بسم الله الرحمن الرحيم

Olfaction and Gustation

MID | Lecture 4

﴿إِنِّي تَوَكَّلْتُ عَلَى ٱللَّهِ رَبِّي وَرَبِّكُم ۚ مَّا مِن دَآبَّةٍ إِلَّا هُوَ ءَاخِذٌۢ بِنَاصِيَتِهَآ ۚ إِنَّ رَبِّي عَلَىٰ صِرَٰطٍ مُّسْتَقِيمٍ﴾

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PHYSIOLOGY

رحلة اليقين مع سورة يس

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

قَالُواْ مَآ أَنتُمۡ إِلَّا بَشَرٞ مِّثۡلُنَا وَمَآ أَنزَلَ ٱلرَّحۡمَٰنُ مِن شَيۡءٍ إِنۡ أَنتُمۡ إِلَّا تَكۡذِبُونَ (١٥) قَالُواْ رَبُّنَا يَعۡلَمُ إِنَّآ إِلَيۡكُمۡ
لَمُرۡسَلُونَ (١٦) وَمَا عَلَيۡنَآ إِلَّا ٱلۡبَلَٰغُ ٱلۡمُبِينُ (١٧)

فأجابوهم بالجواب الذي ما زال مشهورا عند من رد دعوة الرسل: فـ { قَالُوا مَا أَنْتُمْ إِلَّا بَشَرٌ مِثْلُنَا } أي: فما الذي فضلكم علينا وخصكم من دوننا؟ قالت الرسل لأممهم: { إِنْ نَحْنُ إِلَّا بَشَرٌ مِثْلُكُمْ وَلَكِنَّ اللَّهَ يَمُنُّ عَلَى مَنْ يَشَاءُ مِنْ عِبَادِهِ } { وَمَا أَنْزَلَ الرَّحْمَنُ مِنْ شَيْءٍ } أي: أنكروا عموم الرسالة، ثم أنكروا أيضا المخاطبين لهم،فقالوا: { إِنْ أَنْتُمْ إِلَّا تَكْذِبُونَ } ، فقالت هؤلاء الرسل الثلاثة: { رَبُّنَا يَعْلَمُ إِنَّا إِلَيْكُمْ لَمُرْسَلُونَ } فلو كنا كاذبين، لأظهر الله خزينا، ولبادرنا بالعقوبة.

{ وَمَا عَلَيْنَا إِلَّا الْبَلَاغُ الْمُبِينُ } أي: البلاغ المبين الذي يحصل به توضيح الأمور المطلوب بيانها، وما عدا هذا من آيات الاقتراح، ومن سرعة العذاب، فليس إلينا، وإنما وظيفتنا -التي هي البلاغ المبين- قمنا بها، وبيناها لكم، فإن اهتديتم، فهو حظكم وتوفيقكم، وإن ضللتم، فليس لنا من الأمر شيء.

Neurophysiology

Olfaction and Gustation

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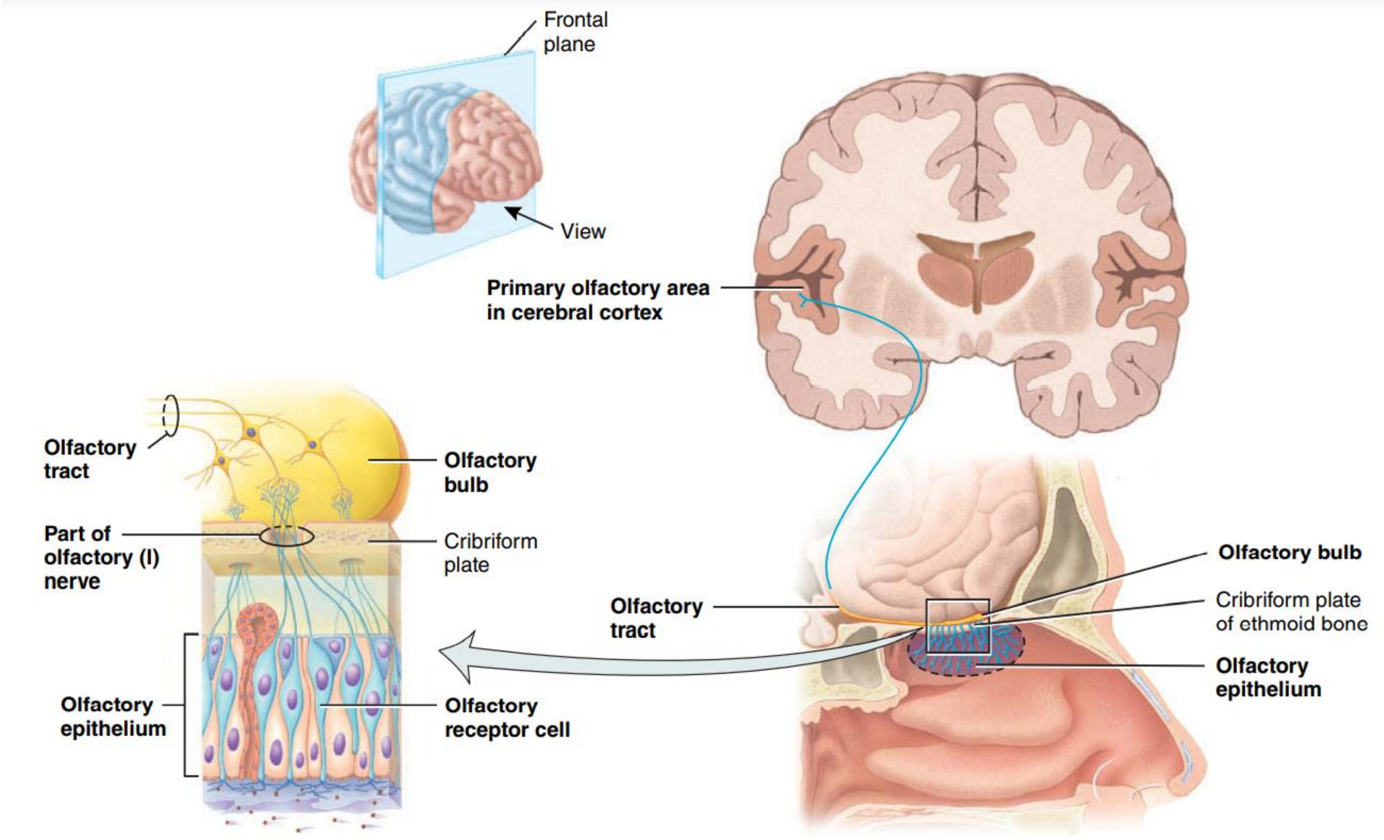
Special senses

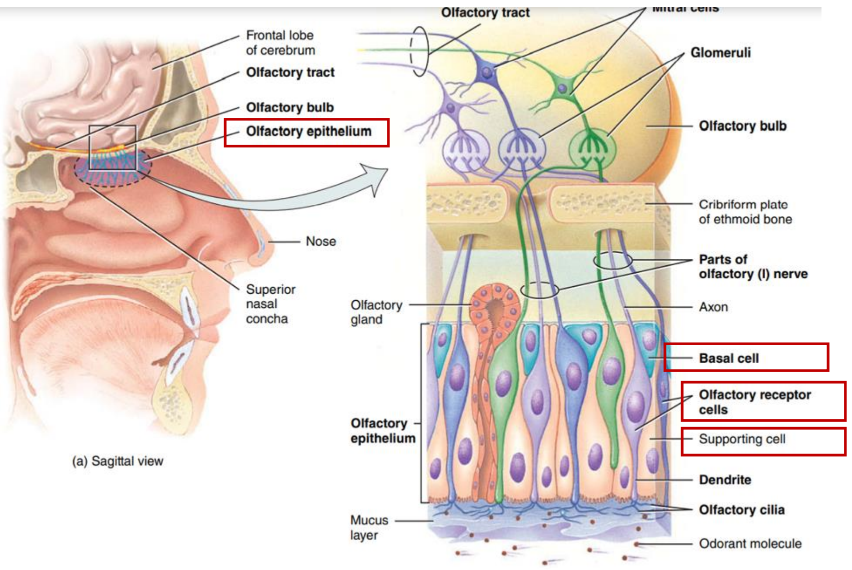
- Olfaction (smell) and gustation (taste) are chemical senses.

➢ This means that the stimulus is a chemical substance that will bind to the sensory receptors.



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.

Next slides

Olfactory epithelium

1. olfactory receptor cell is a **bipolar** neuron (first-order neuron of olfactory pathway) with an exposed, knob-shaped dendrite with **non-motile cilia** coming out of it, which are the **sites of olfactory transduction**, and other end an axon projecting through the cribriform plate that ends in the olfactory bulb where it will synapse with the 2nd order neurons.
2. Supporting cells (sustentacular cells) are columnar epithelial cells lined with microvilli at their mucosal border and filled with **secretory granules**.
3. Basal cells are located at the base of the olfactory epithelium and are undifferentiated stem cells that give rise to the olfactory receptor cells for **regeneration** every 2-3 months.
4. 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. (this mucus will be covering the olfactory receptor cells cilia with its olfactory receptor proteins).

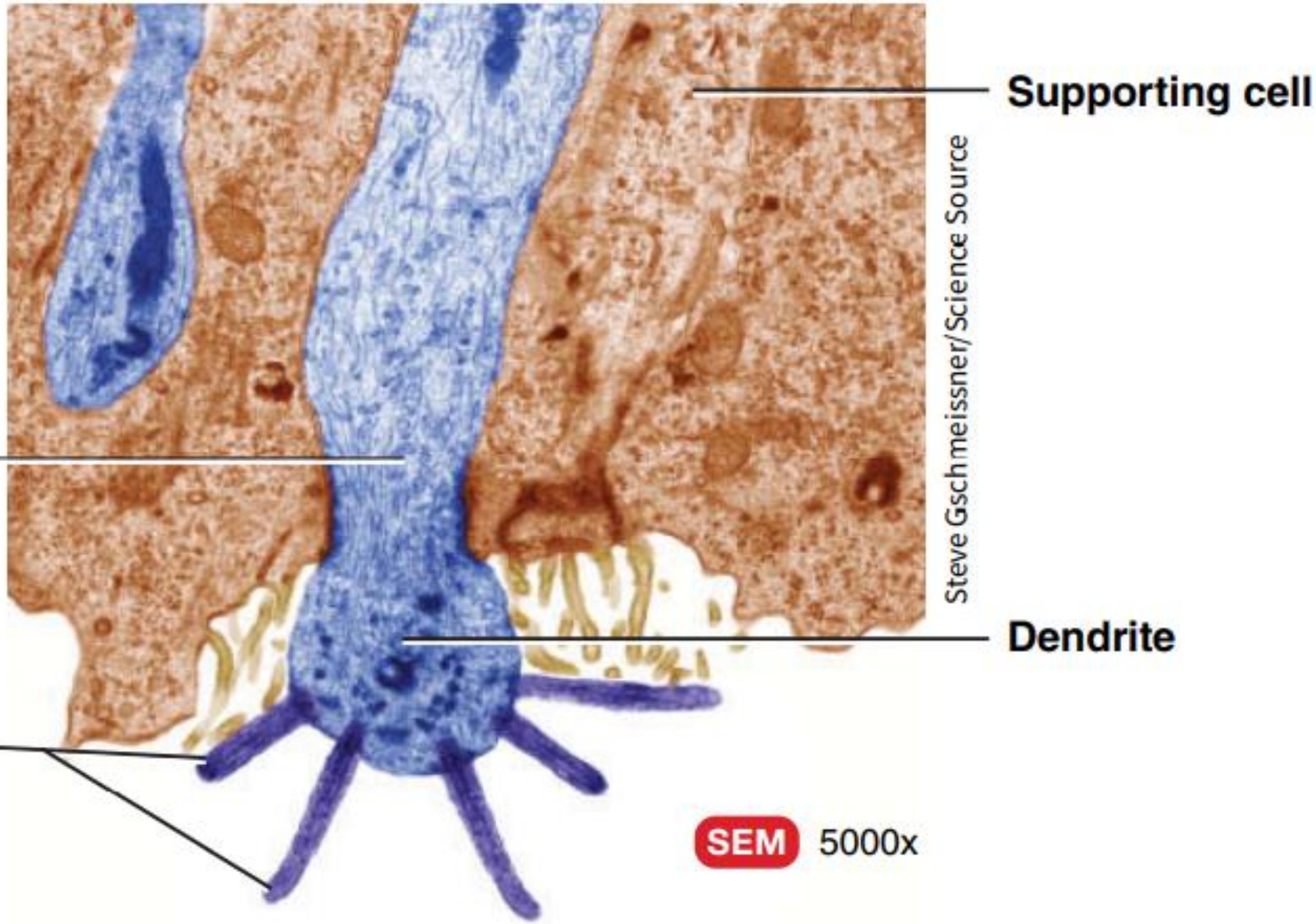
- For any molecule to be smelled, it has to have the following two characteristics:

1. Be **Volatile**, so it will be able to move from the air through the nasal cavity to the olfactory epithelium. It can also come from the mouth up through the pharynx to the olfactory epithelium.
2. Be **Water Soluble**, so it can dissolve in the mucus layer and be able to interact with the olfactory receptors. This means that **there are** substances that we **can't smell** bcz they're water insoluble like **natural gas.**

- Olfaction has a very **high sensitivity**, meaning it has a very low threshold, so very few odorant molecules are needed for them to be sensed and smelled.

- **Applications:**
  - the substance **methyl mercaptan** can be smelled when only one 25 trillionth of a gram is present in each milliliter of air. Because of this **very low threshold**, this substance is mixed with **natural gas** to give the gas an odor that can be detected when even small amounts of gas leak from a pipeline (**safety reason**).

EM image shows an olfactory receptor cell which is the 1st order neuron in olfaction



Olfactory receptor cell (blue)

The extensions represent the non-motile cilia covered with olfactory receptors

Olfactory receptor cells

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

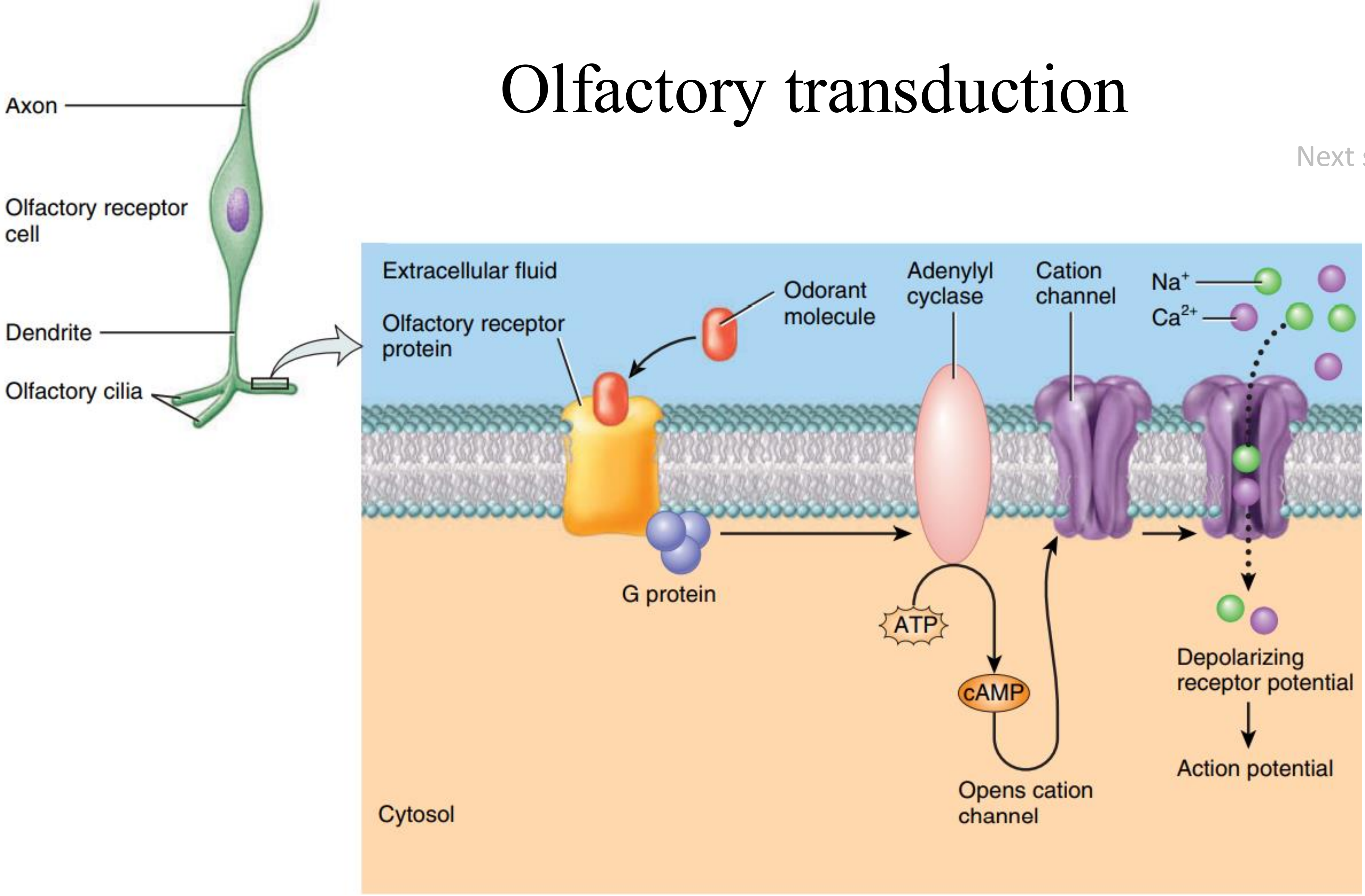
- Olfactory receptors are many types. Each type of olfactory receptor can react to only a select group of odorants.

- 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.

  - We have **thousands** of olfactory receptors, yet we can recognize **tens of thousands** of odors, and this is because one odor can activate a combination of receptors.

Olfactory transduction

Next slides



Olfactory transduction

- The steps in olfactory transduction are as follows:

- 1. Odorant molecules will go to the nasal cavity until they reach the epithelium, where they will dissolve in the mucus layer and 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.

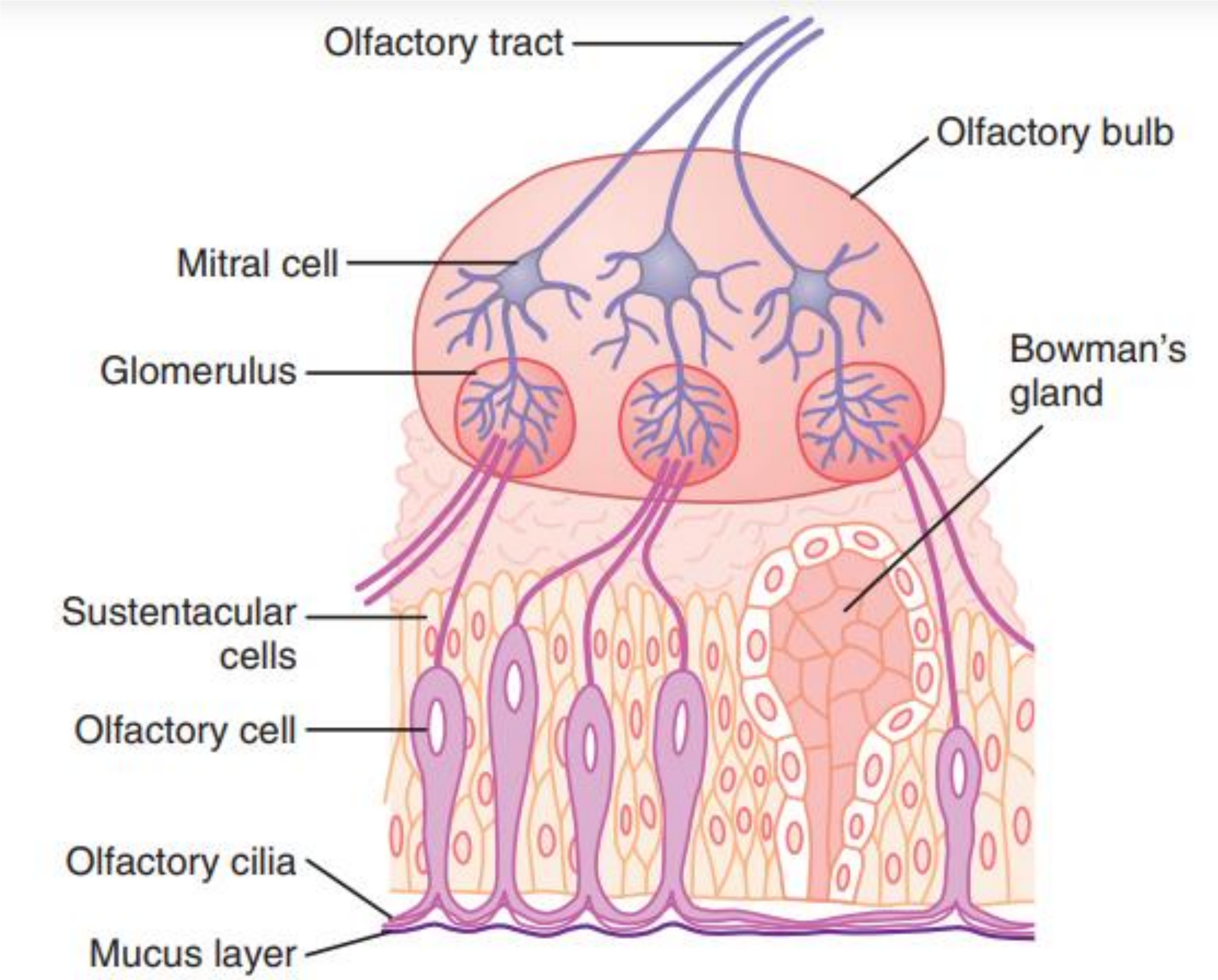
Olfactory transduction

- 6. Signals will go up through axons of olfactory cells through the holes of the cribriform plate until they reach the bulbs, where they will synapse with second-order neurons which are the **mitral cells**, in clusters called glomeruli. (Different combinations of olfactory cells will synapse with different mitral cells, which gives us the sensation of a broad range of different odorants.)

✓ Not only do olfactory cells synapse with mitral cells, but also many **interneurons** will be found in between, such as periglomerular cells and tufted cells, which will mainly function in lateral inhibition (their functions aren't that well-understood).

- 7. Then, mitral cells will project as the olfactory tract, which will go to the base of the brain, where it divides into medial and lateral tracts, both going to higher centers in the brain.

See the figure in the next slide

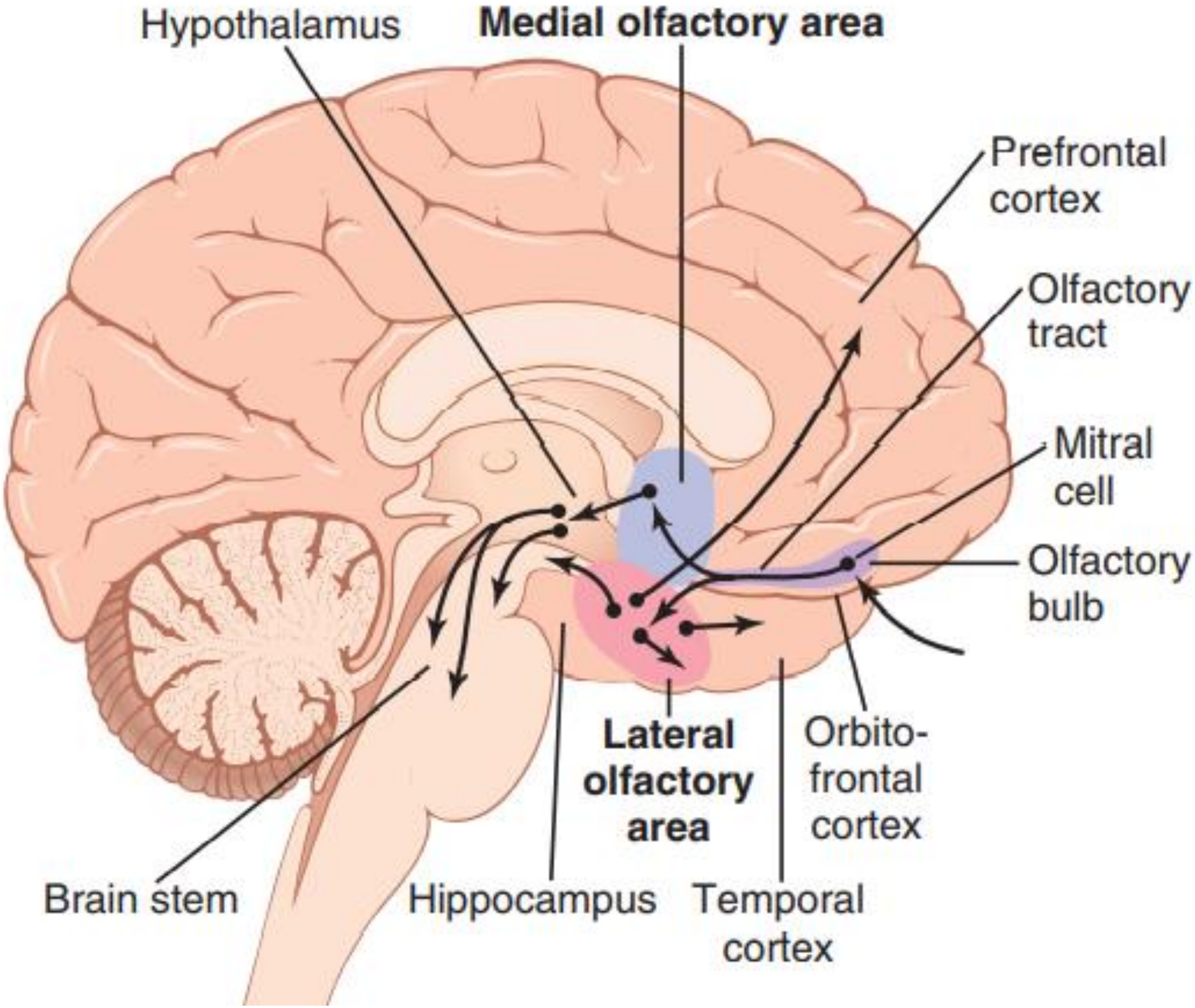

Olfactory tract
Olfactory bulb
Mitral cell
Glomerulus
Bowman's gland
Sustentacular cells
Olfactory cell
Olfactory cilia
Mucus layer

- The olfactory tract will divide into:
- Medial olfactory area: which is located **anterior to the hypothalamus**, It will connect to **both the hypothalamus and the limbic system**, where it will be concerned with **basic behaviors** associated with smell, like lip licking, salivation, and gastric secretions.

- Lateral olfactory area: It is **more advanced** in its function as it goes to the **hippocampus** in the limbic system. It's related to learning associated with olfaction (like liking or disliking something just based on the smell and previous experiences). It is also associated with the paleocortex, **The Only** part that receives sensory information **without passing through the thalamus first**.

- There is a new area that sends information to the cerebral cortex related to perception (not very well understood).

Figure in Next slide


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

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 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.

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.

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 olfactory information processing, 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 <u>paleocortex</u> in the anteromedial portion of the temporal lobe.

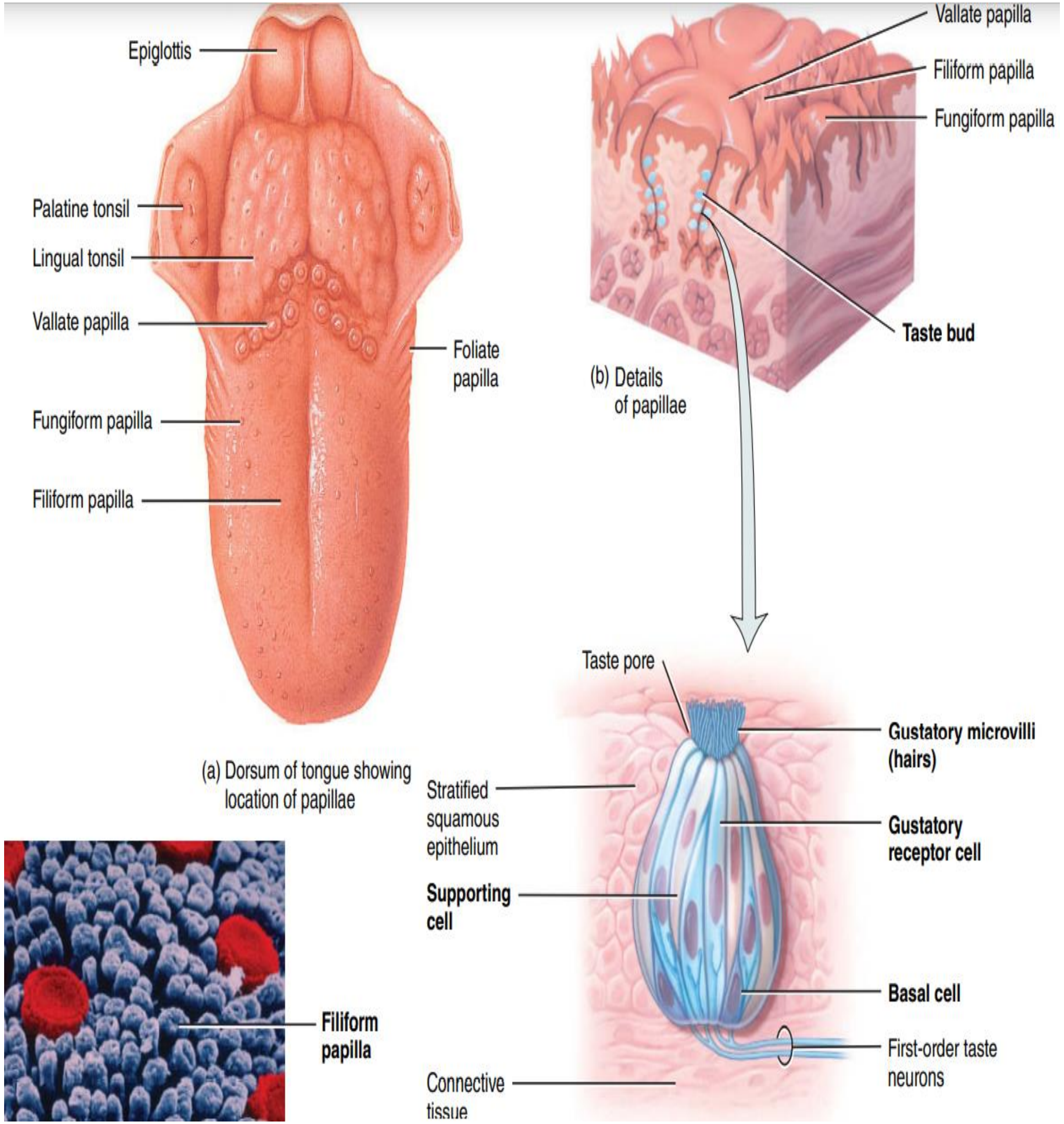
- **This area is the only area of the entire cerebral cortex where sensory signals pass directly to the cortex without passing first through the thalamus.**

- The olfactory receptors are rapidly adapting -> you'll stop smelling a certain odor after seconds of being exposed to it. This is mainly adaptation at the receptor level. However, new studies have shown that it can also adapt at the central level through negative feedback messages to the olfactory bulb.

- Olfactory dysfunction is not only related to respiratory disorders such as chronic rhinosinusitis and COVID-19 infection, but also to psychiatric and neurodegenerative disorders such as Parkinson's disease and Alzheimer's disease.

Gustation

Gustation, or the sense of taste, is a chemical sense, which means that the chemicals we ingest in the mouth must **dissolve** in saliva so they can be detected by receptor proteins **located in the taste buds** in the oral cavity. However, the experience of tasting food is much **more complex** and does not involve only the activation of taste receptors.



Gustation

- Tasting food is a holistic sensory experience that involves more than just taste buds

1) **Olfactory receptors** detect volatile food particles that travel to the olfactory epithelium in the nasal cavity, which is why a blocked sense of smell (e.g., during flu) can make food seem tasteless.
2) **Tactile receptors** sense the texture and movement of food in the mouth,
3) **thermoreceptors** detect whether food is hot or cold.
4) **Pain receptors** (**nociceptors**) are also activated by certain foods, such as chili peppers, producing a burning sensation. So tasting food is not just activating the taste buds !

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 (flavor). 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 greatly alter the taste experience, Orbitofrontal cortex associate these sensations to give a perception of “flavor”.

- 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

- The five primary sensation of taste are sour, salty, sweet, bitter, and "umami", (?recent suggestions of adding fat as a 6th tastant).

- 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 (more specifically the cations more than the anions in these 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 (it is not only elicited by sugar). 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.

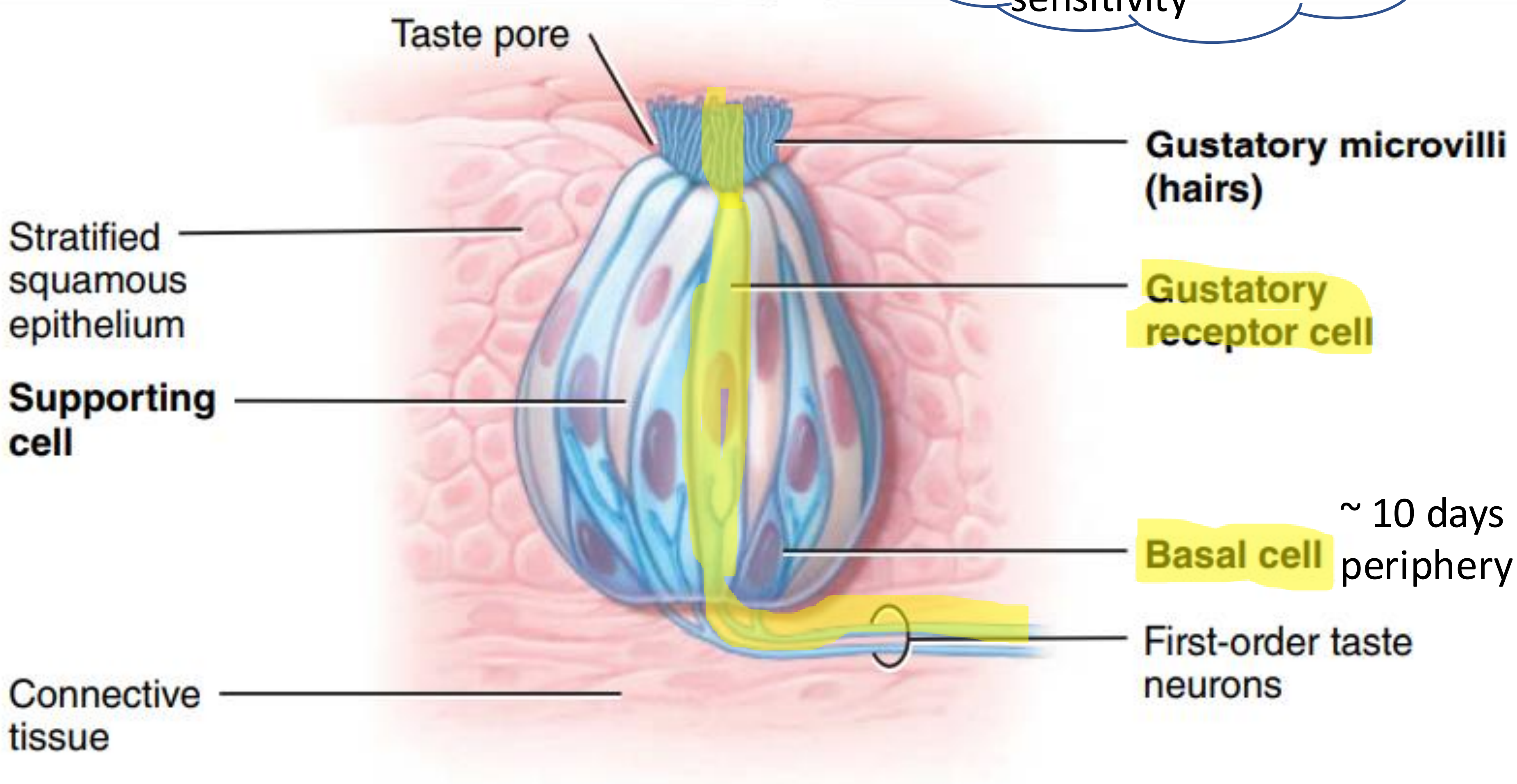
- The bitter taste, when it occurs in high intensity, usually causes the person to reject the food. This reaction is important because many deadly toxins found in poisonous plants are alkaloids, and virtually all of these alkaloids cause an intensely bitter taste.
- Taste in general has a **low threshold**, but it varies with different categories of these five primary sensations. **Bitter taste has the lowest threshold**, which means Sensation can be triggered by just a few molecules

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 bud

Number Decreases with age, so is the taste sensitivity



~ 10 days periphery

Taste buds

- The taste bud is composed of about 50 modified epithelial cells, some are supporting cells (also called sustentacular) and taste sensory neuron as well as basal cells.

- The taste cells are continually being replaced by mitotic division of surrounding epithelial cells (basal 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 in saliva.

- 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.

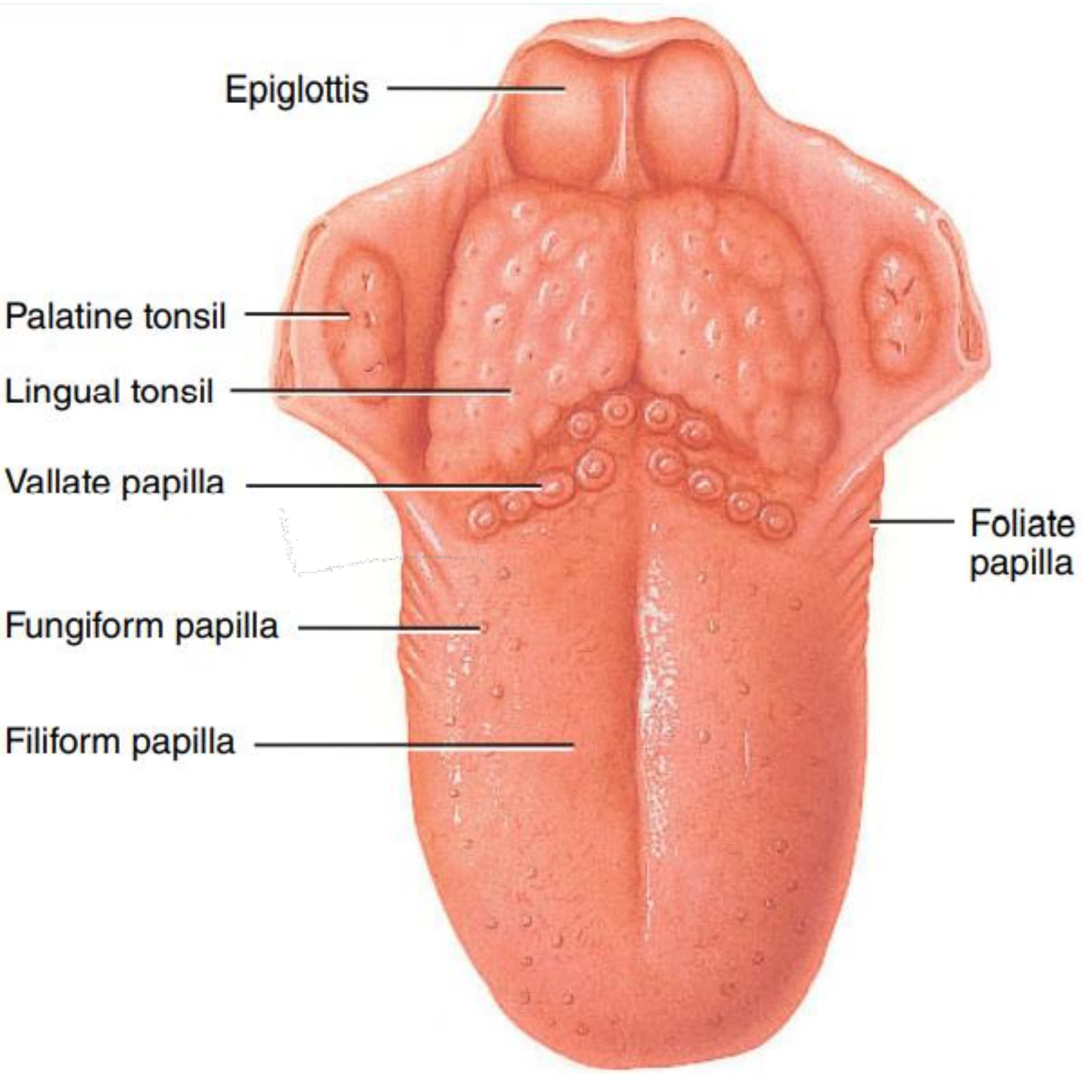
Taste buds

- 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 (the microvilli contain the receptor proteins) .
- The body of the cells is connected with the **first order** taste neurons.
- 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.
- The number of taste buds **decreases** with age, which is why taste sensitivity is **lower** in older adults compared to younger people and children.

Location of taste buds

Taste buds are
located within papilla



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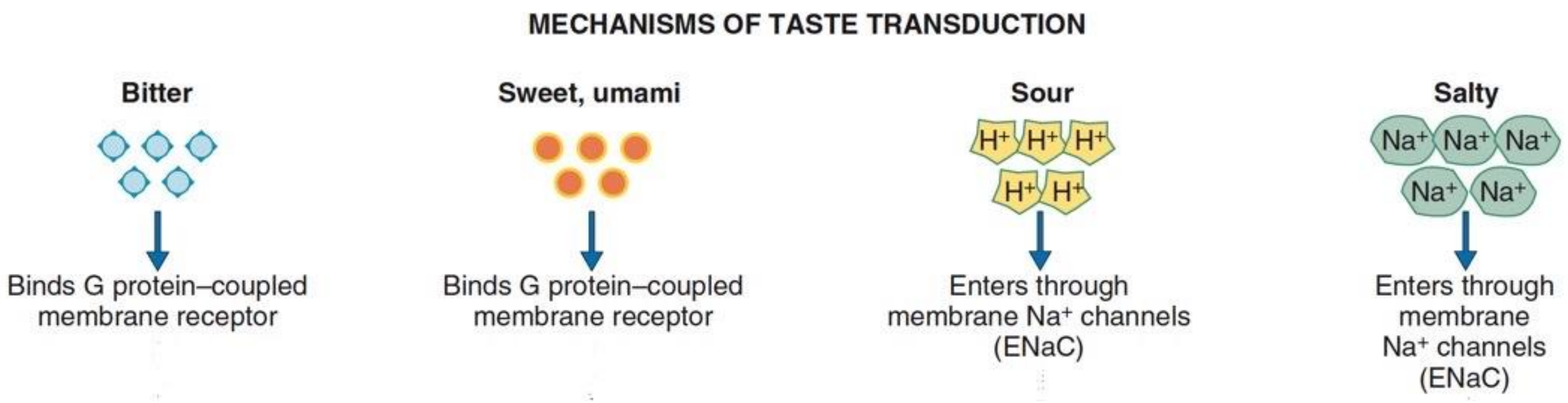
Location of taste buds

- 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.


MECHANISMS OF TASTE TRANSDUCTION
Bitter
Binds G protein–coupled membrane receptor
Sweet, umami
Binds G protein–coupled membrane receptor
Sour
H+
Enters through membrane Na+ channels (ENaC)
Salty
Na+
Enters through membrane Na+ channels (ENaC)

Taste transduction

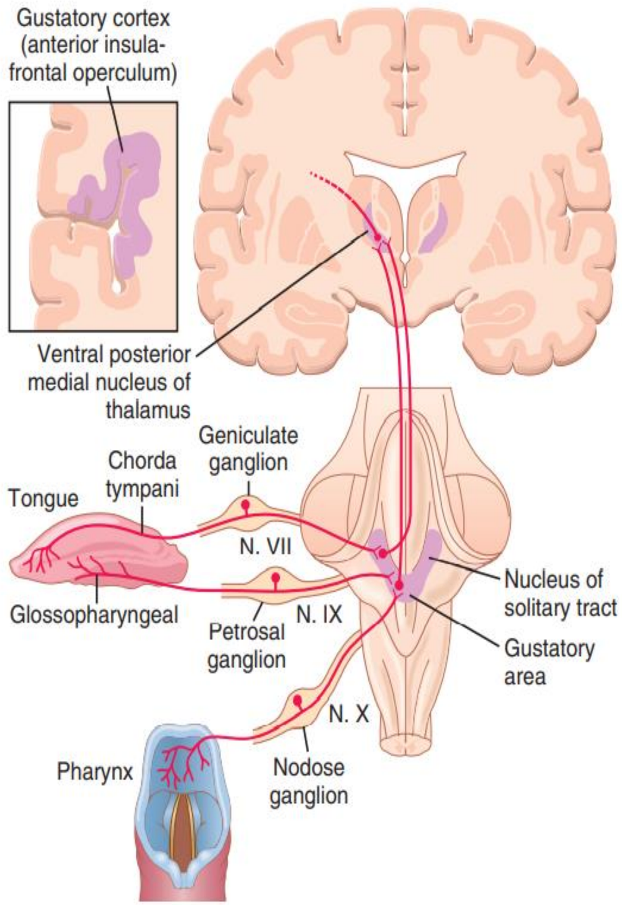
- The mechanism by which most stimulating substances react with the taste villi to initiate the receptor potential is by binding of the taste chemical to a protein receptor molecule that lies on the outer surface of the taste receptor cell near to or protruding through a villus membrane (microvilli).

- This action, in turn, opens ion channels, which allows positively charged sodium ions or hydrogen ions to enter and depolarize the cell (A higher concentration of the substance produces a larger amplitude and greater magnitude of the receptor potential) .
- 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, which cause intracellular chemical changes that elicit the taste signals.



- After signal transduction, a receptor potential develops in the taste receptor cells, which then activates first-order neurons. When these neurons reach threshold, they generate action potentials that carry the signal to the central nervous system. **Unlike** other special senses—for example, vision, which uses **only the optic nerve**, or olfaction, which uses **only the olfactory nerve**—taste signals are transmitted by **three cranial nerves**, depending on the region of the oral cavity.
- Signals from the **anterior two-thirds** of the tongue travel via the **lingual nerve**, then the chorda tympani, and finally the facial nerve (VII).
- Signals from the **posterior third** of the tongue travel via the **glossopharyngeal nerve (IX)**.
- **Pharyngeal stimuli are carried by the vagus nerve (X)**.

- All first-order neurons terminate in the **nucleus tractus solitarius (NTS)** in the brainstem. Second-order neurons then project from the NTS to the **ventral posterior medial (VPM)** nucleus of the **thalamus**, located near the pathway for somatosensory signals. From the thalamus, third-order neurons carry the signals to the **gustatory cortex in the postcentral gyrus, near the somatosensory area for the tongue**.
-

- This isn't the only pathway that transmit taste sensation, we need taste sensation for **reflexes** that depend on the presence of food, such as **salivary reflex**.
- These sensory information goes to the **superior and inferior salivary nuclei to initiate this reflex**.

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.

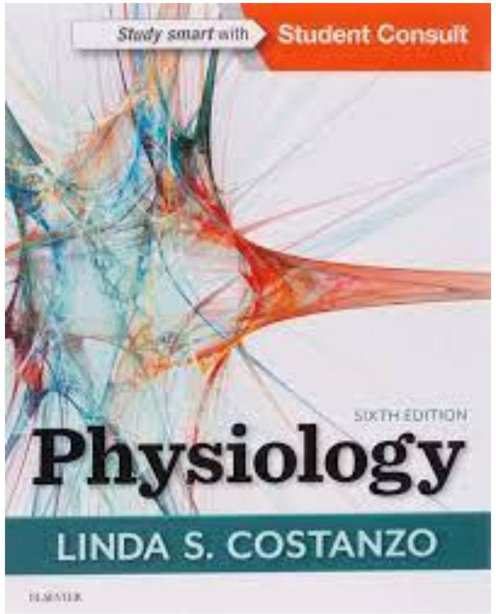
- From the thalamus, third-order neurons are transmitted to the lower tip of the postcentral gyrus in the parietal cerebral cortex, where it curls deep into the sylvian fissure, and into the adjacent opercular insular area. This area lies slightly lateral, ventral, and rostral to the area for tongue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

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.

References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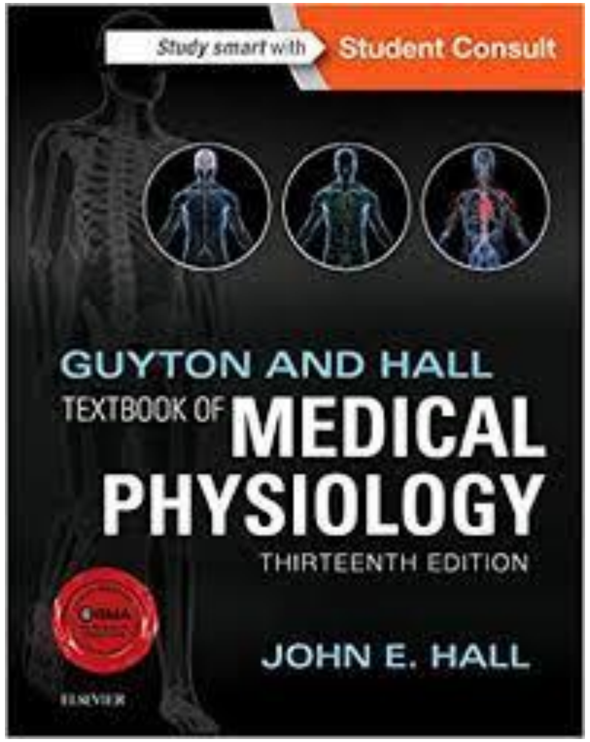
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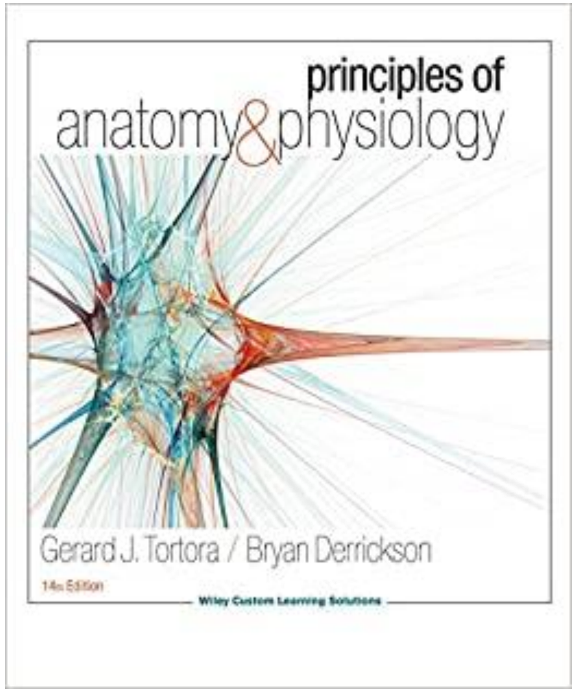
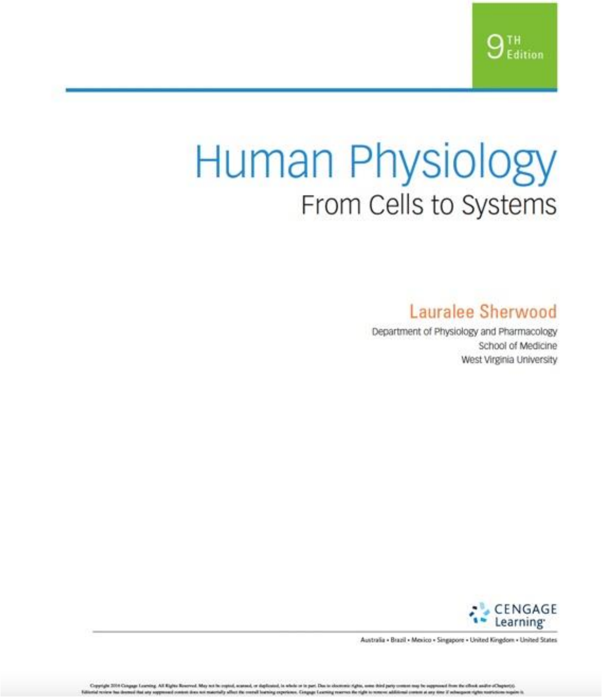

principles of
anatomy & physiology
Gerard J. Tortora / Bryan Derrickson
14th Edition
Wiley Custom Learning Solutions


9TH Edition
Human Physiology
From Cells to Systems
Lauralee Sherwood
Department of Physiology and Pharmacology
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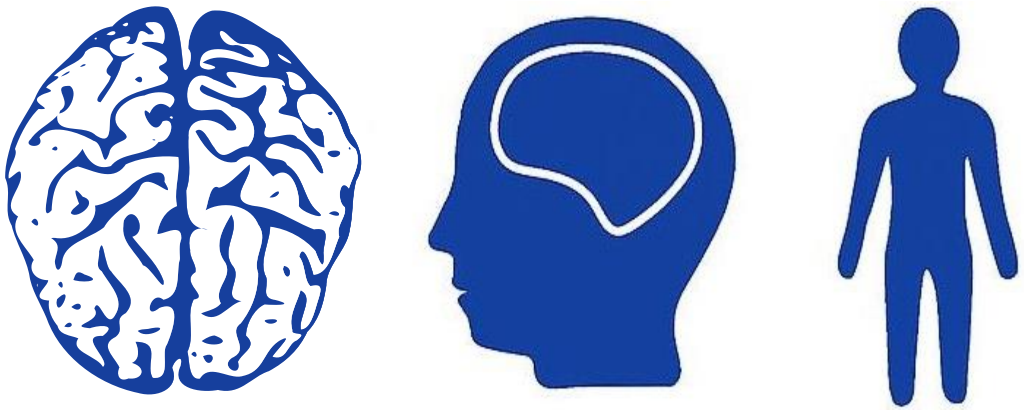
Thank you



PHYSIOLOGY QUIZ

LECTURE 4

External Resources

رسالة من الفريق العلمي

References:
Doctor’s lecture

اللهم إن عمر عطية في ذمتك وحبل جوارك، فقِهِ من فتنة القبر وعذاب النار،
أنت أهل الوفاء والحق، فاغفر له وارحمه إنك أنت الغفور الرحيم.

Scan the QR code or click it for FEEDBACK

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1	8	The extensions represent the non-motile cilia covered with olfactory receptor cells	The extensions represent the non-motile cilia covered with olfactory receptors
V1 → V2			