The blue highlight = what were explained by the doctor
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CNS for medical students 2022

Olfaction and Gustation

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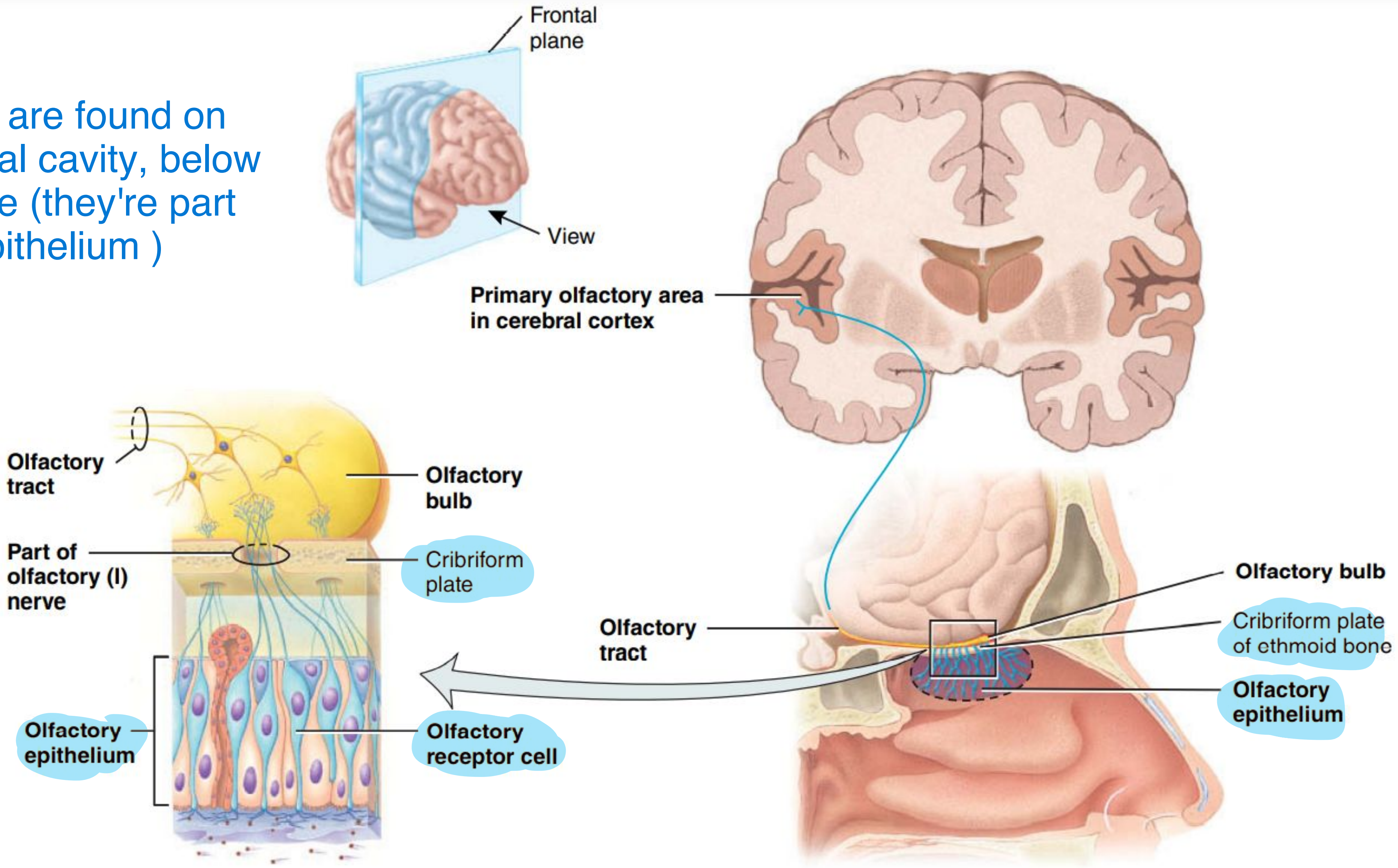
Special senses

- Olfaction (smell) and gustation (taste) are chemical senses.

Olfaction

olfactory receptor are found on the top of the nasal cavity, below the cribriform plate (they're part of the olfactory epithelium)



Olfactory epithelium

- Olfactory epithelium (membrane) occupies the superior part of the nasal cavity, covering the inferior surface of the cribriform plate and extending along the superior nasal concha.

- The olfactory epithelium consists of three types of cells: olfactory receptor cells, supporting cells, and basal cells.

provides any physical metabolic support to what olfactory receptors cell need

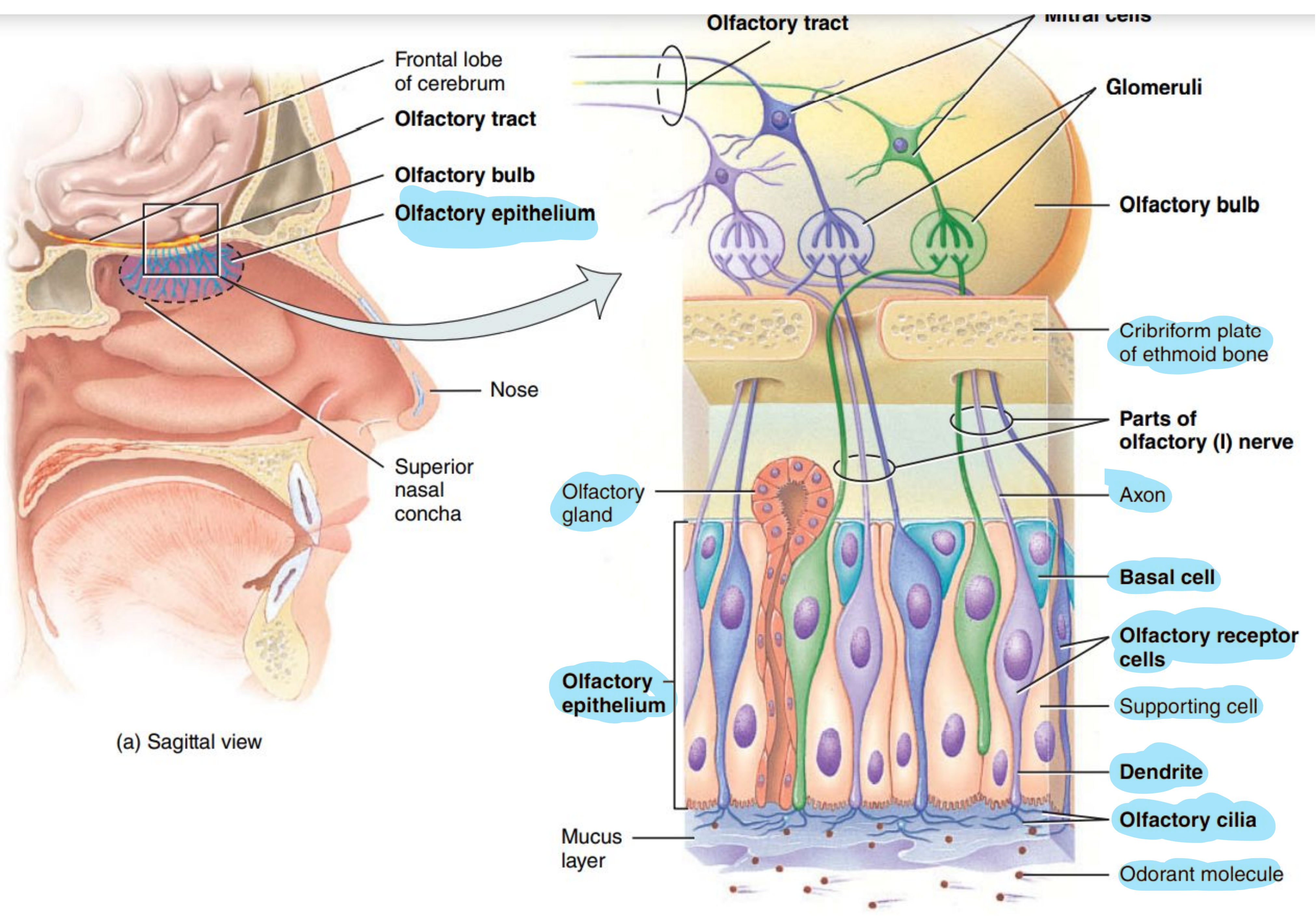
Olfactory epithelium

- **Supporting cells (sustentacular cells)** are columnar epithelial cells lined with microvilli at their mucosal border and filled with secretory granules.

- **Basal cells** are located at the base of the olfactory epithelium and are undifferentiated stem cells that give rise to the olfactory receptor cells.

another name is olfactory gland

- Within the connective tissue that supports the olfactory epithelium are **Bowman's glands**, which produce mucus that moistens the surface of the olfactory epithelium and dissolves odorants so that transduction can occur.


Frontal lobe of cerebrum
Olfactory tract
Olfactory bulb
Olfactory epithelium
Nose
Superior nasal concha
(a) Sagittal view
Olfactory tract
Mitral cells
Glomeruli
Olfactory bulb
Cribriform plate of ethmoid bone
Parts of olfactory (I) nerve
Olfactory gland
Axon
Basal cell
Olfactory receptor cells
Olfactory epithelium
Supporting cell
Dendrite
Olfactory cilia
Mucus layer
Odorant molecule

Olfactory receptor cells

Each olfactory receptor cell is a bipolar neuron (first-order neuron of olfactory pathway) with an exposed, knob-shaped dendrite and an axon projecting through the cribriform plate that ends in the olfactory bulb.

Extending from the dendrite of an olfactory receptor cell are several nonmotile olfactory cilia, which are the sites of olfactory transduction.

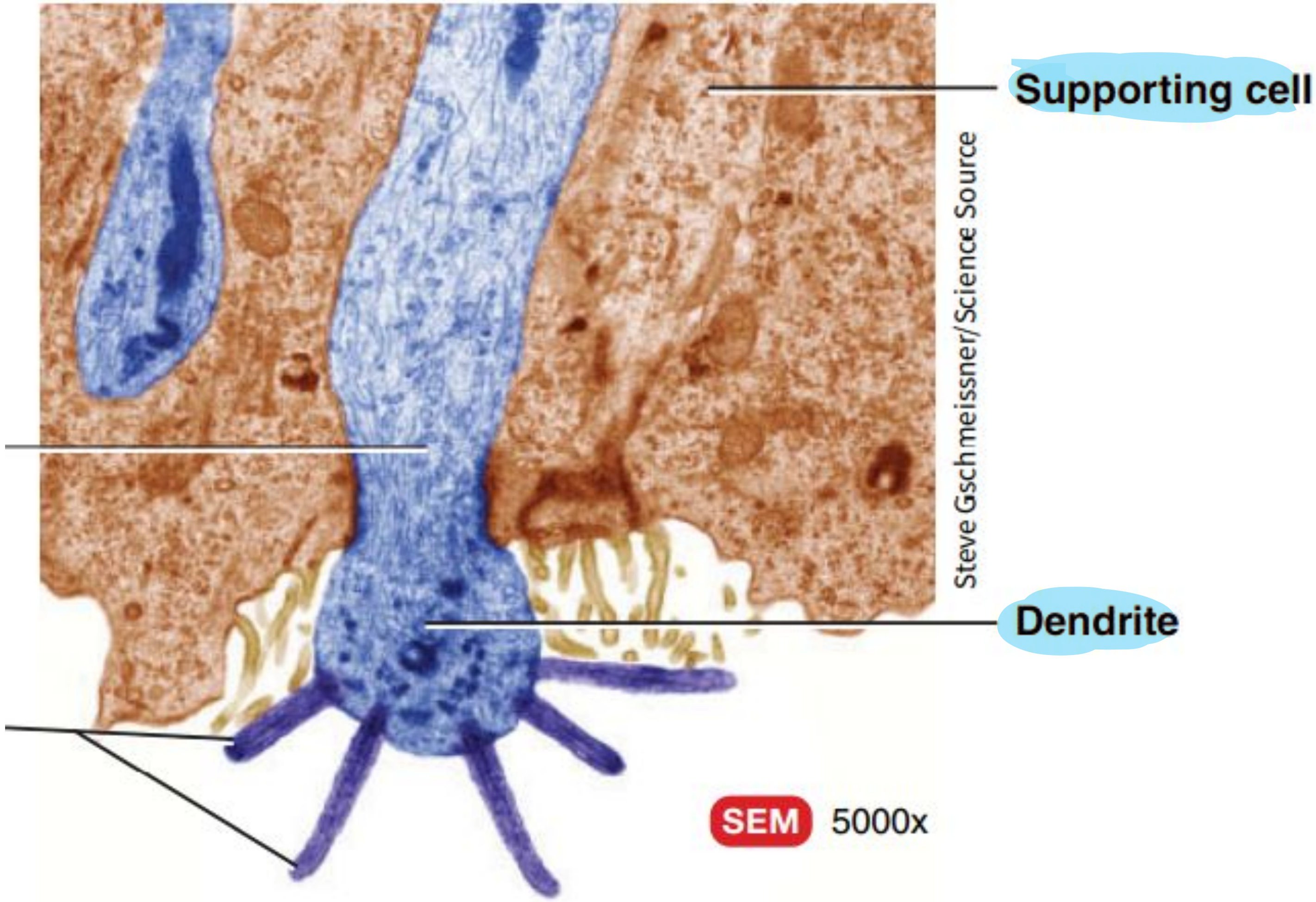
Olfactory receptor cells

Within the plasma membranes of the olfactory cilia are olfactory receptor proteins that detect inhaled chemicals.

Chemicals that bind to and stimulate the olfactory receptors in the olfactory cilia are called odorants.

Stimulus

Olfactory receptor cells respond to the chemical stimulation of an odorant molecule by producing a receptor potential, thus initiating the olfactory response.



Olfactory receptor cell (blue)

-Remember there is a difference between olfactory receptor cells and olfactory receptors

Olfactory receptors

- Olfactory receptors are about 400 different functional types. Each type of olfactory receptor can react to only a select group of odorants.

- Only one type of receptor is found in any given olfactory receptor cell.

- Genetic evidence now suggests the existence of hundreds of primary odors. Our ability to recognize about 10,000 different odors probably depends on patterns of activity in the brain that arise from activation of many different combinations of the olfactory receptor cells.

Olfactory transduction

- The conversion of a chemical signal into an electrical signal that can be transmitted to the CNS.

- The steps in olfactory transduction are as follows: receptor
- 1. Odorant molecules bind to specific olfactory receptor proteins located on the cilia of olfactory receptor cells. There are at least 1000 different olfactory receptor proteins (members of the superfamily of G protein–coupled receptors), each encoded by a different gene and each found on a different olfactory receptor cell.

stimulus

first-order neuron

- 2. The olfactory receptor proteins are coupled to adenylyl cyclase via a G protein. G-protein coupled receptor

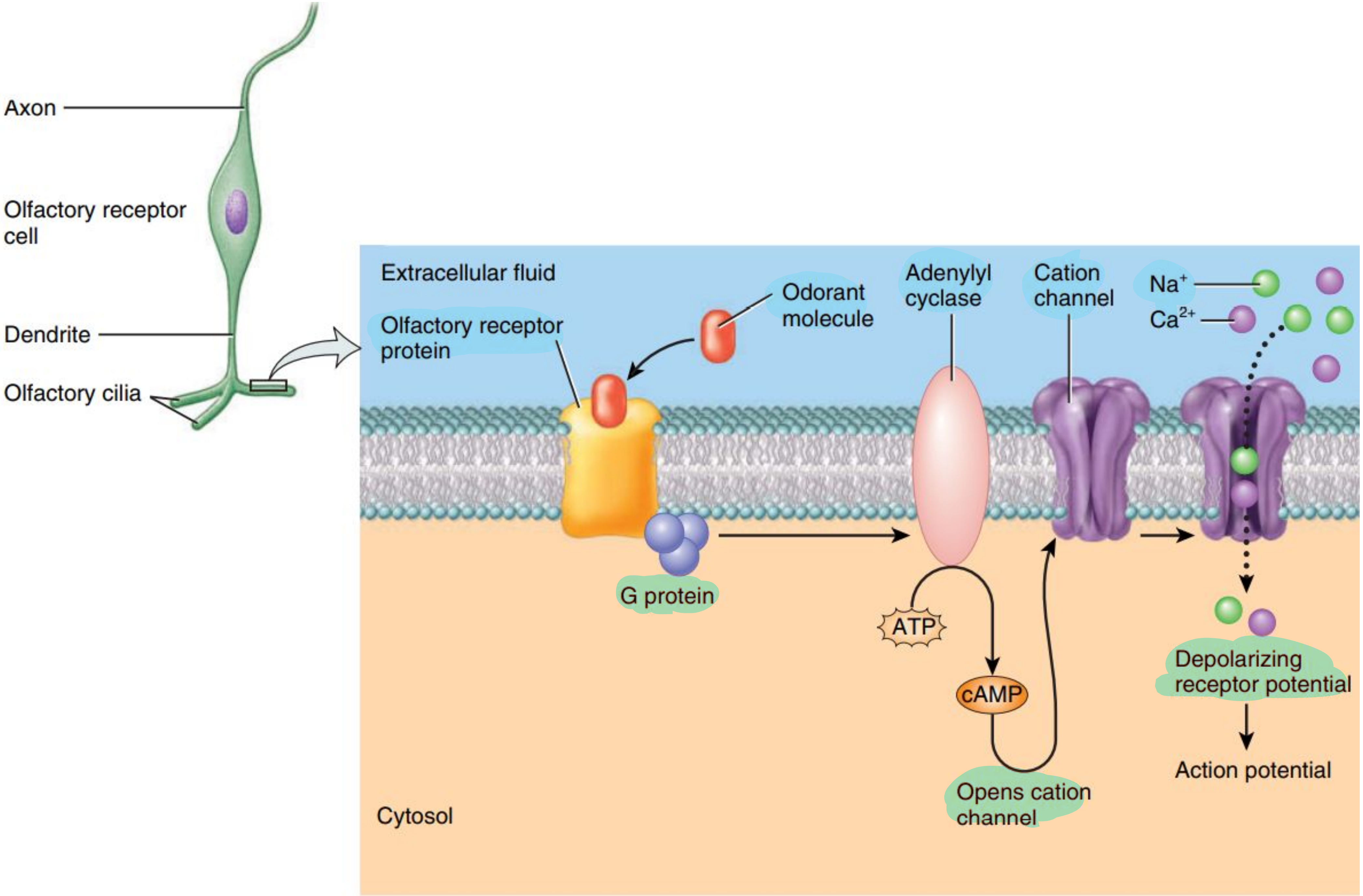
Olfactory transduction

- 3. Adenylyl cyclase catalyzes the conversion of ATP to cAMP. Intracellular levels of cAMP increase, which opens cation channels in the cell membrane of the olfactory receptor.

which is Na+ channel, some people say it can be Ca+ channel in addition to Na+ channel

- 4. The receptor cell membrane depolarizes.

- 5. Action potentials are then generated and propagated along the olfactory nerve axons toward the olfactory bulb.



Axon
Olfactory receptor cell
Dendrite
Olfactory cilia
Extracellular fluid
Olfactory receptor protein
Odorant molecule
Adenylyl cyclase
Cation channel
Na+
Ca2+
G protein
ATP
cAMP
Opens cation channel
Depolarizing receptor potential
Action potential
Cytosol

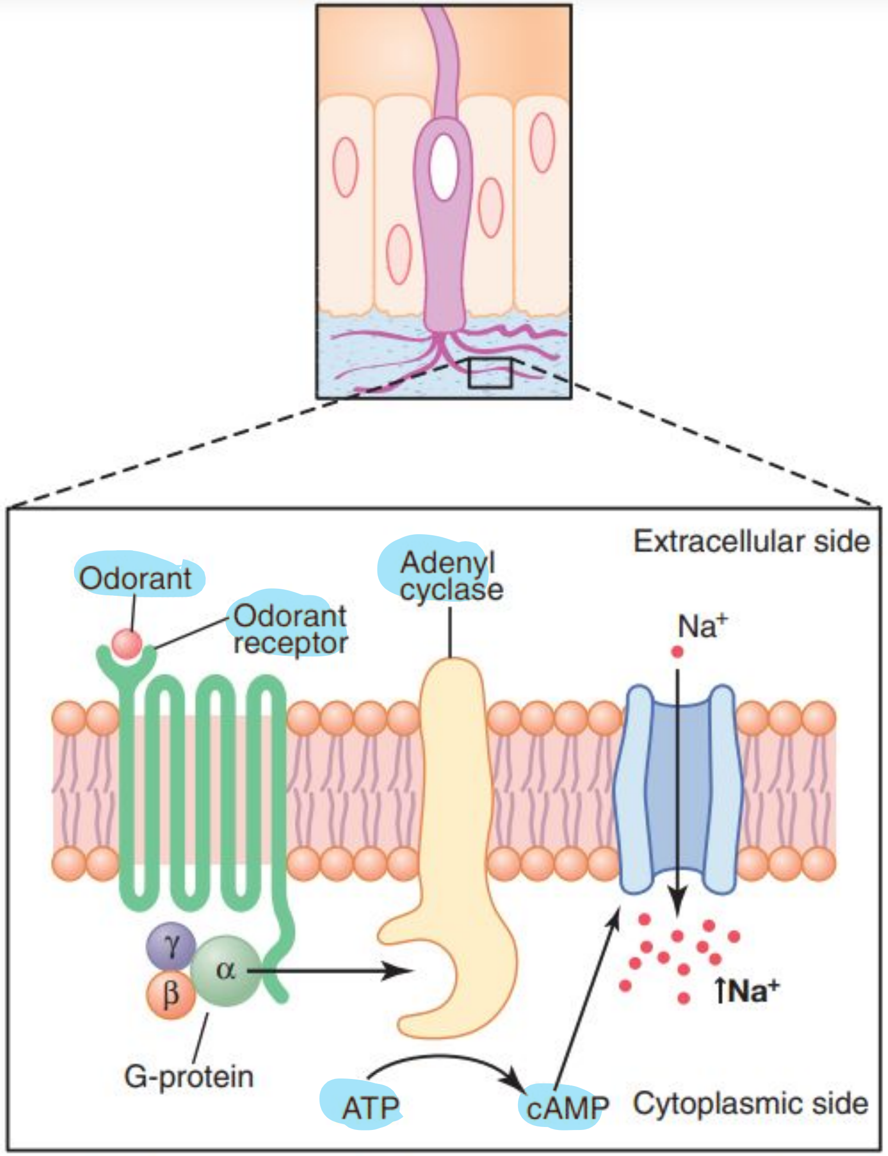


Figure 54-4. Summary of olfactory signal transduction. Binding of the odorant to a G-protein–coupled receptor causes activation of adenylate cyclase, which converts ATP to cAMP. The cAMP activates a gated sodium channel that increases sodium influx and depolarizes the cell, exciting the olfactory neuron and transmitting action potentials to the central nervous system.

Olfactory threshold

- The importance of this mechanism for activating olfactory nerves is that it greatly multiplies the excitatory effect of even the weakest odorant.

Amplification

- Even a minute concentration of a specific odorant initiates a cascading effect that opens extremely large numbers of sodium channels. This process accounts for the exquisite sensitivity of the olfactory neurons to even the slightest amount of odorant.

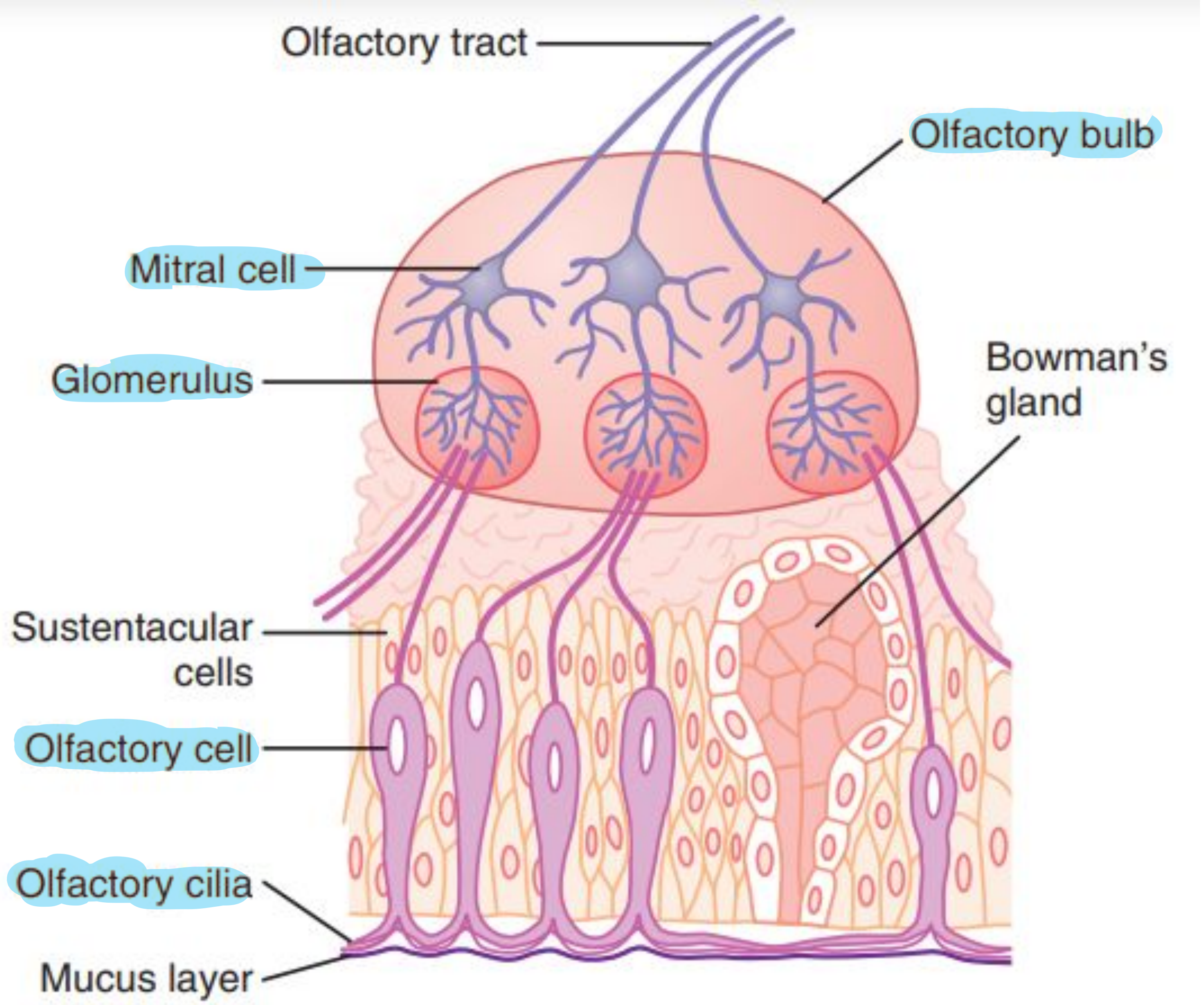
low threshold

- Olfaction, like all the special senses, has a low threshold. Only a few molecules of certain substances need to be present in air to be perceived as an odor.

Olfactory pathways

- Axons from the receptor cells leave the olfactory epithelium, pass through the cribriform plate, and synapse on apical dendrites of mitral cells (the second-order neurons) in the olfactory bulb. These synapses occur in clusters called glomeruli.

- In the glomeruli, the mitral cells are arranged in a single layer in the olfactory bulb and have lateral dendrites in addition to the apical dendrites.



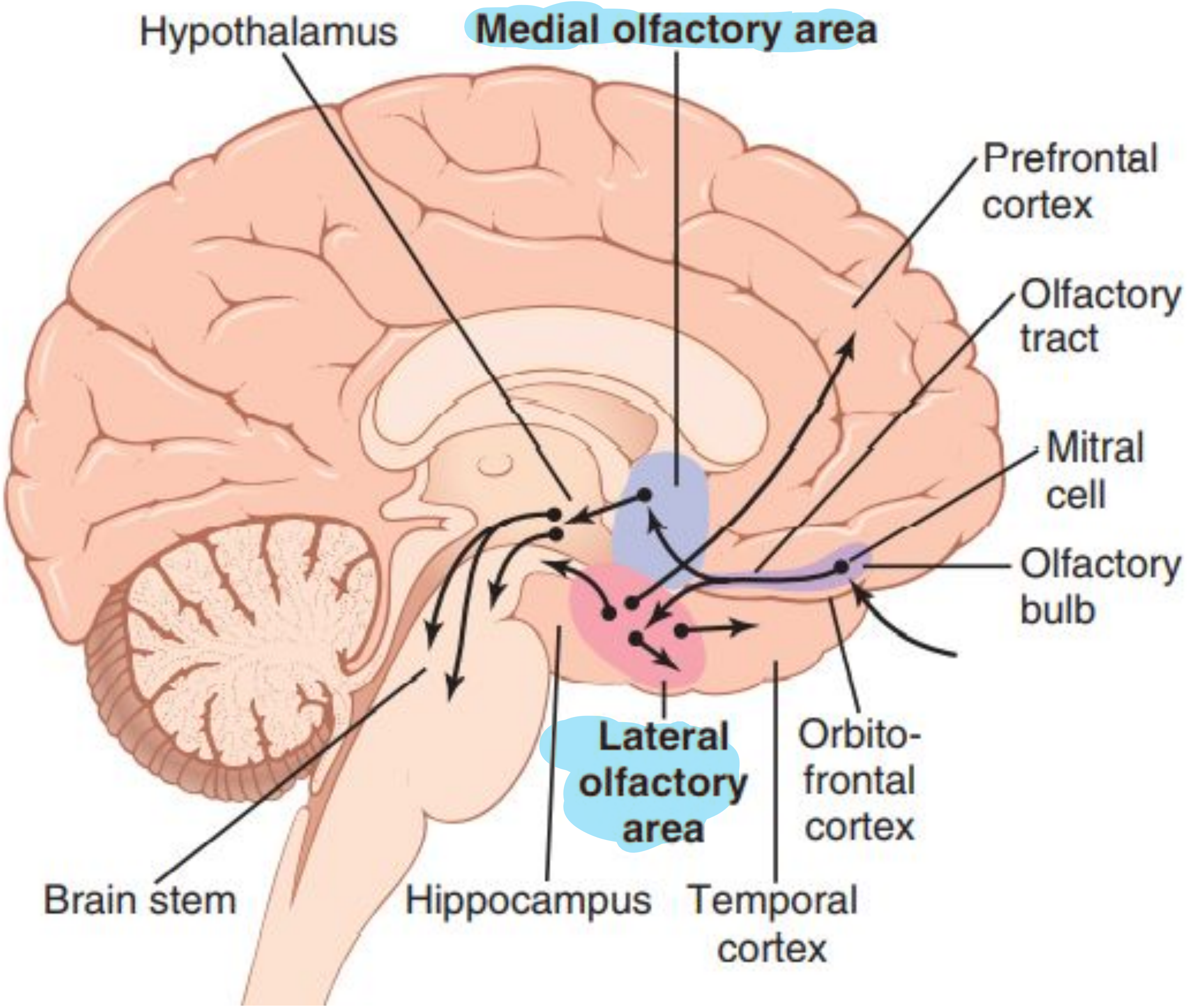
Olfactory tract
Olfactory bulb
Mitral cell
Glomerulus
Bowman's gland
Sustentacular cells
Olfactory cell
Olfactory cilia
Mucus layer

Olfactory pathways

- The olfactory bulb also contains granule cells and periglomerular cells. The granule and periglomerular cells are inhibitory interneurons that make dendro-dendritic synapses on neighboring mitral cells. The inhibitory inputs serve a function similar to that of the horizontal cells of the retina and may provide lateral inhibition that "sharpens" the information projected to the CNS.

important

- Mitral cells of the olfactory bulb project to higher centers in the CNS. As the olfactory tract approaches the base of the brain, it divides into two major tracts, a lateral tract and a medial tract.


Hypothalamus
Medial olfactory area
Prefrontal cortex
Olfactory tract
Mitral cell
Olfactory bulb
Brain stem
Lateral olfactory area
Orbito-frontal cortex
Hippocampus
Temporal cortex

Olfactory pathways

- **The medial olfactory stria** is responsible for autonomic responses associated with olfaction, such as an increase in salivation and gastric peristalsis/secretion in response to the smell of food.
- The medial olfactory stria sends projections to the ipsilateral anterior olfactory nucleus and through the anterior commissure to the contralateral olfactory bulb. These projections end in septal nuclei surrounding the para-terminal gyrus from which two fiber bundles split: the medullary stria and the olfacto-hypothalamic-tegmental bundle.
- The medullary stria pathway is responsible for salivation in response to the smell of food. It involves the activation of the superior and inferior salivatory nuclei via projections to the habenacular nuclei and the tegmentum.
- The olfacto-hypothalamic-tegmental bundle interacts with the dorsal vagal nucleus in the medulla and is responsible for increased peristalsis and gastric secretion in response to the smell of food.

Olfactory pathways

it goes to the olfactory cortex so perception of sensations occurs, it's also associated to memory and emotions towards that odor

- **The lateral olfactory stria** contains the largest number of fibers in the olfactory tract and is responsible for the majority of functional olfactory transmission.
- The lateral olfactory stria carries the efferent projections of the olfactory bulb toward the limen of the insula, where it bends medially to enter the temporal lobe near the uncus, where the primary olfactory cortex is.
- The primary olfactory cortex is the main site of olfactory information processing. The primary olfactory cortex interacts with a wide variety of cortical and limbic structures and refers to the structures that receive axons from the olfactory bulb.
- These structures include the piriform cortex, amygdala, parahippocampal gyrus, olfactory tubercle, and anterior olfactory nucleus. These structures provide a multitude of functions that result in the integration of olfactory sensory information to encode, recognize, and contextualize scenarios.

Olfaction pathway

- An important feature of the lateral olfactory area is that many signal pathways from this area also feed directly into an older part of the cerebral cortex called the paleocortex in the anteromedial portion of the temporal lobe. This area is the only area of the entire cerebral cortex where sensory signals pass directly to the cortex without passing first through the thalamus.

- The participation of the hippocampus and the amygdala in the processing of odor information partly explains the emotional character of odors and the key role of odors in the recalling of (typically children's) memory records.

- The physiology of the cerebral processing of odor impressions is not wholly clear. However, the orbitofrontal cortex plays a major role in the conscious perception of odors; other important structures are the piriform cortex, the amygdala, the hippocampus, the thalamus, the nucleus accumbens, and the cerebellum.

Adaptation of olfactory sensations

- The olfactory receptors adapt about 50 percent in the first second or so after stimulation. Thereafter, they adapt very little and very slowly.

- Most of the adaptation occurs within the central nervous system, which seems to be true for the adaptation of taste sensations as well.

- The following neuronal mechanism for the adaptation is postulated: Large numbers of centrifugal nerve fibers pass from the olfactory regions of the brain backward along the olfactory tract and terminate on special inhibitory cells in the olfactory bulb, the granule cells. It has been postulated that after the onset of an olfactory stimulus, the central nervous system quickly develops strong feedback inhibition to suppress relay of the smell signals through the olfactory bulb.

Range of intensity descrimination

- Although the threshold concentrations of substances that evoke smell are extremely slight, for many odorants, concentrations only 10 to 50 times above the threshold evoke maximum intensity of smell. A much lower range of intensity discrimination than vision or hearing for instance.

- This difference might be explained by the fact that smell is concerned more with detecting the presence or absence of odors rather than with quantitative detection of their intensities.

Affective Nature of Smell

- Smell, even more so than taste, has the affective quality of either pleasantness or unpleasantness, and thus smell is probably even more important than taste for the selection of food.

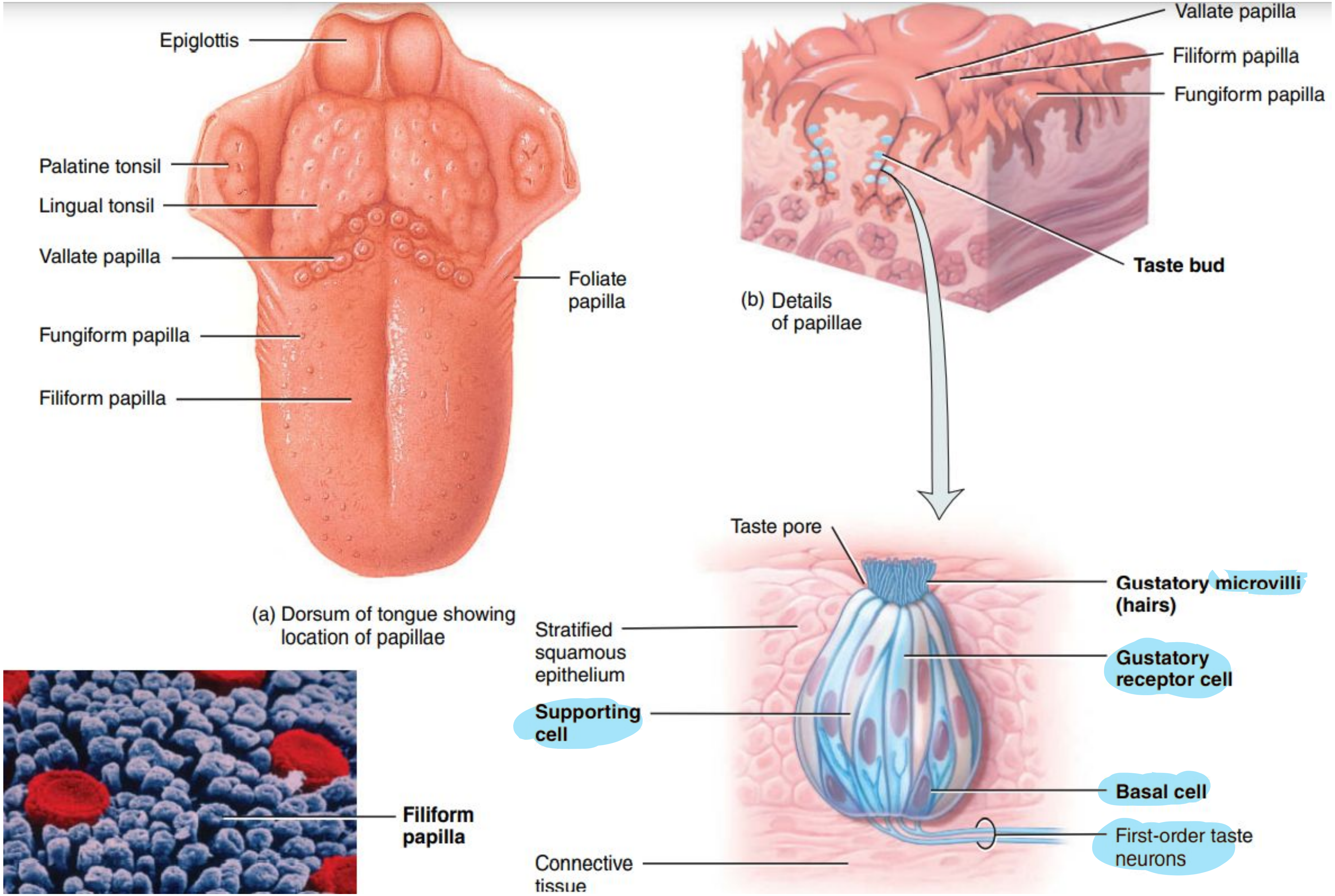
- Indeed, a person who has previously eaten food that disagreed with him or her is often nauseated by the smell of that same food on a second occasion. Conversely, perfume of the right quality can be a powerful stimulant of human emotions.

Main causes of smell disorders

- 1- trauma
- 2- infections (viral) like in Covid
- 3- nasal causes such as sinusitis or polyps (inflammation)
- 4- neurological illnesses such as Parkinson's disease or Alzheimer's disease.
- 5- aging
- 6- smoking
- 7- medications

Gustation: Sense of Taste

Taste



Epiglottis
Palatine tonsil
Lingual tonsil
Vallate papilla
Fungiform papilla
Filiform papilla
Foliate papilla
(a) Dorsum of tongue showing location of papillae
Vallate papilla
Filiform papilla
Fungiform papilla
Taste bud
(b) Details of papillae
Taste pore
Gustatory microvilli (hairs)
Stratified squamous epithelium
Gustatory receptor cell
Supporting cell
Basal cell
First-order taste neurons
Connective tissue
Filiform papilla

Sense of taste

found in the oral cavity in general

- Taste is mainly a function of the taste buds in the mouth, but it is common experience that one's sense of smell also contributes strongly to taste perception. In addition, the texture of food, as detected by tactual senses of the mouth, and the presence of substances in the food that stimulate pain endings, such as pepper, greatly alter the taste experience.

- The importance of taste lies in the fact that it allows a person to select food in accord with desires and often in accord with the body tissues' metabolic need for specific substances.

Primary sensations of taste

- They are sour, salty, sweet, bitter, and “umami.”

- A person can perceive hundreds of different tastes. They are all thought to be combinations of the elementary taste sensations, just as all the colors we can see are combinations of the three primary colors.

Sense of taste

H+

- **Sour Taste**. The sour taste is caused by acids—that is, by the hydrogen ion concentration—and the intensity of this taste sensation is approximately proportional to the logarithm of the hydrogen ion concentration.

Na+

- **Salty Taste**. The salty taste is elicited by ionized salts, mainly by the sodium ion concentration. The quality of the taste varies somewhat from one salt to another because some salts elicit other taste sensations in addition to saltiness. The cations of the salts, especially sodium cations, are mainly responsible for the salty taste, but the anions also contribute to a lesser extent.

Sense of taste

- **Umami Taste**. Umami, a Japanese word meaning “delicious,” designates a pleasant taste sensation that is qualitatively different from sour, salty, sweet, or bitter. Umami is the dominant taste of food containing L-glutamate, such as meat extracts and aging cheese.

Sense of taste

organic+inorganic

- **Sweet Taste**. The sweet taste is not caused by any single class of chemicals. Some of the types of chemicals that cause this taste include sugars, glycols, alcohols, aldehydes, ketones, amides, esters, some amino acids, some small proteins, sulfonic acids, halogenated acids, and inorganic salts of lead and beryllium.

- Note specifically that most of the substances that cause a sweet taste are organic chemicals.

Sense of taste

- **Bitter Taste**. like the sweet taste, is not caused by a single type of chemical agent. They are mostly organic substances, such as long-chain organic substances that contain nitrogen and alkaloids, which include many of the drugs used in medicines, such as quinine, caffeine, strychnine, and nicotine. Some substances that initially taste sweet have a bitter aftertaste, such as saccharin.

- The bitter taste, when it occurs in high intensity, usually causes the person or animal to reject the food. This reaction is important because many deadly toxins found in poisonous plants are alkaloids, and virtually all of these alkaloids cause an intensely bitter taste. it's a protective mechanism

Threshold for taste

The threshold differs from one receptor to another

- The threshold for stimulation of the sour taste by hydrochloric acid averages 0.0009 M; for stimulation of the salty taste by sodium chloride, 0.01 M; for the sweet taste by sucrose, 0.01 M; and for the bitter taste by quinine, 0.000008 M.

lowest threshold

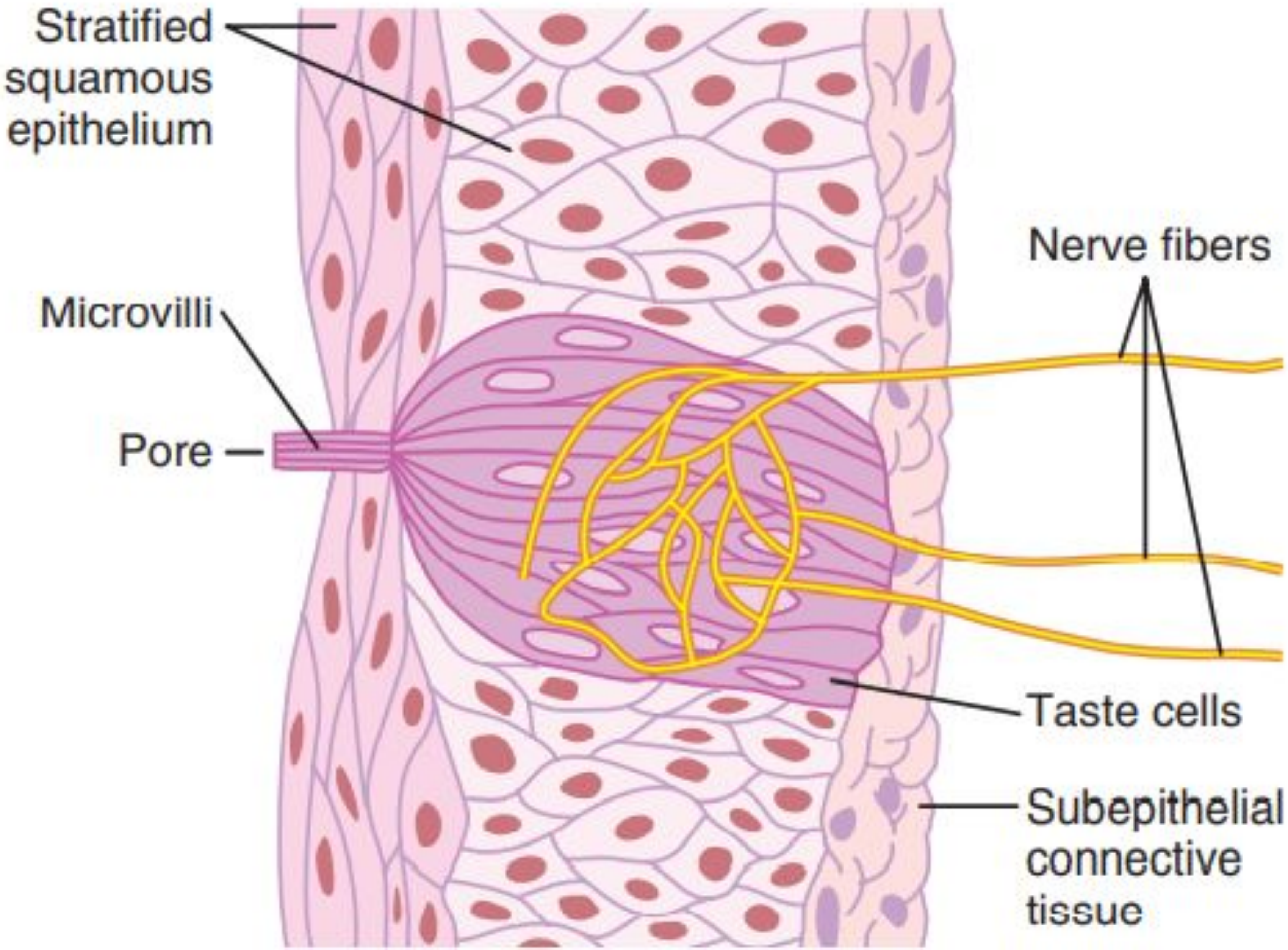
- Note especially how much more sensitive the bitter taste sense is than all the others, which would be expected, because this sensation provides an important protective function against many dangerous toxins in food.

Taste buds

- The taste bud is composed of about 50 modified epithelial cells, some are supporting cells and others are taste cells.
- The taste cells are continually being replaced by mitotic division of surrounding epithelial cells, so some taste cells are young cells. Others are mature cells that lie toward the center of the bud; these cells soon break up and dissolve.

while the newer is on periphery

- Adults have about 10,000 taste buds, and children have a few more. Beyond the age of 45 years, many taste buds degenerate, causing taste sensitivity to decrease in old age.


Stratified
squamous
epithelium
Microvilli
Pore
Nerve fibers
Taste cells
Subepithelial
connective
tissue

Taste buds

- The life span of each taste cell is about 10 days.
- The outer tips of the taste cells are arranged around a minute taste pore. From the tip of each taste cell, several microvilli protrude outward into the taste pore to approach the cavity of the mouth. These microvilli provide the receptor surface for taste.
- Interwoven around the bodies of the taste cells is a branching terminal network of taste nerve fibers that are stimulated by the taste receptor cells.
- Many vesicles form beneath the cell membrane near the fibers. It is believed that these vesicles contain a neurotransmitter substance that is released through the cell membrane to excite the nerve fiber endings in response to taste stimulation.

Location of taste buds

- The taste buds are found on three types of papillae of the tongue, as follows:
- (1) a large number of taste buds are on the walls of the troughs that surround the **circumvallate papillae**, which form a V line on the surface of the posterior tongue.
- (2) moderate numbers of taste buds are on the **fungiform papillae** over the flat anterior surface of the tongue.
- (3) moderate numbers are on the **foliate papillae** located in the folds along the lateral surfaces of the tongue.

- Additional taste buds are located on the palate, and a few are found on the tonsillar pillars, on the epiglottis, and even in the proximal esophagus.

Taste transduction

- The mechanism by which most stimulating substances react with the taste villi to initiate the receptor potential is by binding of the taste chemical to a protein receptor molecule that lies on the outer surface of the taste receptor cell near to or protruding through a villus membrane.

- This action, in turn, opens ion channels, which allows positively charged sodium ions or hydrogen ions to enter and depolarize the cell. Then the taste chemical is gradually washed away from the taste villus by the saliva, which removes the stimulus.

Taste transduction

- The type of receptor protein in each taste villus determines the type of taste that will be perceived. For sodium ions and hydrogen ions, which elicit salty and sour taste sensations, respectively, the receptor proteins open specific ion channels in the apical membranes of the taste cells, thereby activating the receptors.

- However, for the sweet and bitter taste sensations, the portions of the receptor protein molecules that protrude through the apical membranes (GPCR) activate second-messenger transmitter substances inside the taste cells, and these second messengers cause intracellular chemical changes that elicit the taste signals.

Taste transduction

- On first application of the taste stimulus, the rate of discharge of the nerve fibers from taste buds rises to a peak in a small fraction of a second but then adapts within the next few seconds back to a lower, steady level as long as the taste stimulus remains.

Taste pathway

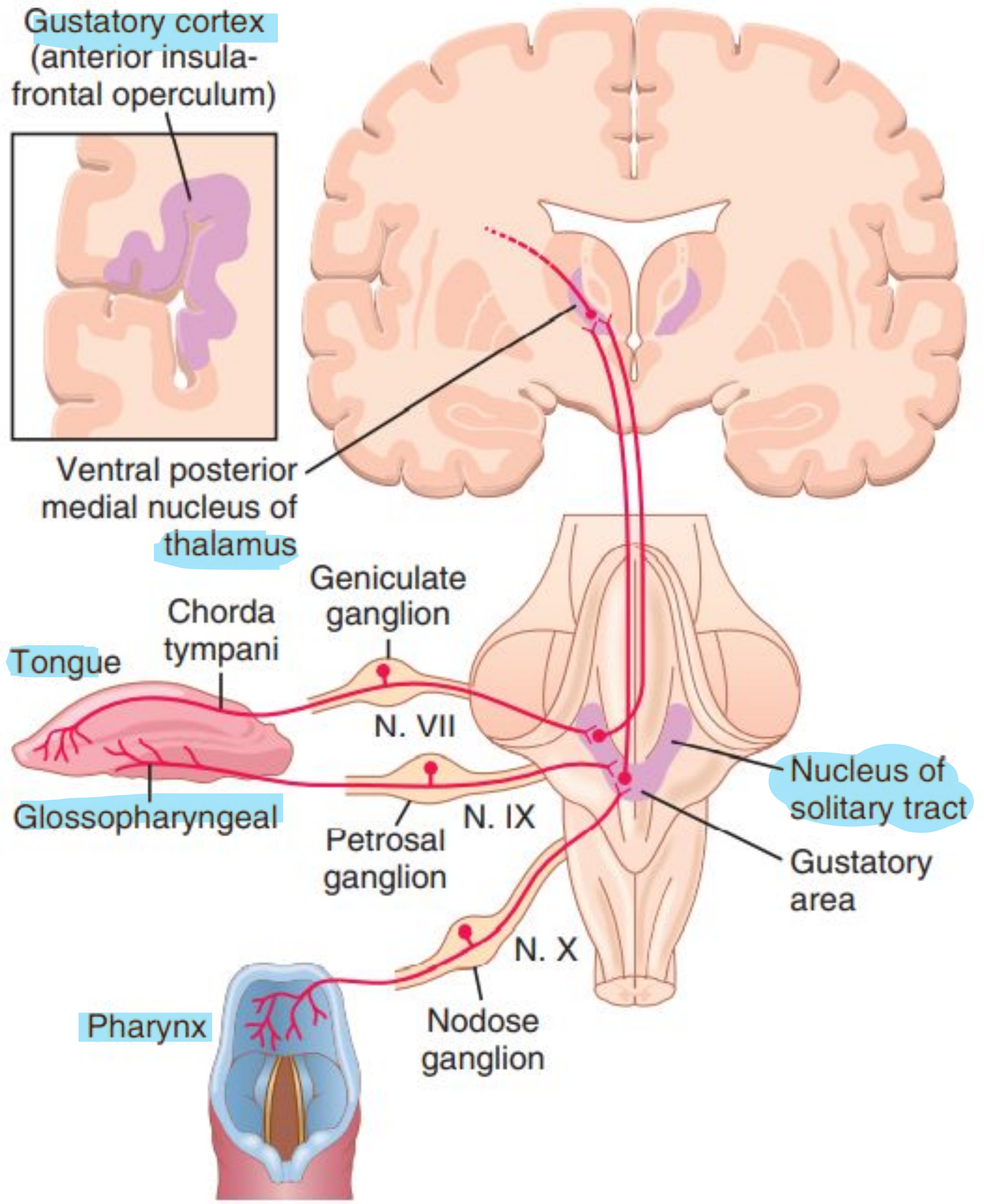
- Taste impulses from the anterior two thirds of the tongue pass first into the lingual nerve, then through the chorda tympani into the facial nerve, and finally into the tractus solitarius in the brain stem. supplied by
- Taste sensations from the circumvallate papillae on the back of the tongue and from other posterior regions of the mouth and throat are transmitted through the glossopharyngeal nerve also into the tractus solitarius, but at a slightly more posterior level.
- Finally, a few taste signals are transmitted into the tractus solitarius from the base of the tongue and other parts of the pharyngeal region by way of the vagus nerve.

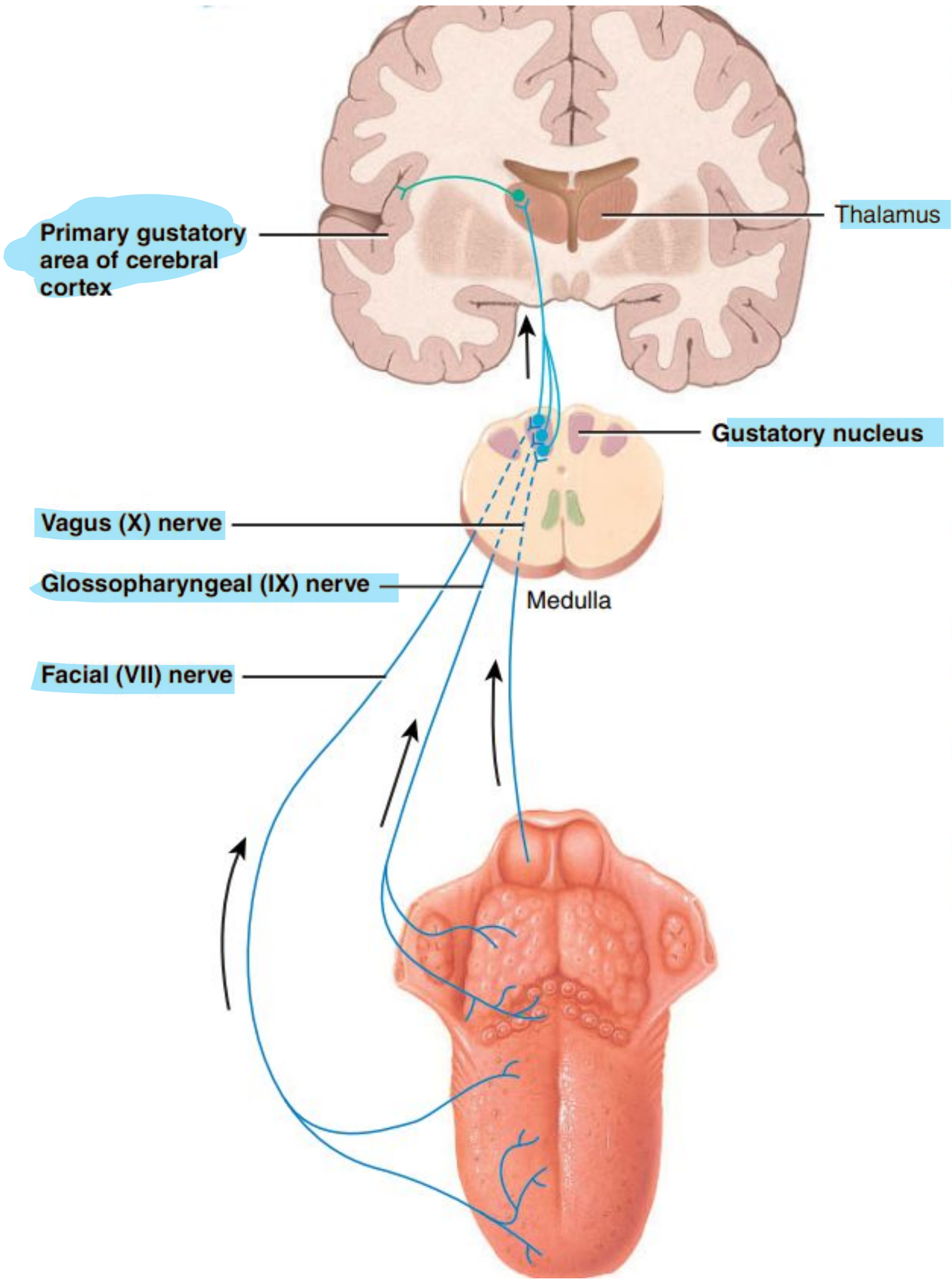
Taste pathway

- All taste fibers synapse in the posterior brain stem in the nuclei of the tractus solitarius. These nuclei send second-order neurons to a small area of the ventral posterior medial nucleus of the thalamus.

- From the thalamus, third-order neurons are transmitted to the lower tip of the postcentral gyrus in the parietal cerebral cortex, where it curls deep into the sylvian fissure, and into the adjacent opercular insular area. This area lies slightly lateral, ventral, and rostral to the area for tongue tactile signals in cerebral somatic area I.

- From this description of the taste pathways, it is evident that they closely parallel the somatosensory pathways from the tongue.


Gustatory cortex
(anterior insula-
frontal operculum)
Ventral posterior
medial nucleus of
thalamus
Geniculate
ganglion
Chorda
tympani
Tongue
N. VII
Nucleus of
solitary tract
Glossopharyngeal
N. IX
Petrosal
ganglion
Gustatory
area
N. X
Pharynx
Nodose
ganglion



Primary gustatory area of cerebral cortex
Thalamus
Gustatory nucleus
Vagus (X) nerve
Glossopharyngeal (IX) nerve
Medulla
Facial (VII) nerve

Taste reflexes

it might travel from tractus solitarius then whithout passing the cortex (by taste reflexes) it might go to salivatory

- From the tractus solitarius, many taste signals are transmitted within the brain stem itself directly into the superior and inferior salivatory nuclei, and these areas transmit signals to the submandibular, sublingual, and parotid glands to help control the secretion of saliva during the ingestion and digestion of food.

Main causes of taste disorders

- Olfactory dysfunction is more common than taste dysfunction.
- Ageusia: total loss of taste is rare due to multiple pathways.
- Oral and perioral infections, head trauma, dental interventions, tumor, medications.

the reason is

- As in the olfactory system, somatosensory sensations (e.g., stinging, burning, cooling and sharpness) can be induced by many foods (e.g., hot peppers) through trigeminal nerve fibers in the tongue and oral cavity.

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Thank you