CNS for medical students

Olfaction and Gustation

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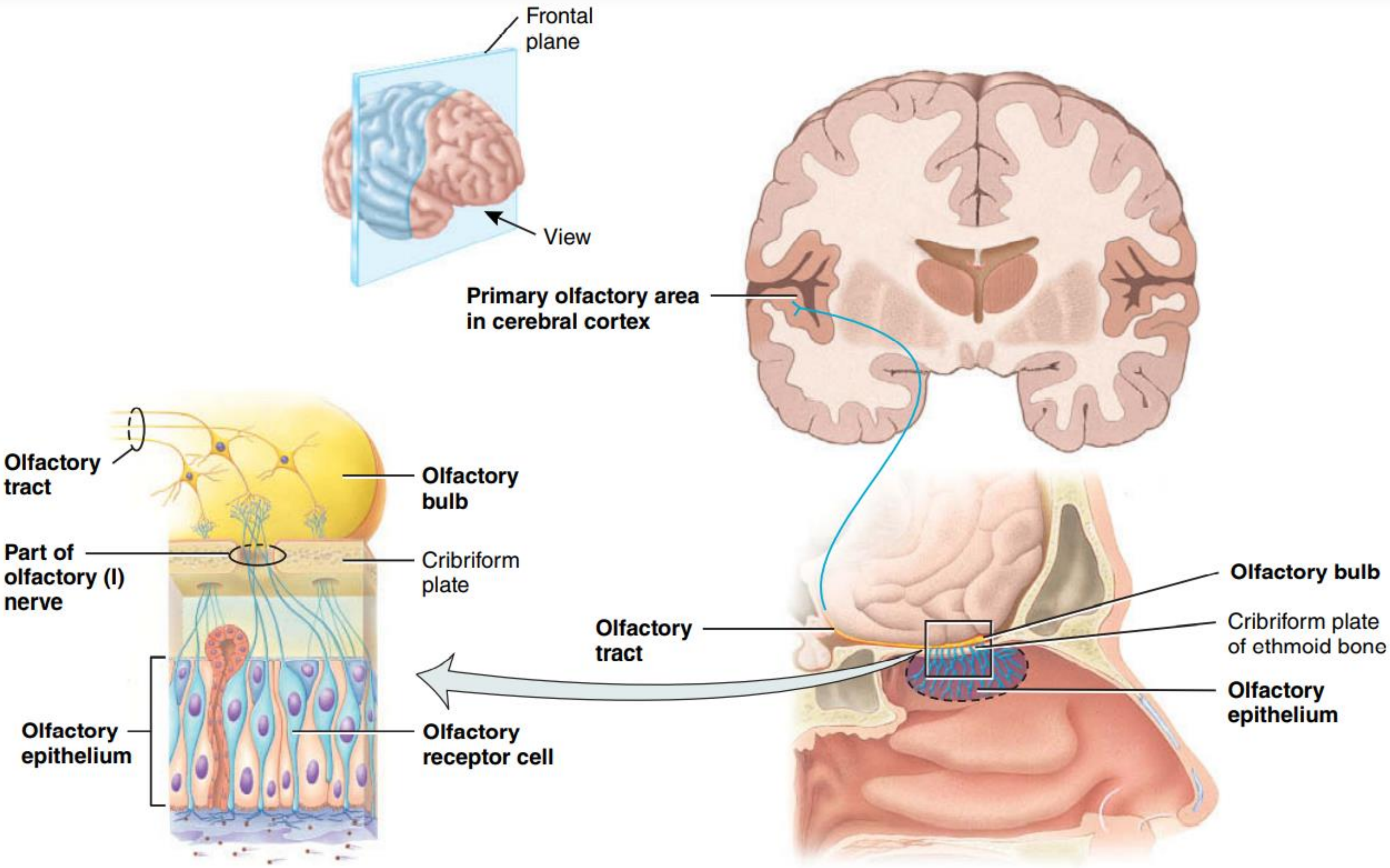
Special senses

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

Olfaction


Frontal plane
View
Primary olfactory area in cerebral cortex
Olfactory tract
Olfactory bulb
Part of olfactory (I) nerve
Cribriform plate
Olfactory epithelium
Olfactory receptor cell
Olfactory tract
Olfactory bulb
Cribriform plate of ethmoid bone
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.

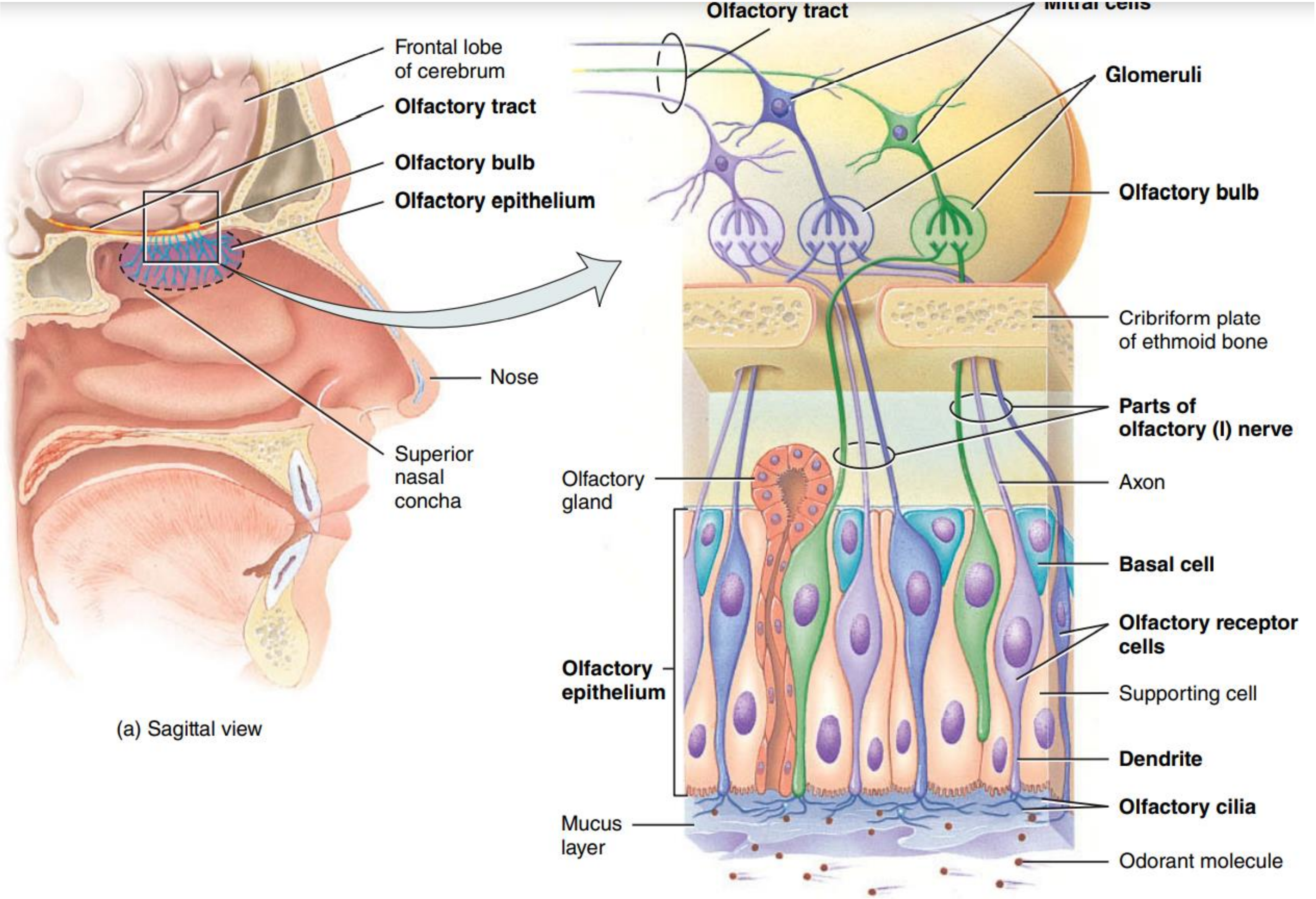
- The olfactory epithelium consists of three types of cells: olfactory receptor cells, supporting cells, and basal cells.

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.

- 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.



(a) Sagittal view

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.

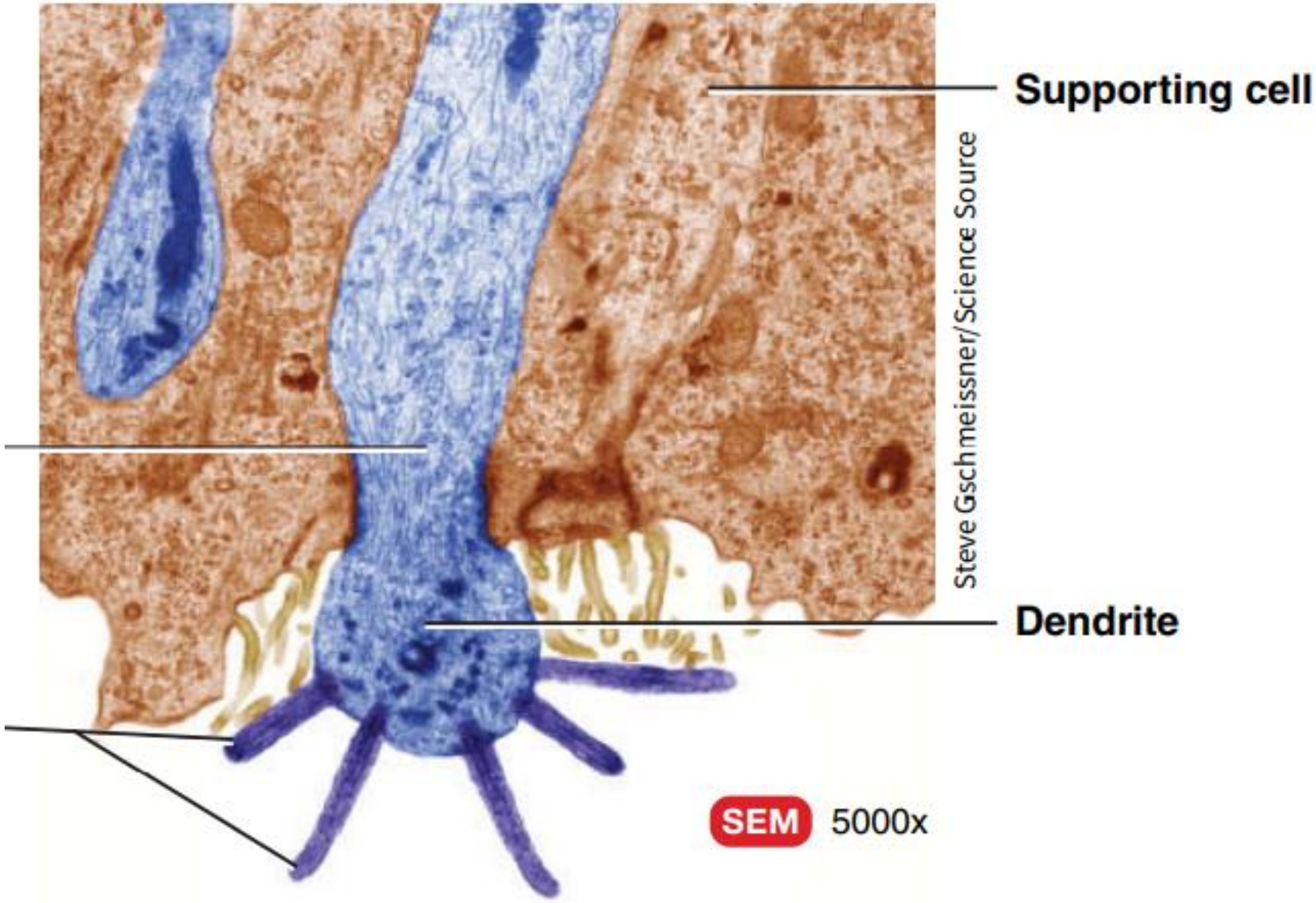
Extending from the dendrite of an olfactory receptor cell are several nonmotile olfactory cilia, which are the sites of olfactory transduction.

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.

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)

Olfactory receptors

- Olfactory receptors are many types. Each type of olfactory receptor can react to only a select group of odorants.

- Genetic studies suggest 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 steps in olfactory transduction are as follows:

- 1. Odorant molecules bind to specific olfactory receptor proteins located on the cilia of olfactory receptor cells. Olfactory receptor proteins are members of the superfamily of G protein–coupled receptors, each encoded by a different gene and each found on a different olfactory receptor cell.

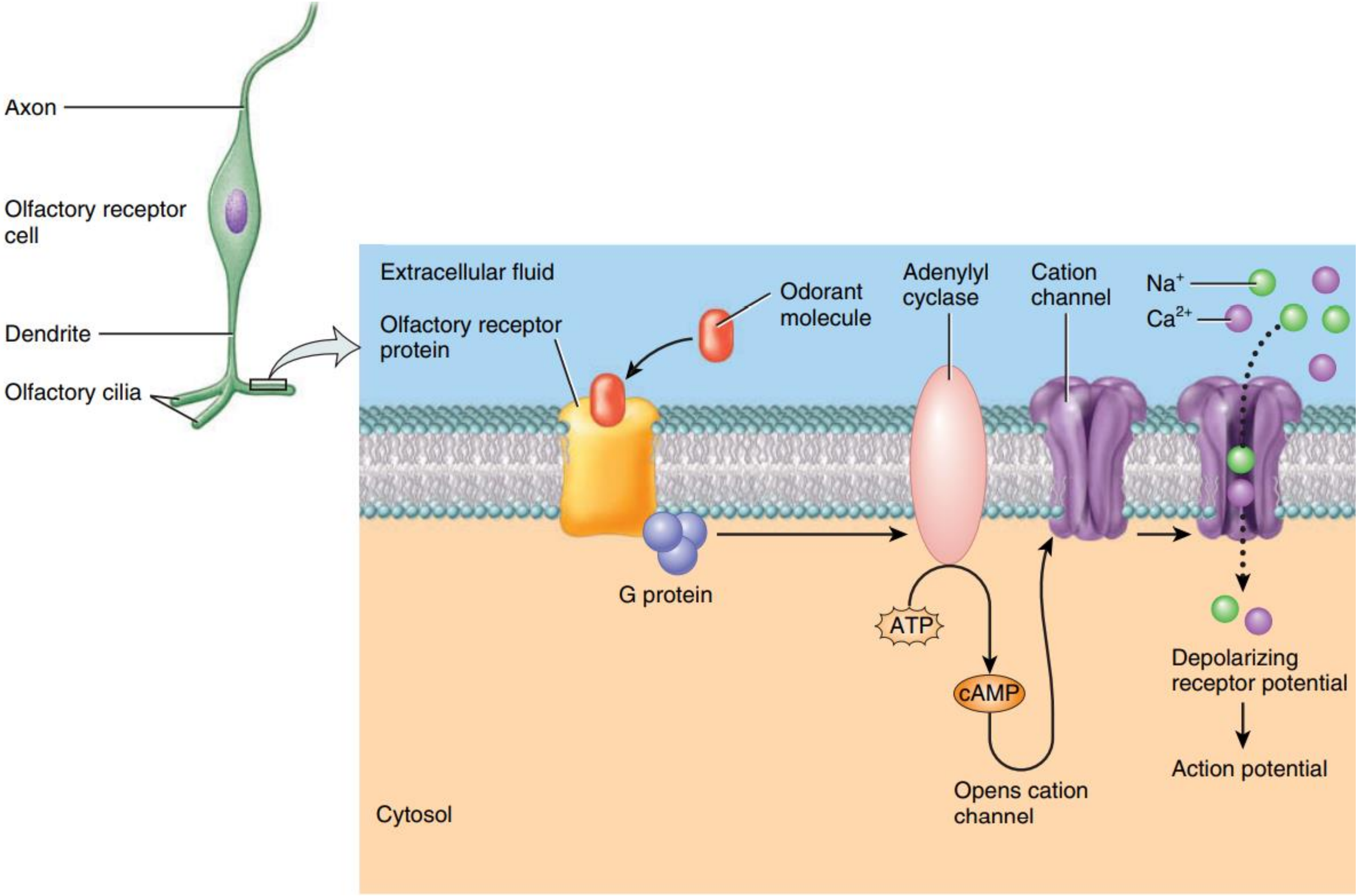
- 2. The olfactory receptor proteins are coupled to adenylyl cyclase via a G protein.

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.

- 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

Olfactory threshold

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

- 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.

- 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.

Characteristics of odorants

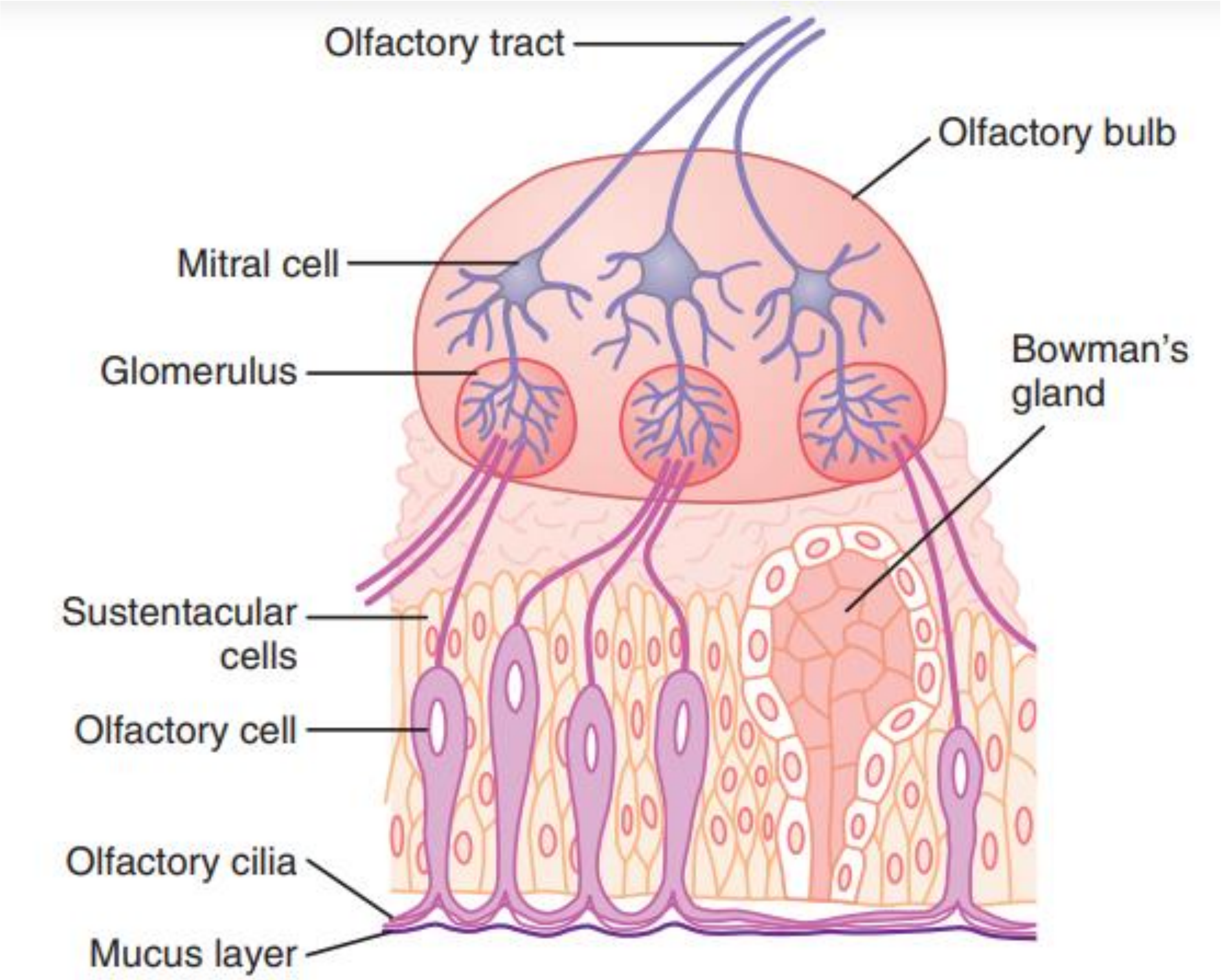
- There are several physical factors affect the degree of stimulation.

- First, only volatile substances that can be sniffed into the nasal cavity can be smelled.
- Second, the stimulating substance must be at least slightly water-soluble so that it can pass through the mucus to reach the olfactory cilia.
- Third, it is helpful for the substance to be at least slightly lipid-soluble, presumably because lipid constituents of the cilium are a weak barrier to non–lipid-soluble odorants.

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.

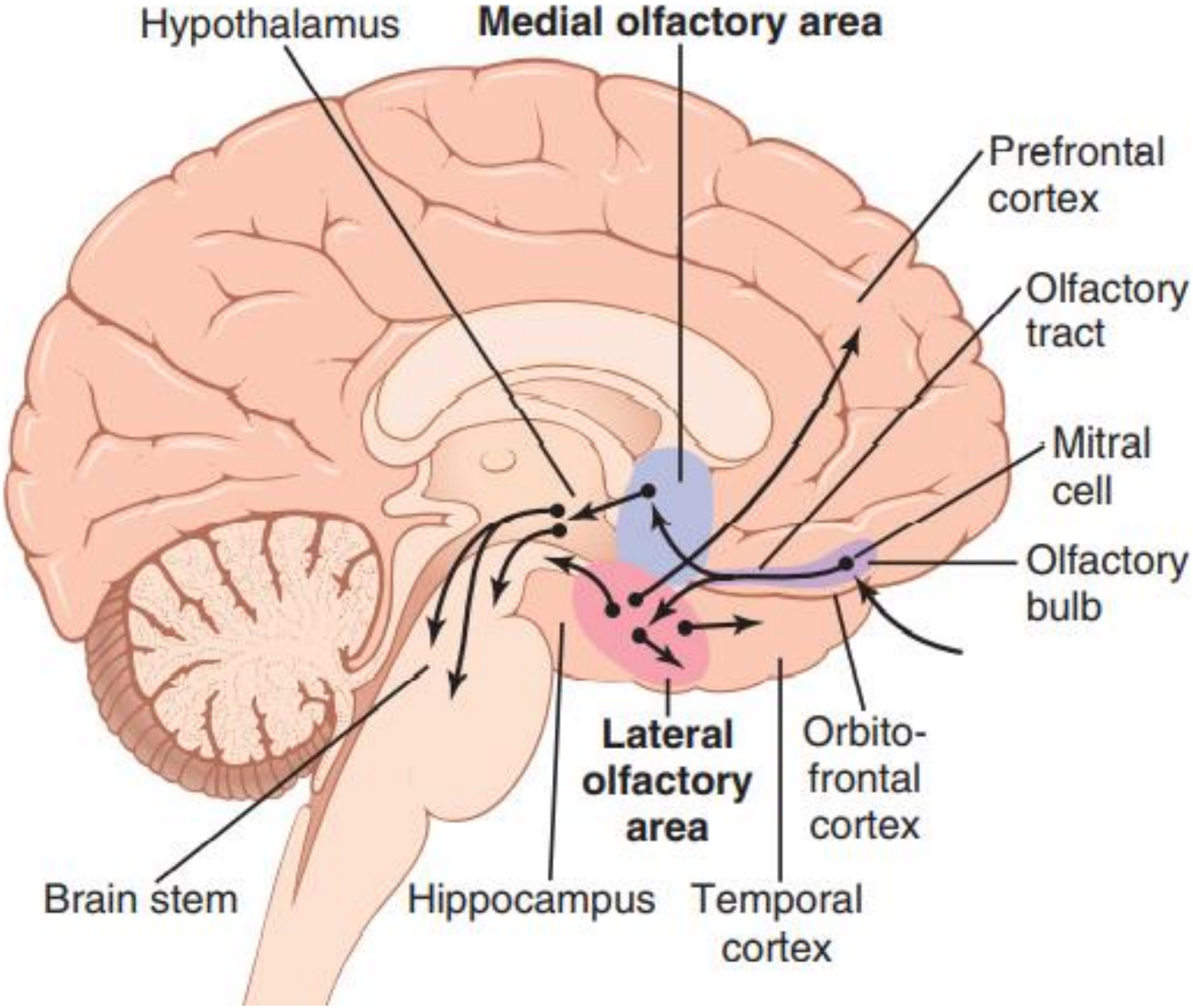
- In the glomeruli, the mitral cells are arranged in a single layer in the olfactory bulb and have lateral dendrites in addition to the apical dendrites.


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 may provide lateral inhibition that “sharpens” the information projected to the CNS.

- 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
Lateral olfactory area
Orbito-frontal cortex
Temporal cortex
Hippocampus
Brain stem

Olfactory pathways

- **The medial olfactory area or primitive olfactory system:**
- Consists of a group of nuclei located in the midbasal portions of the brain immediately anterior to the hypothalamus.
- Most nuclei feed into the hypothalamus and other primitive portions of the limbic system.
- This is the brain area most concerned with basic behavior and autonomic responses associated with olfaction, such as an increase in salivation (activation of superior and inferior salivary nuclei) and gastric peristalsis/secretion in response to the smell of food (interacts with dorsal vagal nucleus in the medulla).

Olfactory pathways

- **The lateral olfactory area** contains the largest number of fibers in the olfactory tract and is responsible for the majority of functional olfactory transmission.
- The primary olfactory cortex is the main site of <u>olfactory information processing,</u> through the integration of olfactory sensory information to encode, recognize, and contextualize scenarios.

Olfactory pathways

- **The lateral olfactory area:**
- Is composed mainly of the prepyriform and pyriform cortex plus the cortical portion of the amygdaloid nuclei.
- From these areas, signal pathways pass into almost all portions of the limbic system especially the hippocampus,
- which seem to be most important for **learning** to like or dislike certain foods depending on one's experiences with them, as well as the **emotional character of odors** and in the recalling of **memory** records.

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.

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.**

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 suggested neuronal mechanism for the adaptation is: 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.

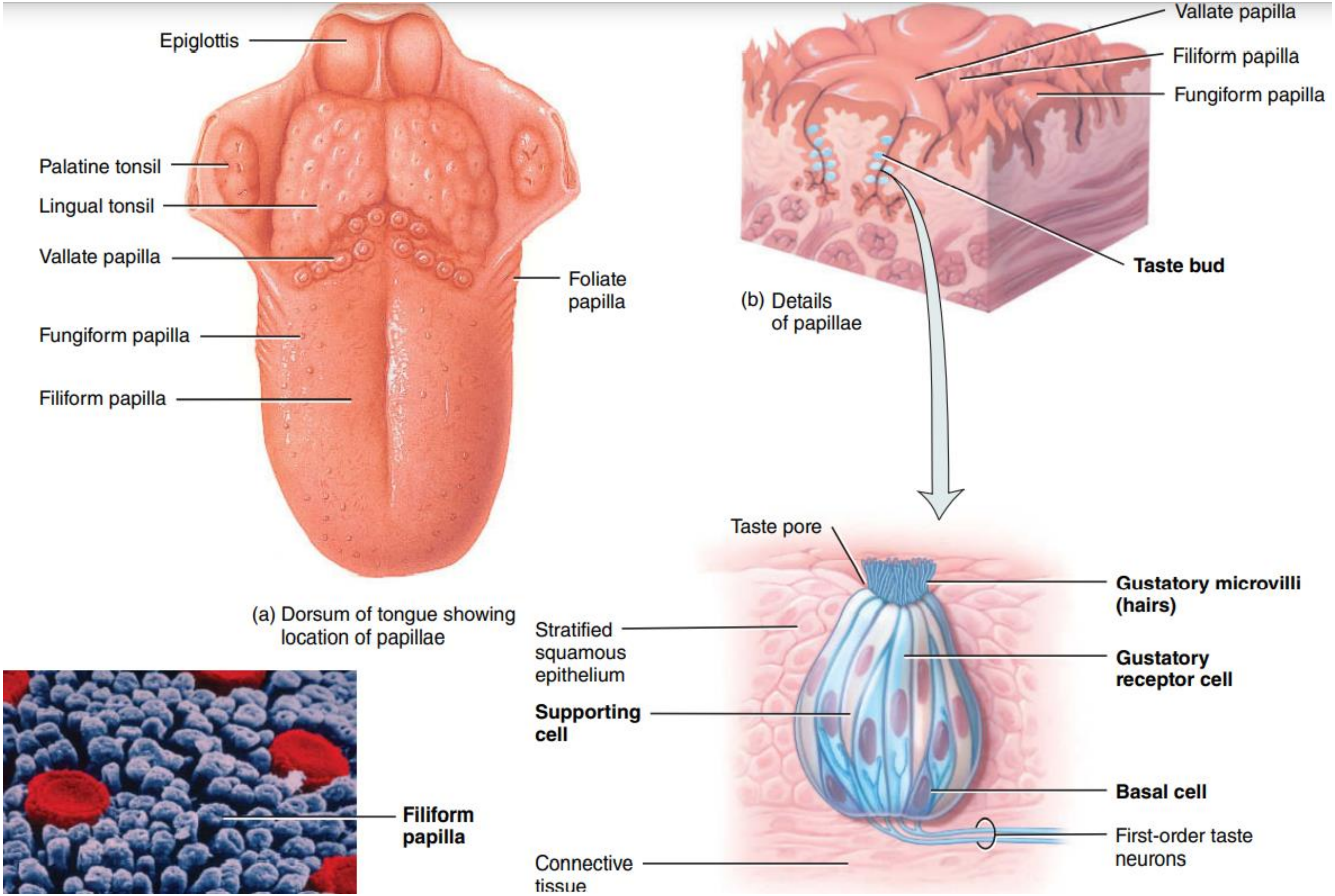
Range of intensity discrimination

- Olfaction has a much lower range of intensity discrimination than vision or hearing.

- 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.

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

- 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

- **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.

- **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

- **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.

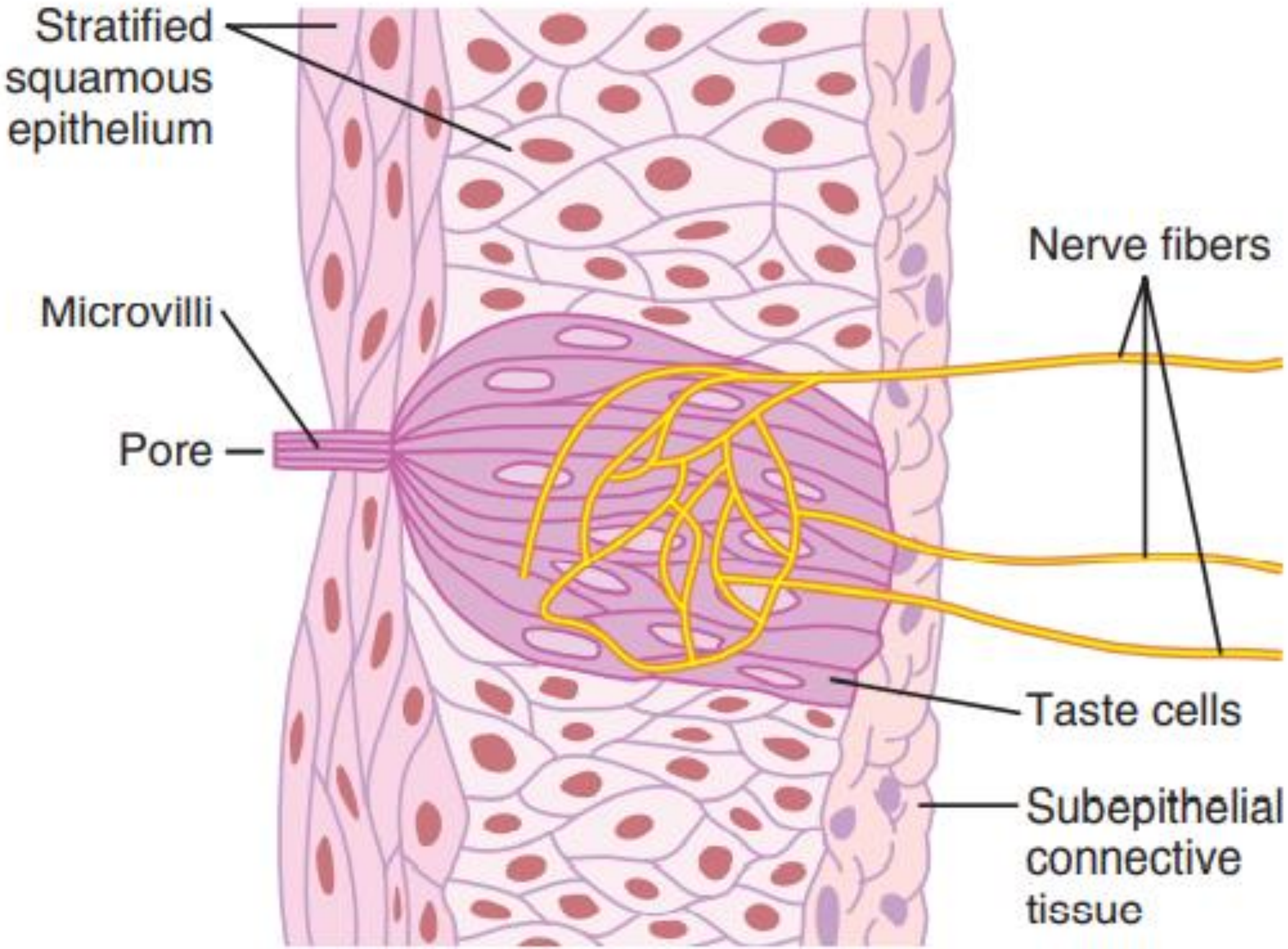
- The bitter taste, when it occurs in high intensity, usually causes the person or animal to reject the food. This reaction is important because many deadly toxins found in poisonous plants are alkaloids, and virtually all of these alkaloids cause an intensely bitter taste.

Threshold for taste

- 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.
- 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.
- 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.



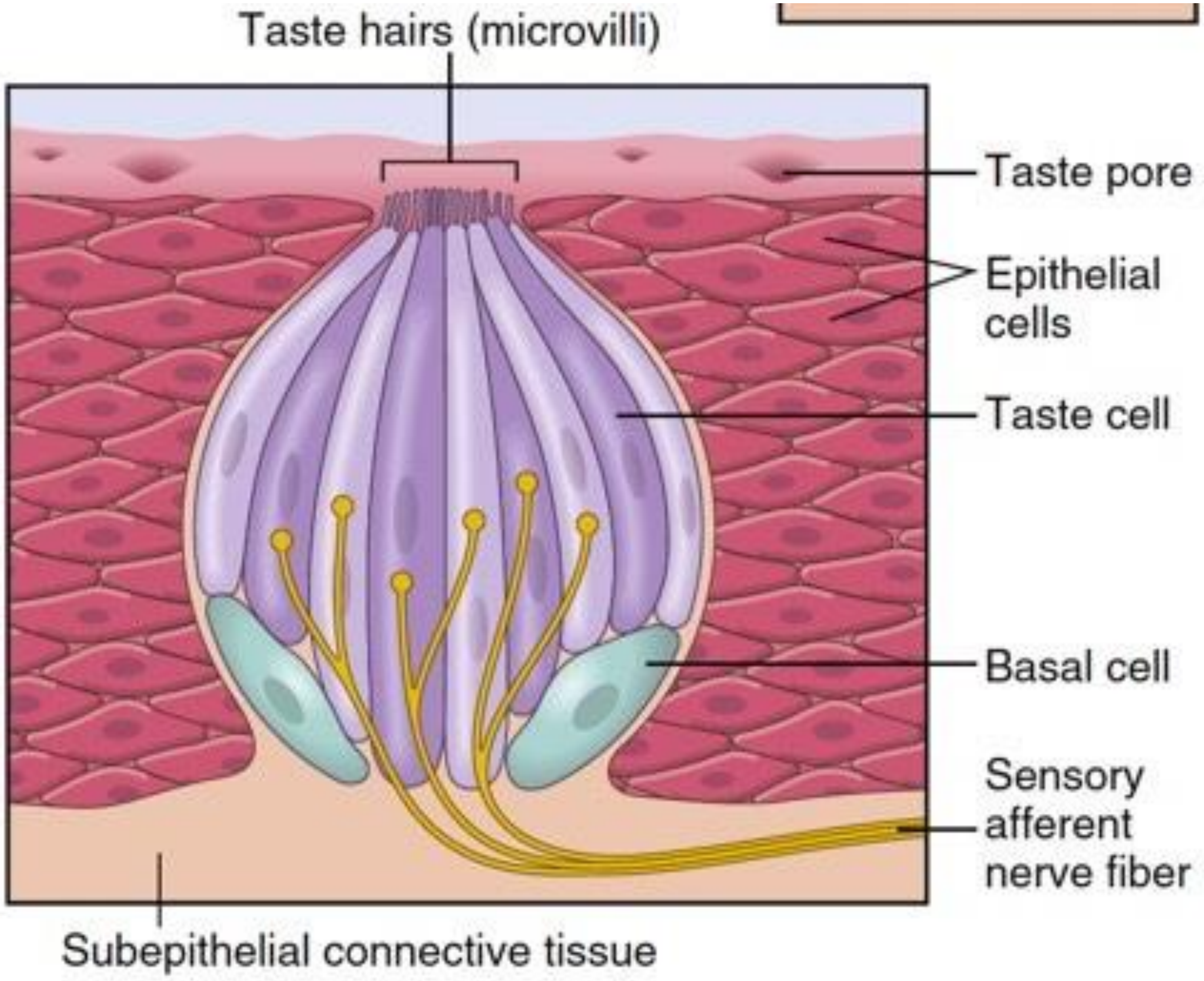
Stratified
squamous
epithelium
Microvilli
Pore
Nerve fibers
Taste cells
Subepithelial
connective
tissue

Taste buds

- The average 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.

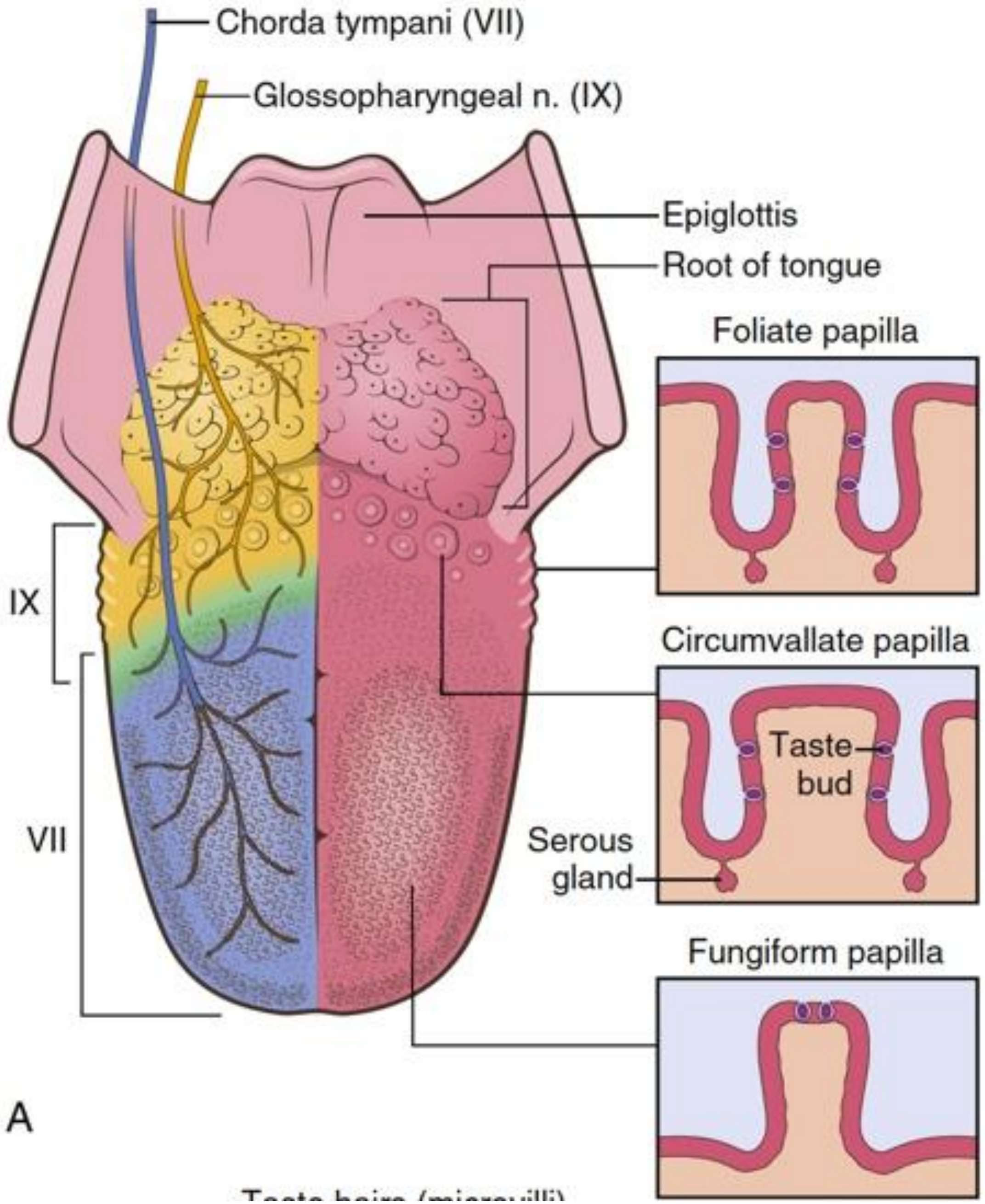
- Many vesicles form beneath the cell membrane near the fibers. It is believed that these vesicles contain a neurotransmitter substance that is released through the cell membrane to excite the nerve fiber endings in response to taste stimulation.


Taste hairs (microvilli)
Taste pore
Epithelial cells
Taste cell
Basal cell
Sensory afferent nerve fiber
Subepithelial connective tissue

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.



Chorda tympani (VII)
Glossopharyngeal n. (IX)
Epiglottis
Root of tongue
Foliate papilla
Circumvallate papilla
Taste bud
Serous gland
Fungiform papilla
IX
VII
A

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.

- 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.

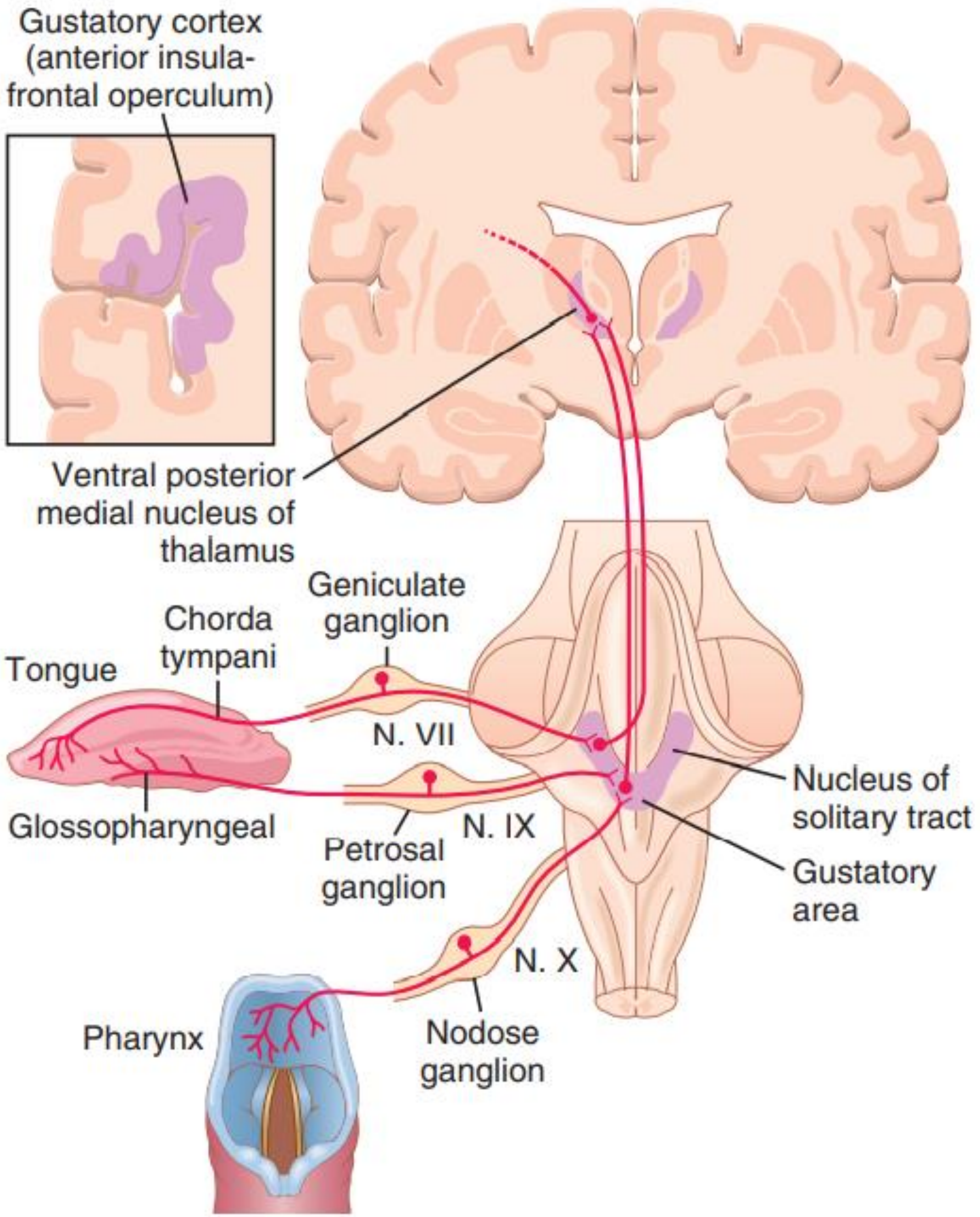
- Finally, a few taste signals are transmitted into the tractus solitarius from the base of the tongue and other parts of the pharyngeal region by way of the vagus nerve.

Taste pathway

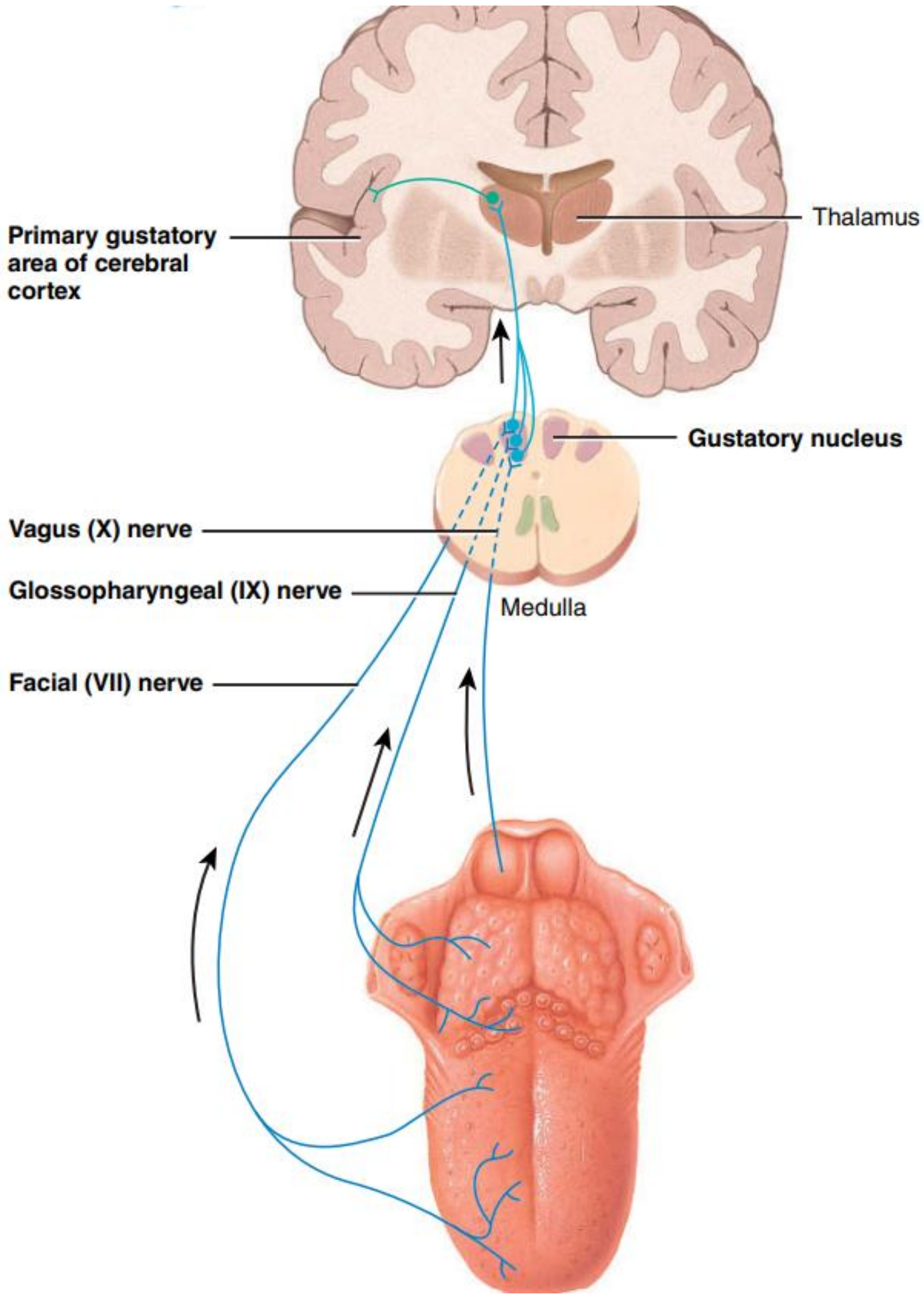
- All taste fibers synapse in the posterior brain stem in the nuclei of the tractus solitarius. These nuclei send second-order neurons to a small area of the ventral posterior medial nucleus of the thalamus.

- 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
Glossopharyngeal
Petrosal
ganglion
N. IX
Nucleus of
solitary tract
Gustatory
area
N. X
Pharynx
Nodose
ganglion


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

Taste reflexes

- 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.

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Thank you