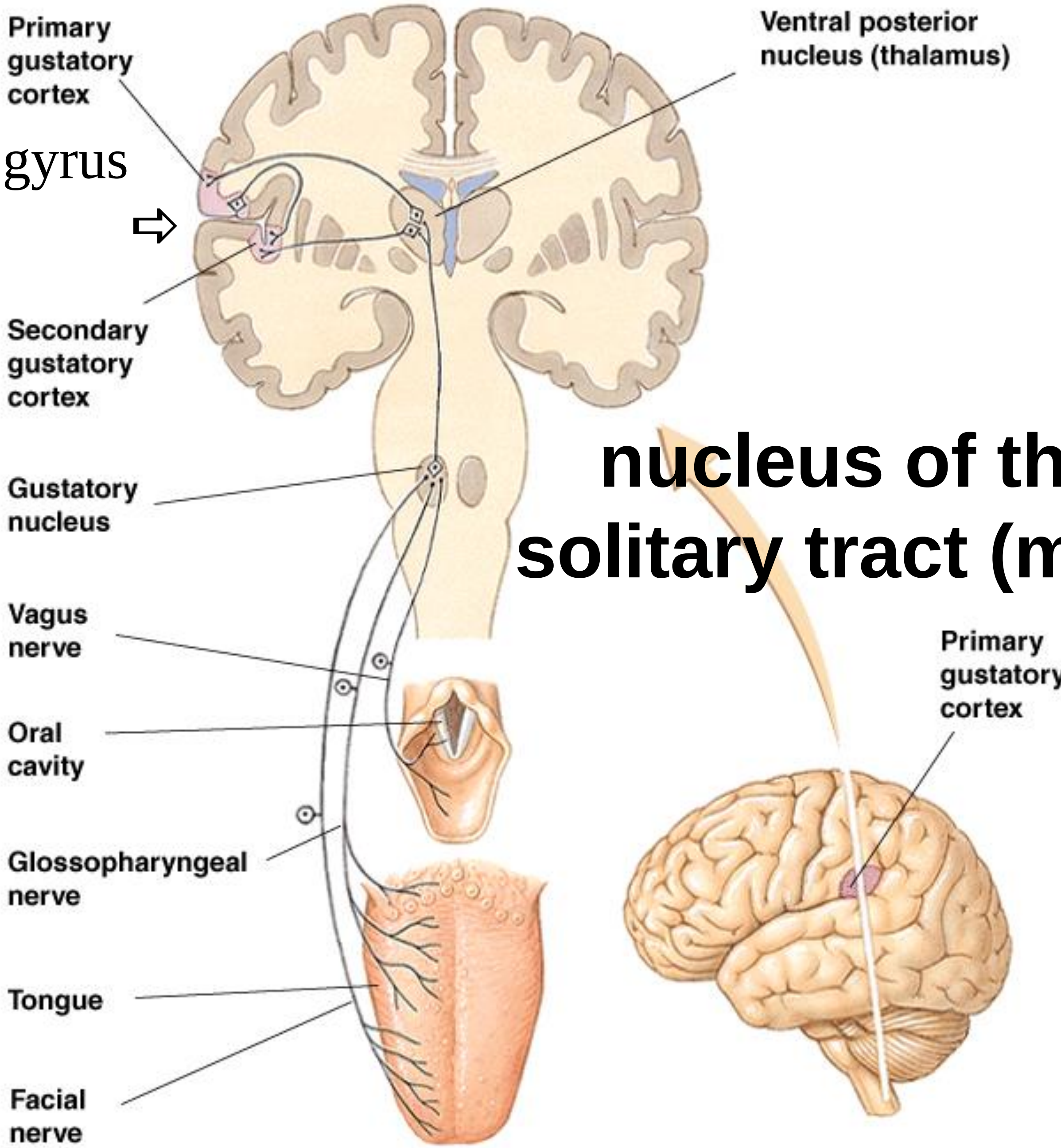
Figure 8.7

Transduction mechanisms for sweet tastants. Tastants bind directly to G-protein-coupled membrane receptors and trigger the synthesis of cAMP, which leads to the blockade of a potassium channel, depolarization, Ca^{2+} entry, and transmitter release.



▸ The Gustatory System

*Post-central gyrus
*Insular ctx



nucleus of the solitary tract (medulla)

Where does that gourmet flavor come from?

- The color, texture, aroma, expectations, temperature, and satiety all play a role in the perception of taste along with the direct activation of the primary tastes
- Smell and taste are us. Secondary to visual capture
- Ill-colored food tastes, “just not right”
- Lumpy mashed potatoes, soggy bacon, celery, or carrots, smoothness of grapes
- Lack of smell make it difficult to distinguish a bite of an apple vs. an onion

Capsaicin

- The active ingredient in spicy food
- Releases substance P from certain nociceptors in the mouth
- Substance P is a peptide synthesized by noci (pain) receptors that causes vasodilation and release of histamine and hyperalgesia (super sensitivity to pain)
- Be forewarned about the searing pain that comes from rubbing your eyes with chili-stained (capsaicin-coated) fingers

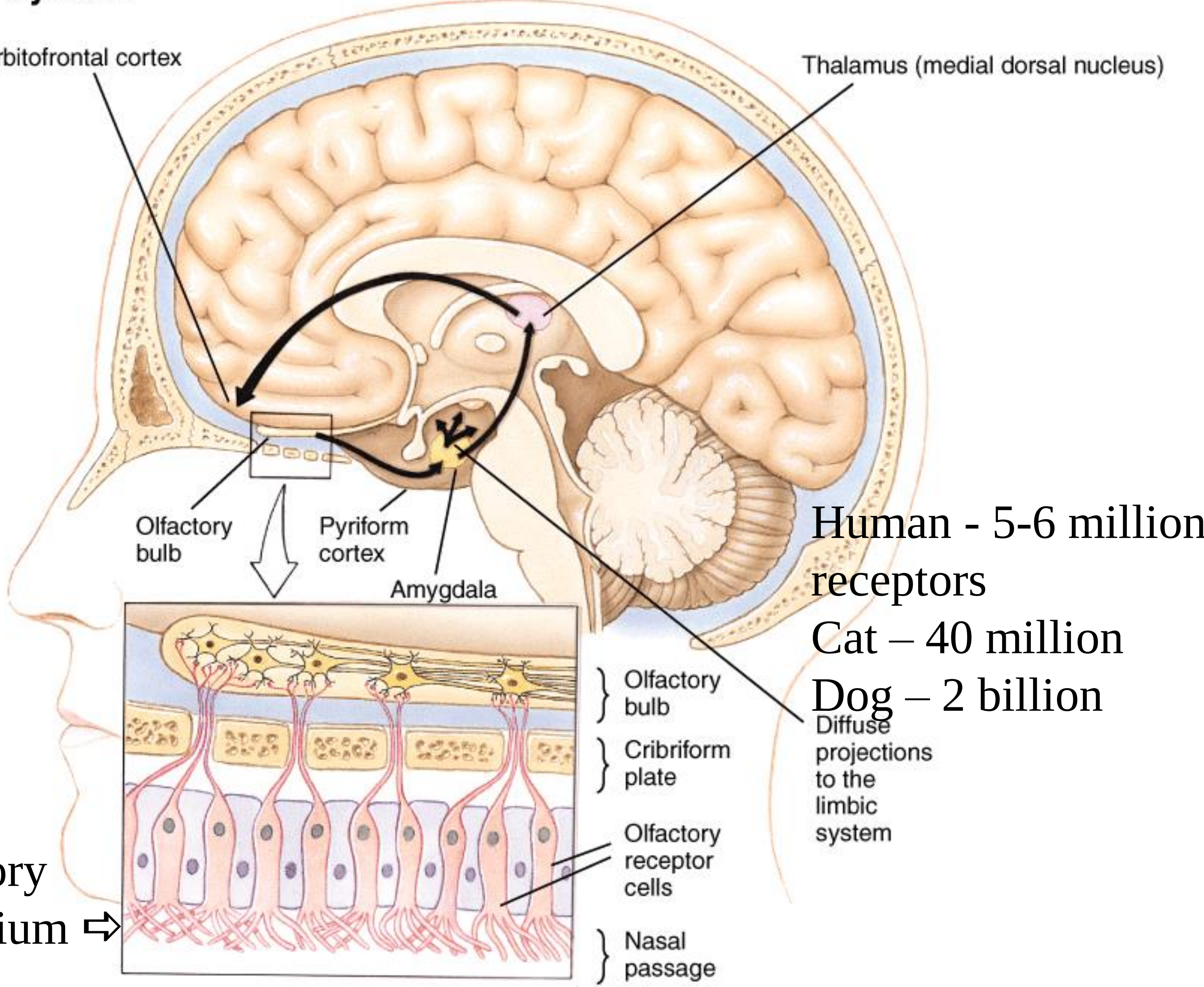
Smell--Olfaction

- We can smell and differentiate between several hundred thousand substances, only about 20% are pleasant and only ~ 16-20 are identifiable
- Anosmia - Odor blindness
- Women are slightly better than men in both detecting and identifying odors
- The ability to detect odors declines somewhat with age
- Smokers show a dulled sense of smell (they found pleasant odors to be less pleasant and unpleasant odors to be less unpleasant)

Smell--Olfaction

- The olfactory system begins in the roof of the nasal cavity
- Olfactory receptors are ciliated epithelial cells capable of detecting thousands of different odors
- Axons from the olfactory receptors project through the cribiform plate and synapse on dendrites of mitral cells in the olfactory bulb
- There is no direct projection to the thalamus
- Primary olfactory cortex – ventral anterior temporal lobe (ispilateral projections fr. Ea. Nostril detect changes in odor)
- Secondary cortex – lateral orbitofrontal ctx. (identifying smell)

► **Olfactory System**



Human - 5-6 million receptors
Cat – 40 million
Dog – 2 billion

Olfactory epithelium ⇨

Smell--Olfaction

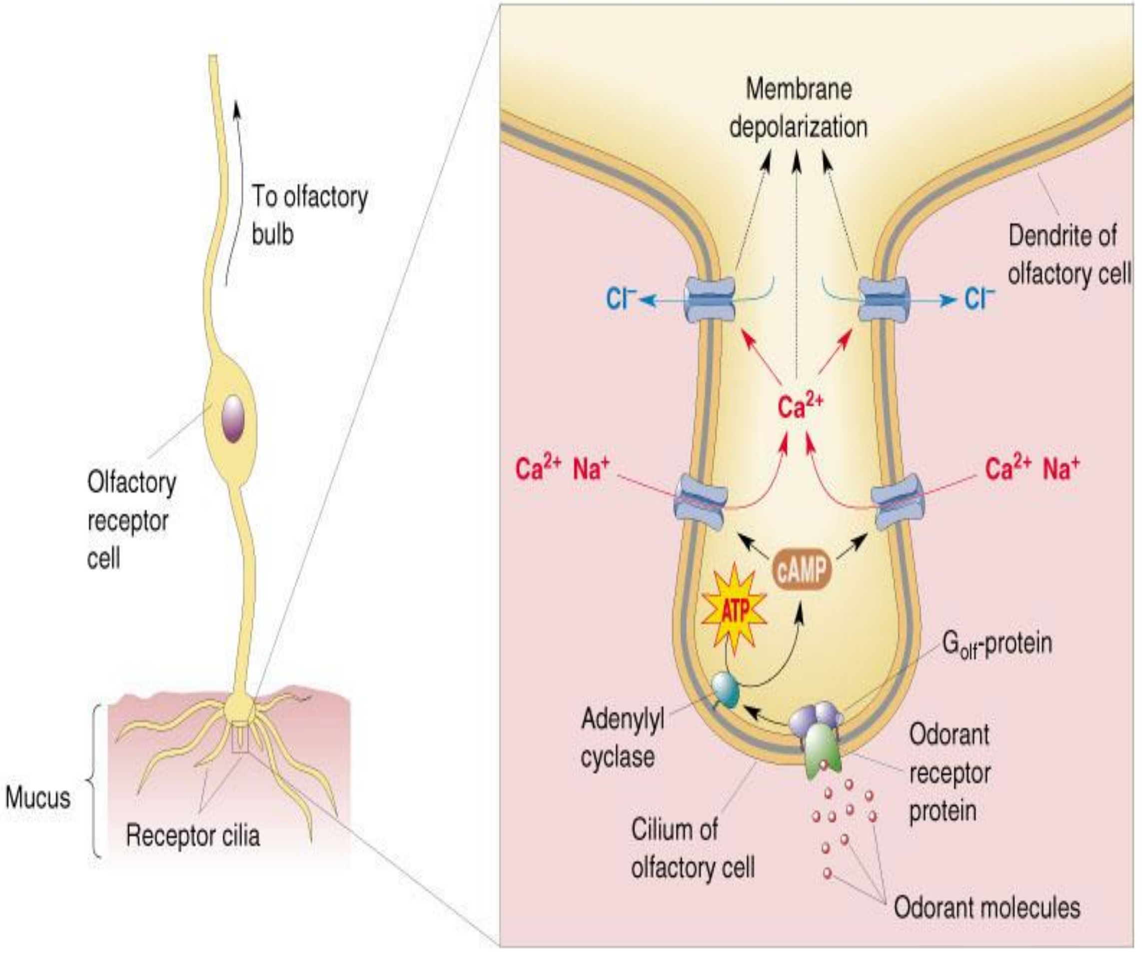
- Olfactory receptors continually die and regenerate in a cycle that lasts about 1-3 mos.
- Mucus (snot) covers the epithelium, flows constantly & is replaced every 10 min. (contains antibodies to protect fr. Virus; provides moisture and removes foreign material from inspired air)

Transduction

- Occurs in the cilia: binding of odorants
  - odorant binds to receptor
  - activates cAMP
  - influx of Na+ and Ca2+

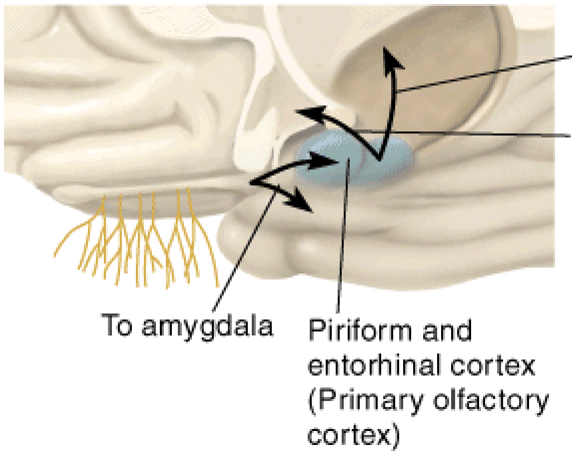
Figure 8.12

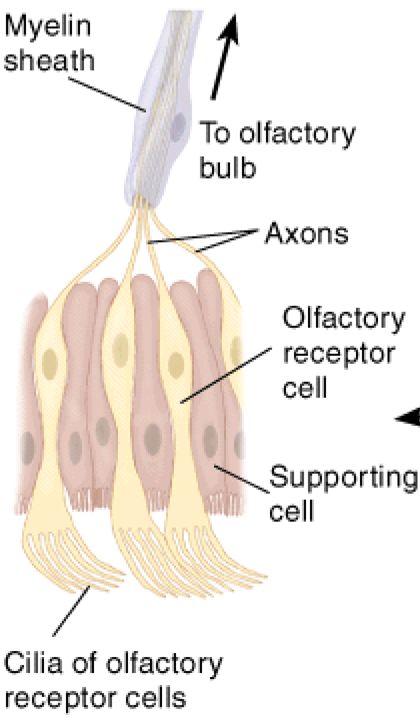
Transduction mechanisms of vertebrate olfactory receptor cells. This drawing shows a single cilium of an olfactory receptor cell and the signaling molecules of olfactory transduction that it contains. Golf is a special form of G-protein found only in olfactory receptor cells.

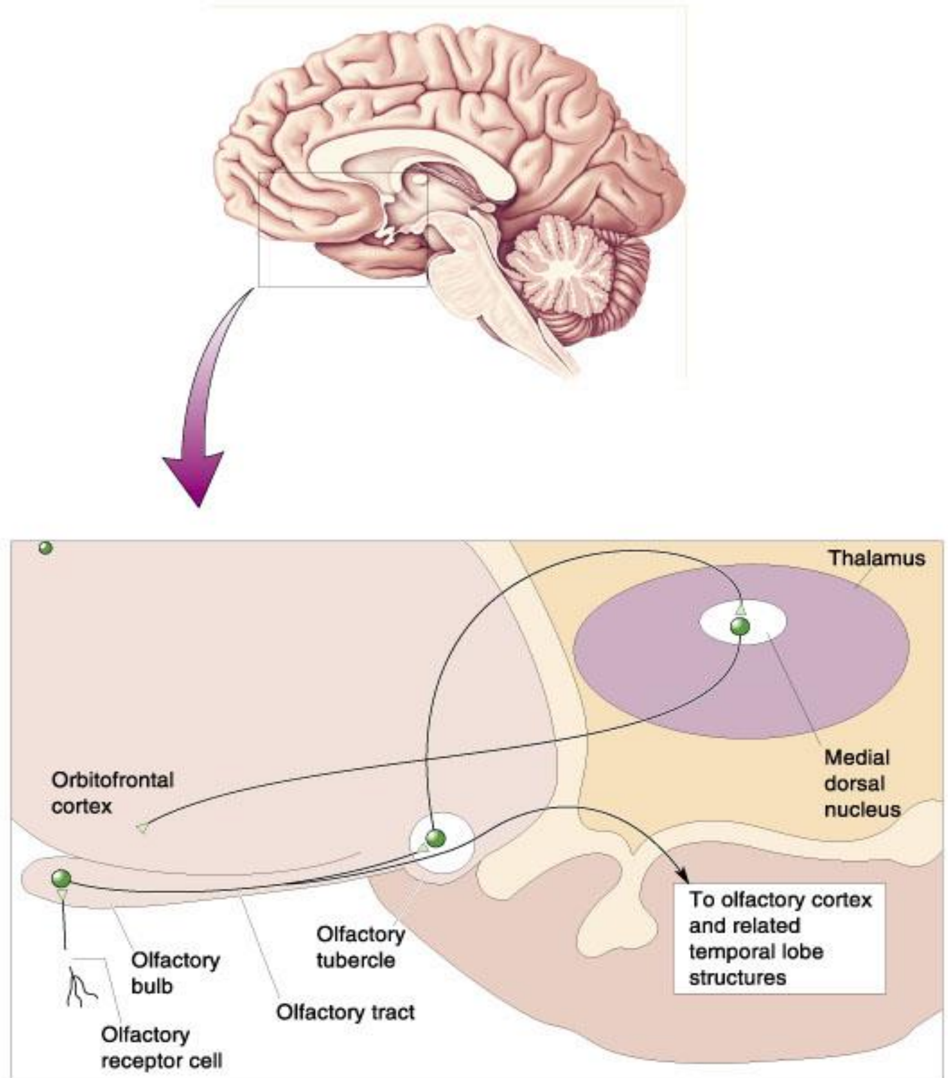


► The Olfactory System

Figure 8.19
Central olfactory pathways. Axons of the olfactory tract branch and enter many regions of the forebrain, including the olfactory cortex. The neocortex is reached only by a pathway that synapses in the medial dorsal nucleus of the thalamus.





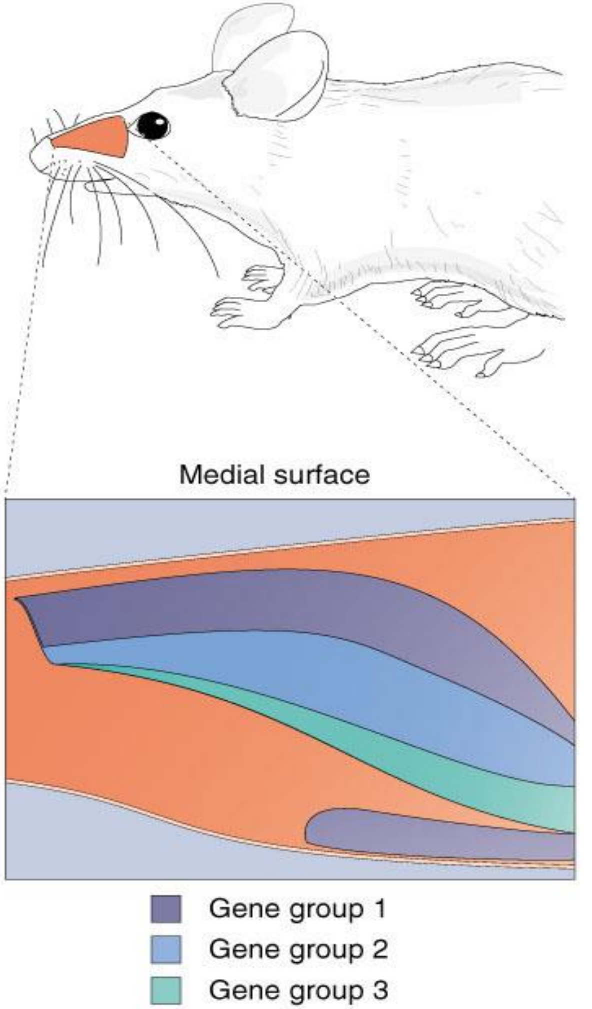


Piriform ctx – 1st perception of odor

Orbitofrontal ctx. – conscious perception or identification of odor

Limbic system – emotional, appetitive, and reproductive aspects of odor

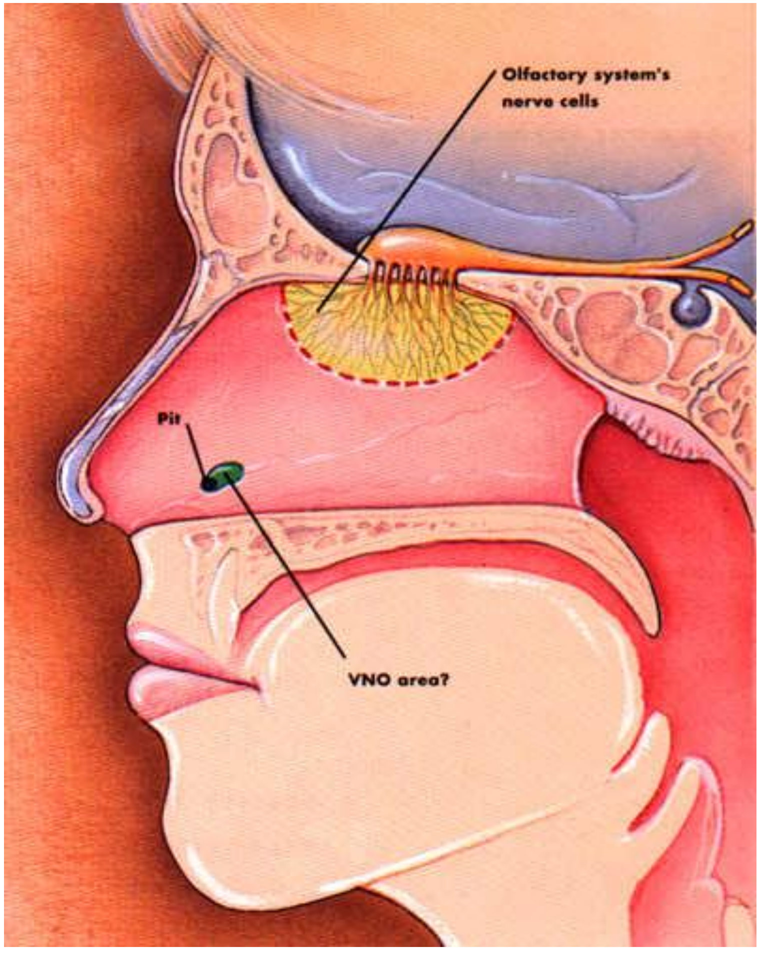
Figure 8.14
Maps of the expression of different olfactory receptor proteins on the olfactory epithelium of a mouse. Three groups of genes were mapped in this case, and each had a separate nonoverlapping zone of distribution. (Source: Adapted from Ressler et al., 1993, p. 602.)



PHEROMONES

* Airborne chemicals released from animals that have a physiological or behavioral effect on another

•Vomeronasal organ (VMO) – ventromedial Hyp.



*While the potency may not compare to the insect system, investigators are beginning to find evidence that many mammals ranging from pigs to elephants can have a pheromone-type response to a sniff of secretions. Yes, even humans appear to respond.

PHEROMONES

- McClintock Effect – synchronization of menstrual cycles in women who live together -
  - Cotton pads underneath the arms of donor women (8hrs.) and then wiped underneath the noses of recipient women (did not wash face for 6 hrs.)
  - The recipients were not told the source of the chemicals and did not consciously perceive any odors
  - Recipient's menstrual cycle either shortened or lengthened
- Researchers have found that female rodents share the same characteristic. Furthermore, chemicals emitted from a female rat during one part of its reproductive cycle will lengthen a fellow rodent's cycle. Chemicals from another part of the cycle will shorten the cycle.

PHEROMONES (Carlson, p. 270)

- Isolated on a remote island for several weeks, a scientist notes that his beard sprouts at a pathetic rate. Back in the company of women, his whisker growth returns to a gallop.

- Male moths will detect the spray of a fertile female as far as a mile away. The pheromone causes them to drop all business and meet the female for mating.

- Bloodhounds have difficulty distinguishing between the smells of identical twins, but not fraternal siblings
- Bruce Effect – a recently impregnated female mouse will abort fetus if encountered by a male mouse other than the one with which she mated

Synesthesia

- The capacity to join sensory experiences across sensory modalities
- 1:25,000 people (Cytowic, 1988)
- Nabokov
- Genetic component undetermined
- Tasting shapes, colored hearing (speech and music have color),