

CNS PHYSIOLOGY

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Gustatory & Olfactory Sensations (Taste and Smell):

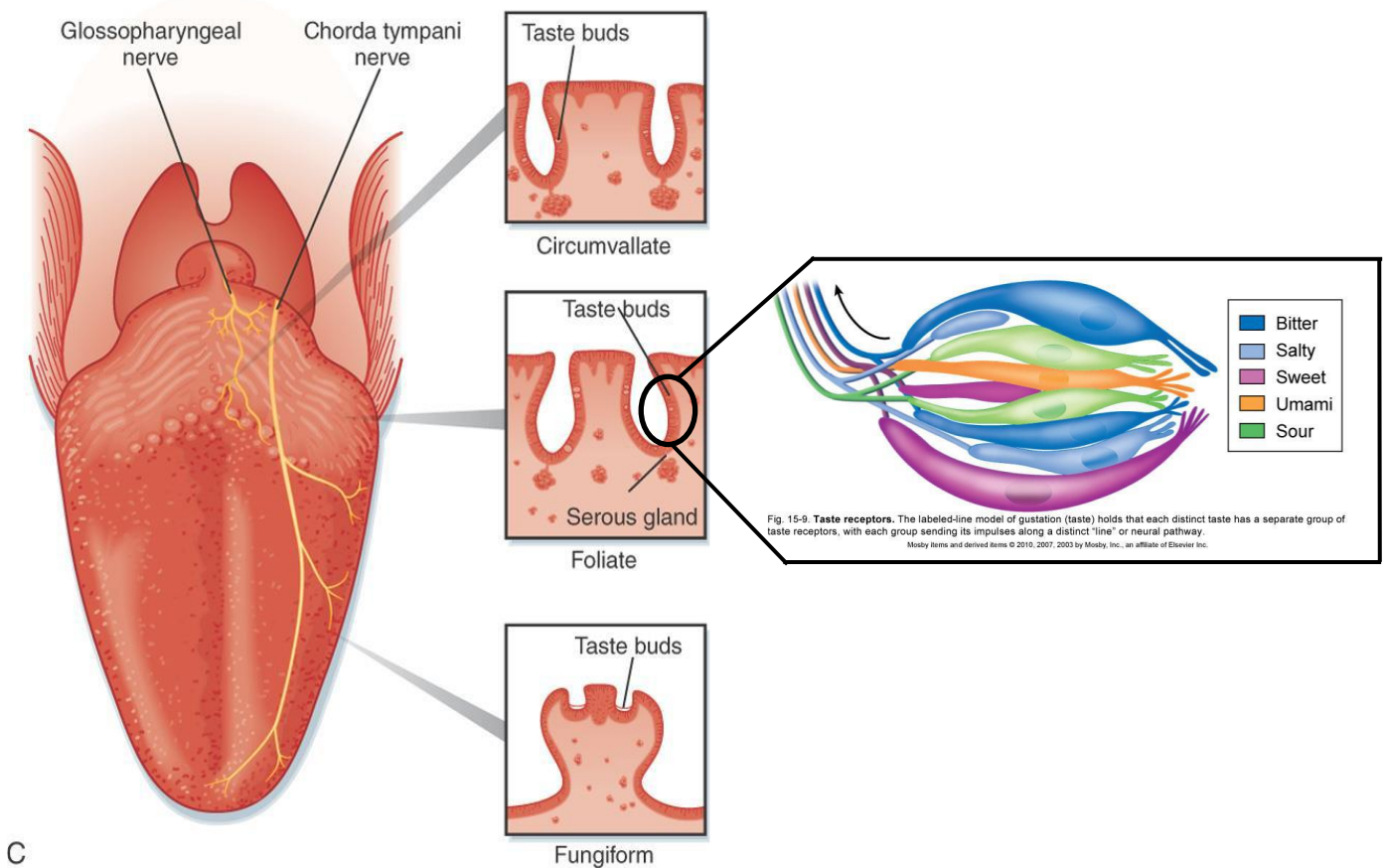
Taste and smell are chemical sensations that allows us to:

- a) Separate undesirable or lethal foods from those that are nutritious
- b) Recognize the proximity of other individuals or animals

Both senses are tied to the primitive emotional and behavioral functions of the nervous system.

1) Taste

Taste receptors are found in taste buds on the tongue. The taste receptors are epithelial cells that are capable of regenerating within 2 weeks of injury.



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(Redrawn from Squire LR et al [eds]: Fundamental Neuroscience. San Diego, CA, Academic Press, 2002.)

Not all chemicals that excite different taste receptors are known. However, for practical reasons, the primary sensations of taste have been grouped into five general categories. **Sour, Salty, Sweet, Bitter, and Umami.**

The human tongue can perceive hundreds of different tastes due to the various combinations of the five primary taste sensations. (this is similar to the ability of perceiving a variety of colors from the 3 basic colors [red, green,blue]).

There are at least 13 possible chemical receptors in taste buds. These chemical receptors include:

For salt sensation:

2 Receptors for Sodium

2 Receptors for Potassium.

1 Receptor for chloride

Caused by ionized salts in the food

For Umami sensation:

1 receptor for adenosine

1 receptor for inosine

1 receptor for glutamate

Not familiar, distinctive and delicious taste associated with certain amino acids such as glutamate and arginine

2 receptors for sweet sensations

Can be caused by many chemicals, but mostly by organic compounds in the food (not necessarily glucose)

For example, Aspartame (sold under the brand NutraSweet), is composed of 2 amino acids which are aspartic acid and phenylalanine (dipeptide). Therefore, people with diagnosed *phenylketonuria* are advised to avoid aspartame.

Phenylketonuria (PKU) is a genetic disease characterized by the decreased ability to metabolize phenylalanine

2 receptors for bitter sensation

Can be caused by alkaloids and long chain organic substances containing nitrogen. These substances are usually toxic (e.g. many drugs used in medicine)

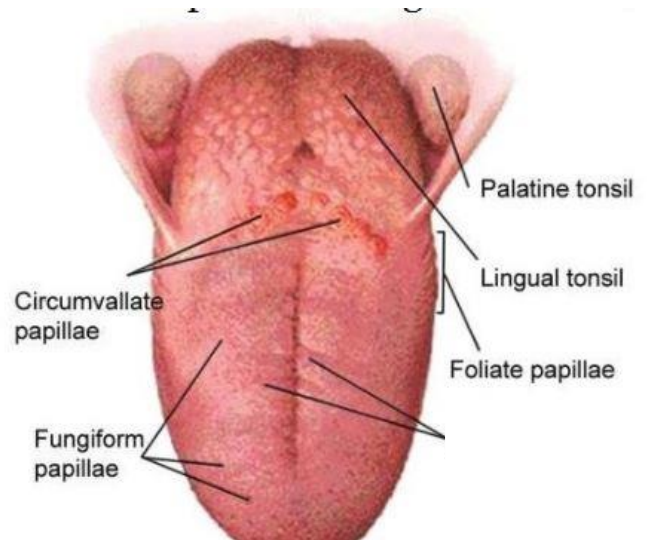
1 receptor for sour sensation (hydrogen ions)

Caused by the acidic concentration of the food.

Location of taste buds

Taste buds are found on three types of papillae of the tongue:

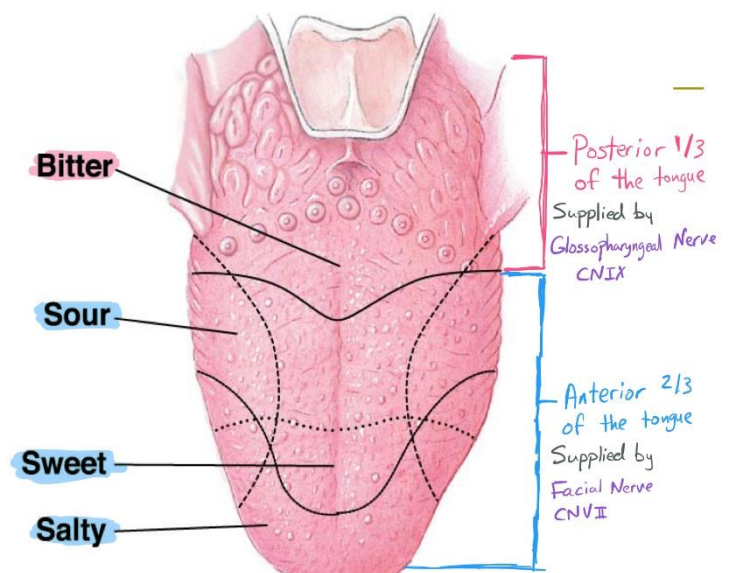
- a) Circumvallate papillae
Forms a V line on the surface of the posterior tongue
- b) Foliate papillae
Located along the lateral surface of the tongue
- c) Fungiform papillae
Located over the flat surface of the tongue



Extraglossal taste buds can also be found on the tonsillar pillars, palate, epiglottis, and proximal esophagus.

Bitter sensation is perceived on the posterior aspect of the tongue.

Whereas sour, sweet, salty, and umami sensation are perceived from anterior aspect of the tongue.



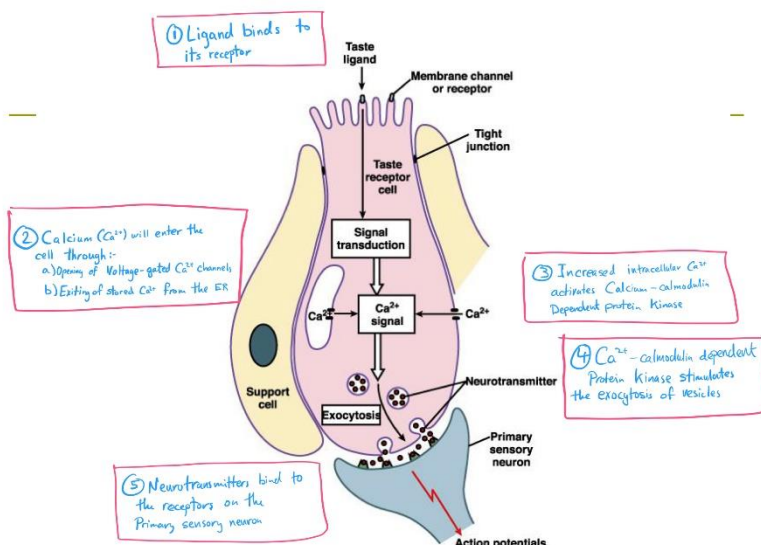
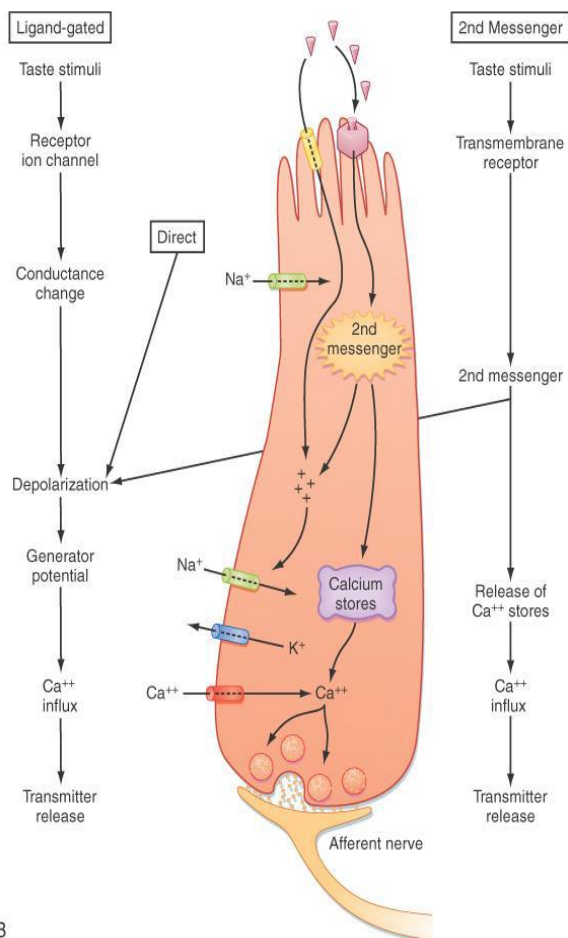
Taste signal transduction:

The membrane of the taste receptor cell is negatively charged on the inside with respect to the outside. Binding of a taste ligand to a taste receptor causes depolarization of the taste receptor cell. However, only generator potential (AKA receptor potential) is achieved. This occurs due to the opening of ion channels such as sodium channels which enters inside the cell in order to depolarize it.

The type of receptor protein in the taste bud determines the type of taste that will be perceived.

And there are two main mechanisms by which a taste signal is transduced. Either ligand-gated mechanism or a second messenger mechanism. The used mechanism depends on the receptor and the taste ligand that is being perceived.

The following diagrams show the general mechanisms.



(Redrawn from Squire LR et al [eds]: Fundamental Neuroscience. San Diego, CA, Academic Press, 2002.)

Now let's discuss each taste sensation and the exact mechanism that it uses.

(follow along with the figure on the next page and remember that depolarization does not mean a full action potential. In this context, it's used only to refer to receptor potential)

1) For salt taste (ligand gated)

Once salt substances bind to its taste receptor on the taste receptor cell, it causes an increase in sodium conductance into the cell and depolarization of the taste receptor cell. The depolarization causes opening of the voltage-gated calcium channels causing an increase in intracellular calcium. Increased intracellular

calcium activates Calcium-calmodulin dependent protein kinase, which triggers the exocytosis of vesicles containing neurotransmitters.

2) For sour taste (ligand gated)

Binding of hydrogen ions to its taste receptor on the taste receptor cell causes the closure of potassium channels, which leads to increased intracellular potassium. This will eventually lead to depolarization of the taste receptor cell due to reduced loss of potassium. Depolarization causes opening of voltage-gated calcium channels which eventually leads to activation of calcium-calmodulin dependent protein kinase, and finally, exocytosis of vesicles containing neurotransmitters.

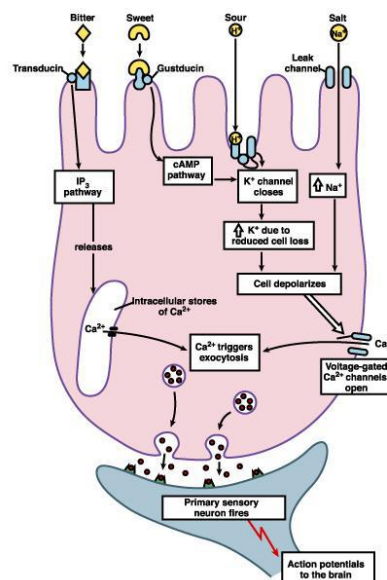
3) For sweet taste (2nd messenger)

When sweet substances bind to its taste receptor, which is a **G-protein coupled receptor**, it causes the dissociation of an alpha subunit of a G-protein which goes and activates adenylate cyclase. Adenylate cyclase forms cAMP from ATP, which causes the closure of potassium channels. The rest of the mechanism similar to the sour taste mechanism mentioned above.

4) For bitter taste (2nd messenger)

When the bitter substance bind to its taste receptor, which is a **G-protein coupled receptor**, it causes the dissociation of an alpha subunit of a G-protein which goes and activates phospholipase C. Phospholipase C increases the production of IP₃ which causes the release of calcium from the endoplasmic reticulum and an increase in intracellular calcium. Increased calcium leads to the activation of calcium-calmodulin dependent protein kinase. And you guessed it, exocytosis of vesicles containing neurotransmitters.

So, as you see the common mechanism of all of them is an increase in intracellular calcium which causes the release of neurotransmitters from the vesicles by different mechanisms.



Taste bud facts:

Adults have 3-10,000 buds, children have more.

Taste receptors are epithelial cells that can regenerate every 10-15 days. Beyond the age of 45, taste buds start to degenerate, and taste becomes less critical.

Sweet and salty buds are located on the tip of the tongue, sour buds are found on the lateral sides of the tongue, and bitter buds on the posterior tongue and soft palate.

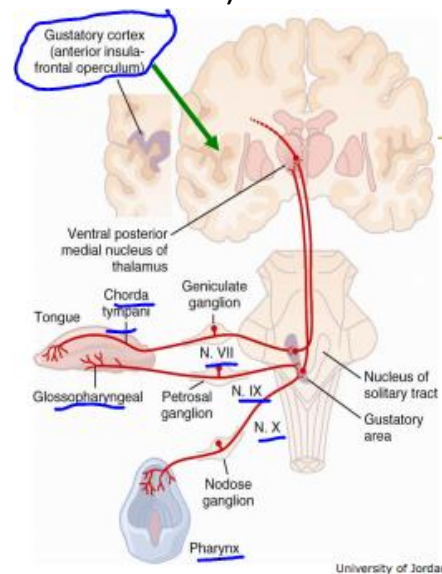
Transmission of taste sensation:

Activation of taste buds excites taste fibers. Anterior 2/3 of tongue through facial nerve (chorda tympani to the geniculate ganglion), posterior 1/3 of tongue through glossopharyngeal nerve (to the petrosal ganglion) and there are other receptors found in the pharynx which are supplied by the vagus nerve. All of them go to the **solitary nucleus of medulla oblongata** and from there they go to the **VPM of the thalamus** then to **cortex (gustatory nucleus** which is found in the insula).

Taste pathway is usually bilateral, but predominantly **uncrossed** (Ipsilateral). Like other sensations, tastes do adapt rapidly. In around one minute or so, there is around 50 percent adaptation.

Adaptation might be at the level of the receptor or sometimes at the level of central adaptation, so, it is one of the sensations that adapt very fast.

The other sensation that adapts even faster than taste is the smell or olfaction.



Taste Pathways:
It is Bilateral but
predominantly
uncrossed

2) Smell (Olfaction)

Now we come to the smell (the second chemical sensation), the least understood of all sensations because it is more developed in lower animals. It is poorly developed in humans.

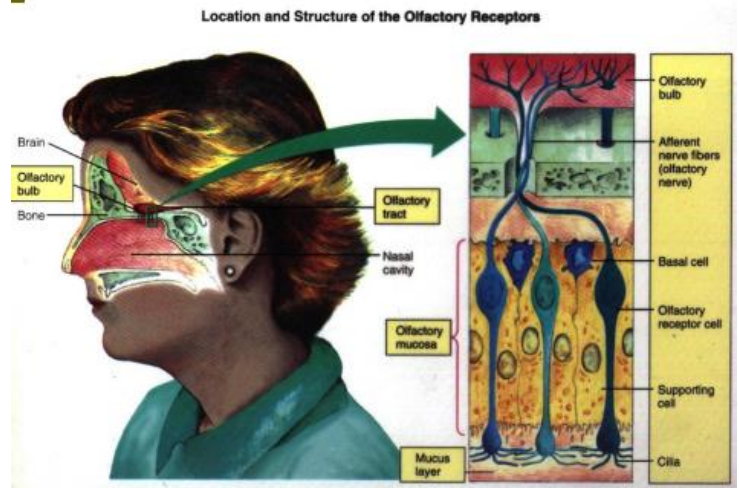
The olfactory membrane is located on the superior part of each nostril.

This is the superior aspect of the nostril where the receptors are located.

Receptor area:

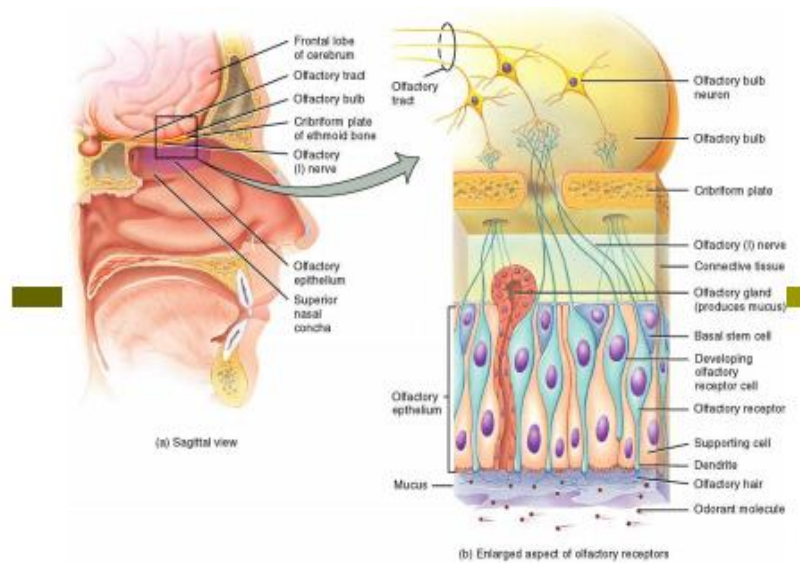
Mucus that is secreted by mucus cells (olfactory glands). Then there are other supporting cells as you see here. They support the receptors.

Smell receptors are actual neurons (**bipolar neurons**), and although they are neurons, they can *regenerate*, but their regeneration time takes around 45 to 60 days. They have these cilia which are embedded in the mucus. and then the axons of bipolar cells enter the skull through openings of the ethmoid bone called cribriform plate.

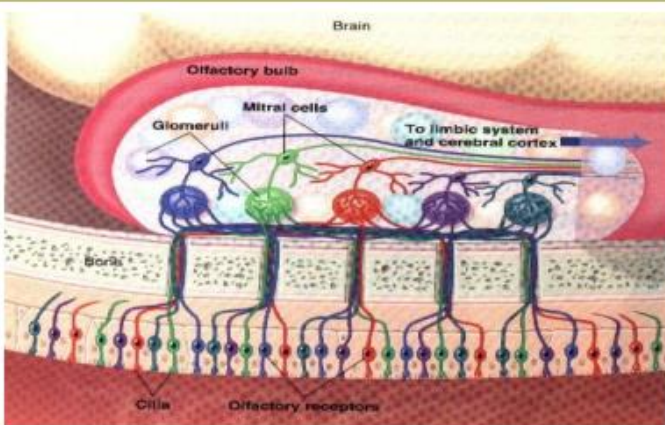


When these axons enter the brain, they synapse with the dendrites of other cells called Mitral cells forming what we called the Glomeruli. Sometimes each glomerulus is specialized for a certain sensation. Then the axons of mitral cells form the olfactory tract which goes to the limbic system and **cerebral cortex**.

This area, just inside the brain, above the cribriform forming what we call the olfactory bulb.



Olfactory bulb



Olfactory receptors

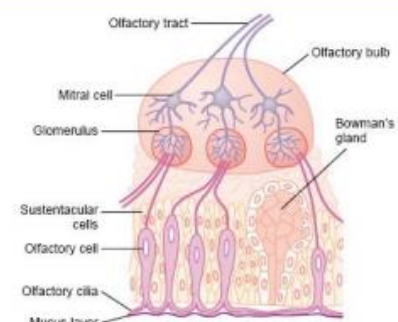


Figure 53-3

Organization of the olfactory membrane and olfactory bulb, and connections to the olfactory tract.