Physiology of Taste & Smell

(Chemosensory System)

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Week Lecture

Chapter 54

(Guyton & Hall)

The Chemical Senses: Taste and Smell

Objectives

By the end of this session students are expected to:

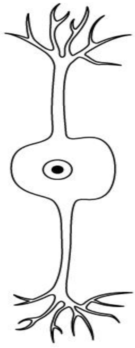
- Describe the location and function of olfactory receptors and olfactory neurons
- Explain the mechanism of smell
- Describe the location and function of taste receptors and taste neurons
- Explain the mechanism of taste

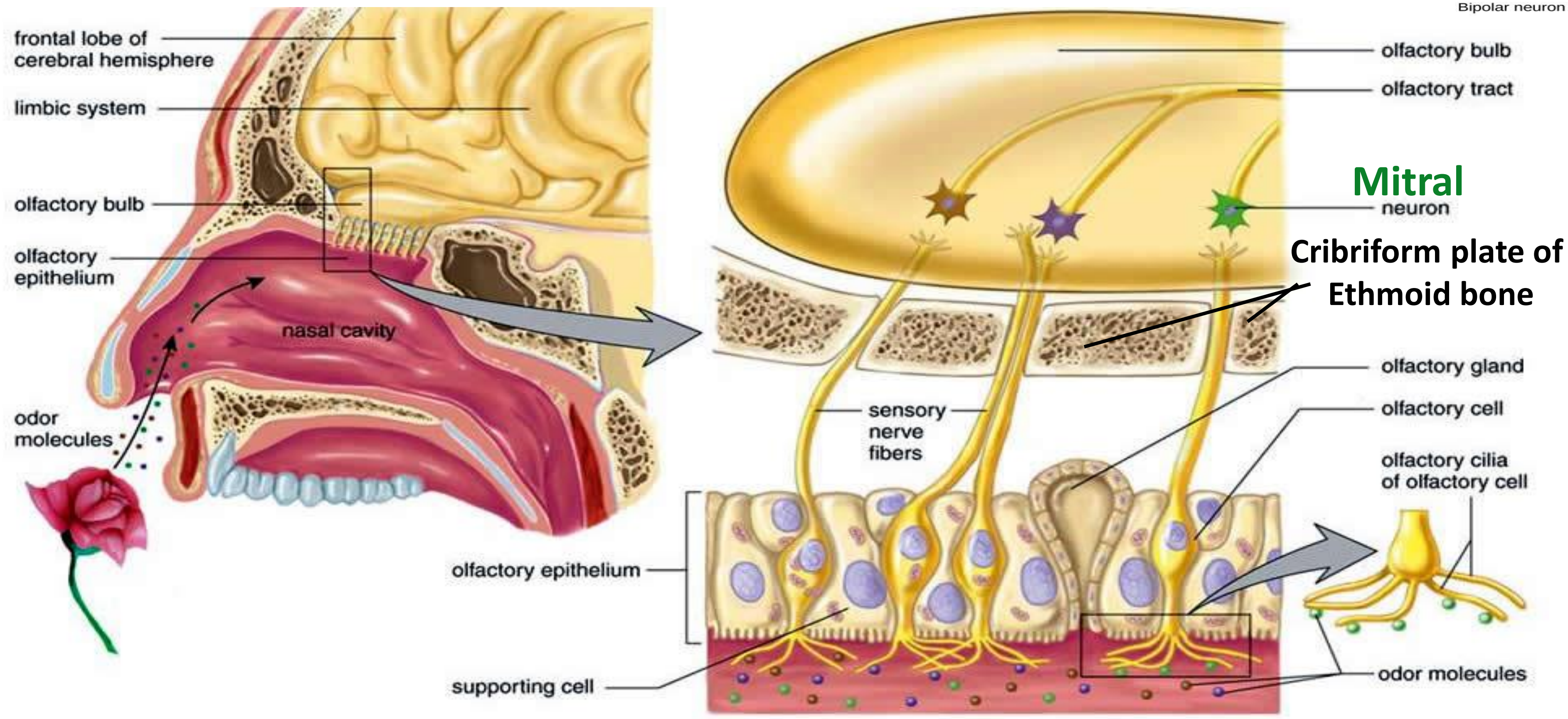
The Olfactory (Smell) System

- The olfactory system is the least understood sensory system
- It helps us enjoy life (e.g. perfume, and food)
- Smell can be a powerful stimulant of human emotions.
- It is also a **warning system** alerting us to dangerous signals (e.g., gas leak, spoiled food)
- It helps in choosing mates in some mammals (release of **pheromones**)
- Minute quantity of an odorant in the air can elicit a smell sensation
- ***Methylmercaptan*** can be smelled when only 25×10^{-12} g is present in each **ml of air**.
- This substance is **mixed with natural gas** so that even a small amount of gas leak can be detected.

Olfaction – The Sense of Smell

- Smell is detected by **olfactory chemoreceptors** which are specialized endings of afferent (bipolar) neurons that convert **olfactory stimuli** (**chemicals in gaseous state**) into nerve impulse
- Are found in the roof of each nasal cavity





What are Olfactory Stimuli?

- Odorants (airborne molecules)
- Odorants must be volatile (they give off vapors)
- More vapors are given off when an **odorant is heated**!! (warm soup smells better than cold soup)

- **Odorants reach olfactory receptors by being inhaled**:
  - Through the nose.
  - Through the mouth (vapors circulate up through throat)

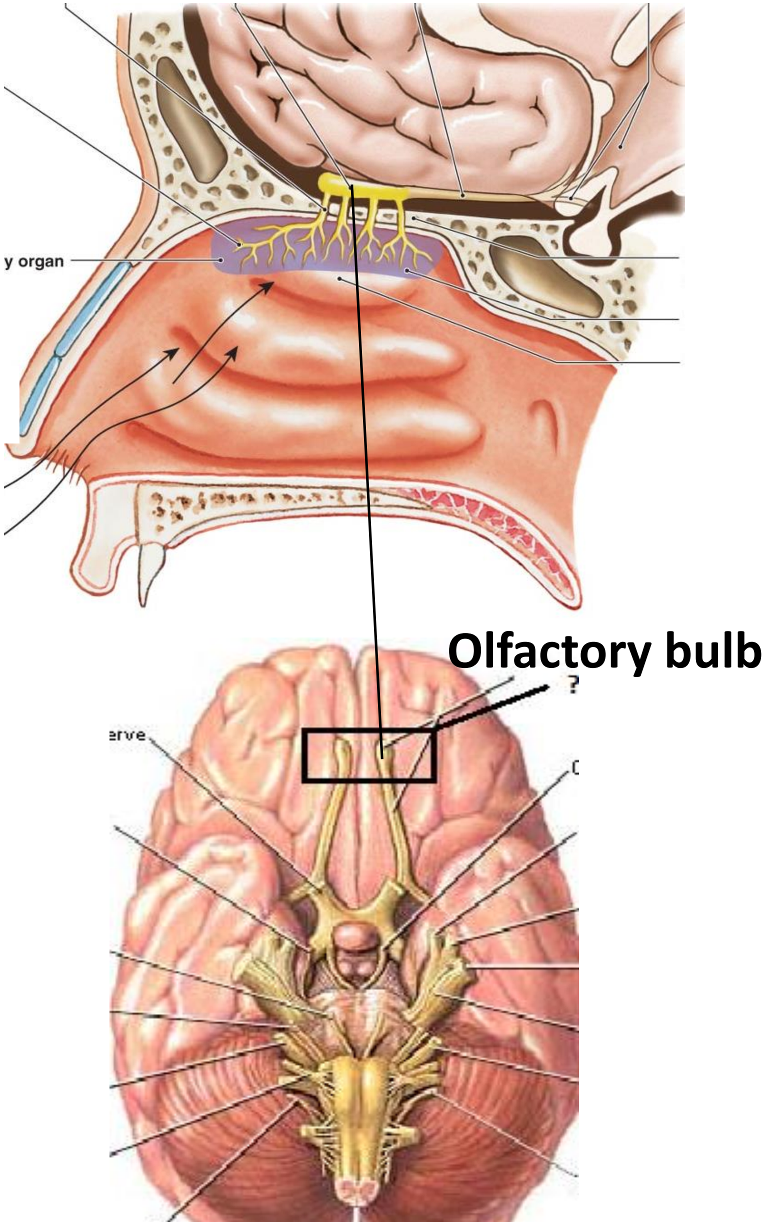
Anatomy of the Olfactory System

A. Peripheral components:

- **Olfactory receptors:** located in the olfactory epithelium
- **Olfactory nerve fibers:** in the the olfactory nerve (**CN I**)

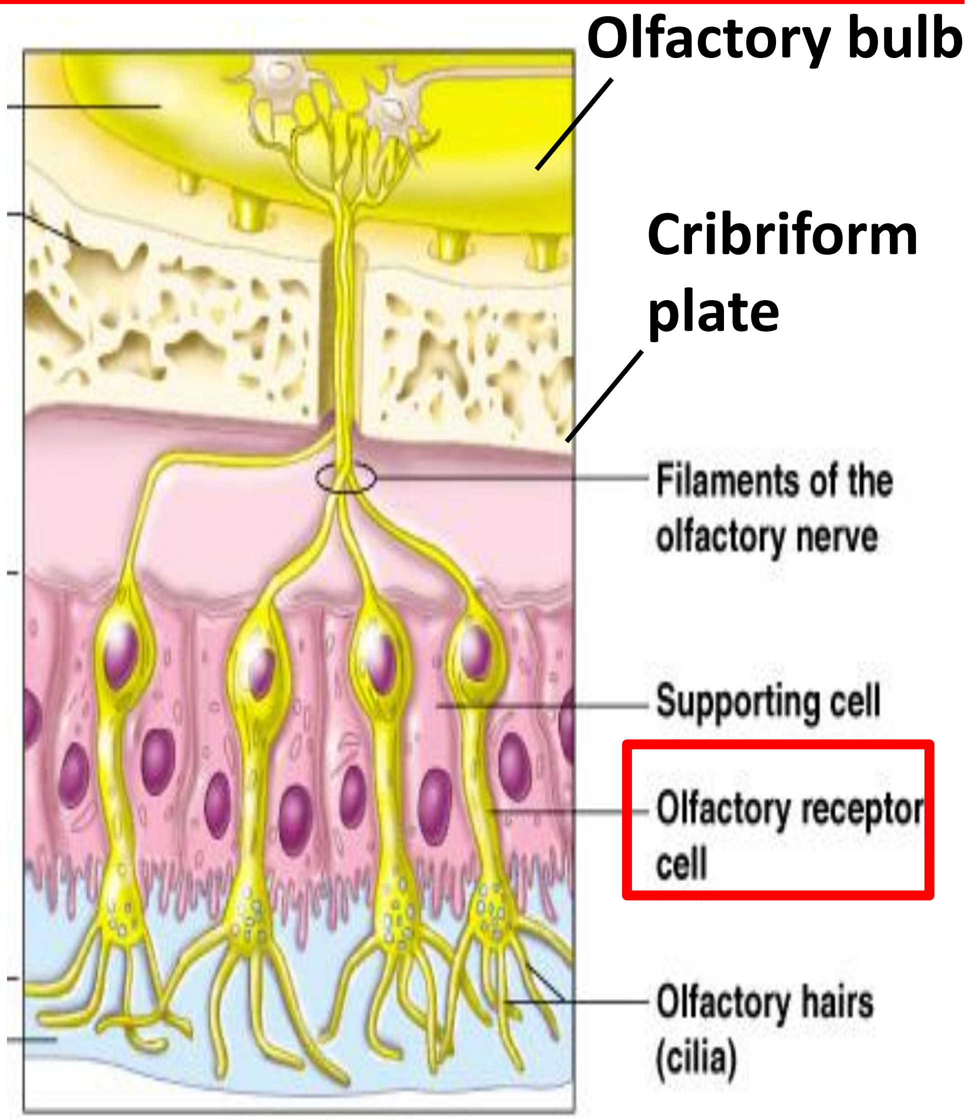
B. Central components:

- **Olfactory bulb :** in the brain
- **Olfactory tract**
- **Olfactory cortex:** deep in temporal lobe and base of frontal lobe (**interpretation of olfactory signals**)



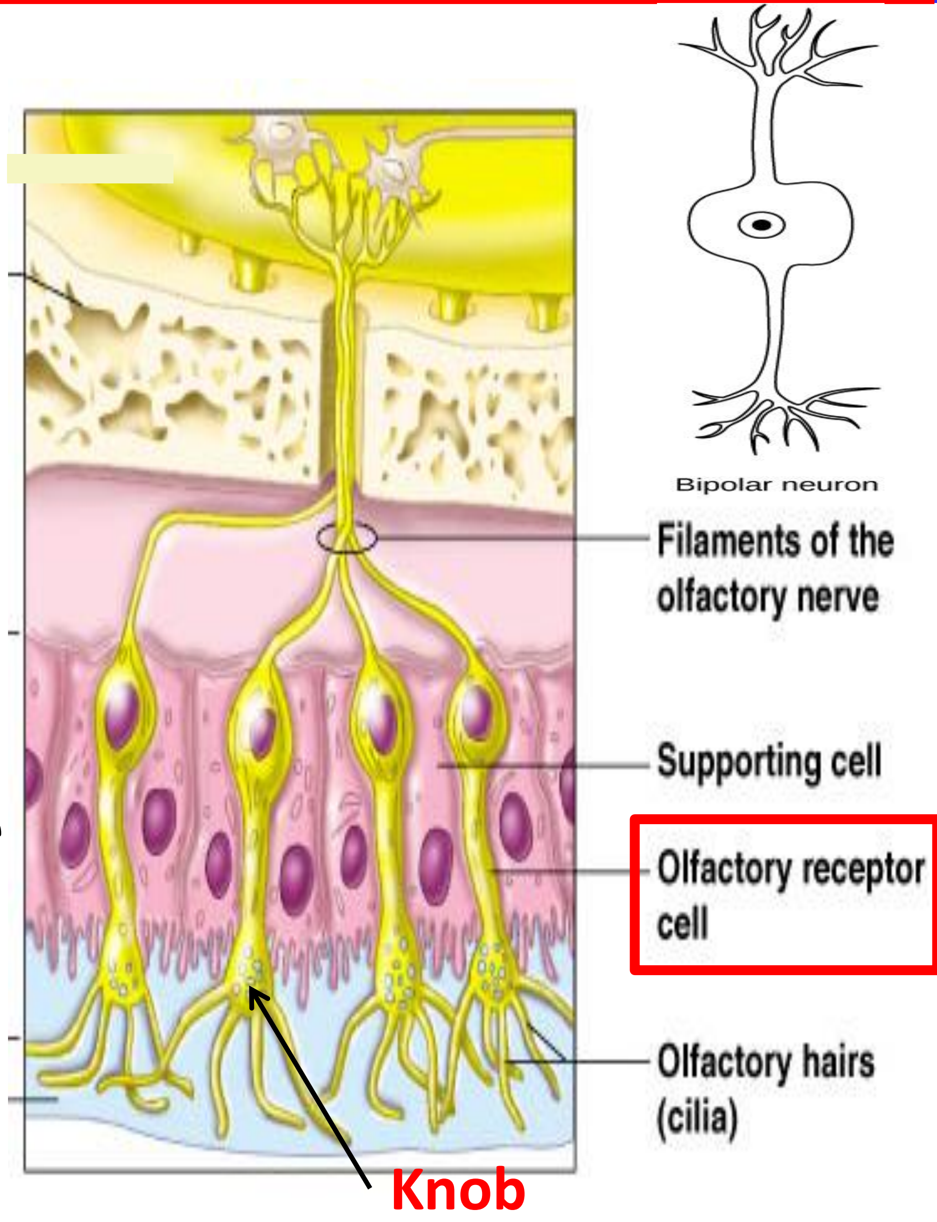
Olfactory Receptor Cells-1

- Are the receptor cells for smell sensation.
- There are **~ 100 million** of these cells in the olfactory epithelium
- Convert **olfactory stimuli** into **nerve impulses**
- Chemicals must be dissolved in mucus for detection



Olfactory Receptor Cells-2

- They are **bipolar** nerve cells and , unlike other primary afferent neurons, terminate **directly in the telencephalon**
- The mucosal end of the olfactory cell forms a **knob**
- 4 to 25 **olfactory hairs (cilia)** emerge from the knob
- The cilia **react to odors** in the air, and **stimulate the olfactory cells (causing** depolarization), but **HOW?**



Mechanism of Excitation of the Olfactory Cells

- Diffusion of the **odorant substance,** into the mucus
- Odorant binds and activates the **receptor protein**, resulting in activation of **G-protein complex**
- This causes activation of **adenyl cyclase** in the cell membrane
- This enzyme converts ATP into cAMP (**a second messenger**).
- This causes activation of **sodium ion channels** resulting in
- **Depolarization and excitation** of the olfactory neuron
- Transmission of nerve impulses into CNS by the olfactory nerve.

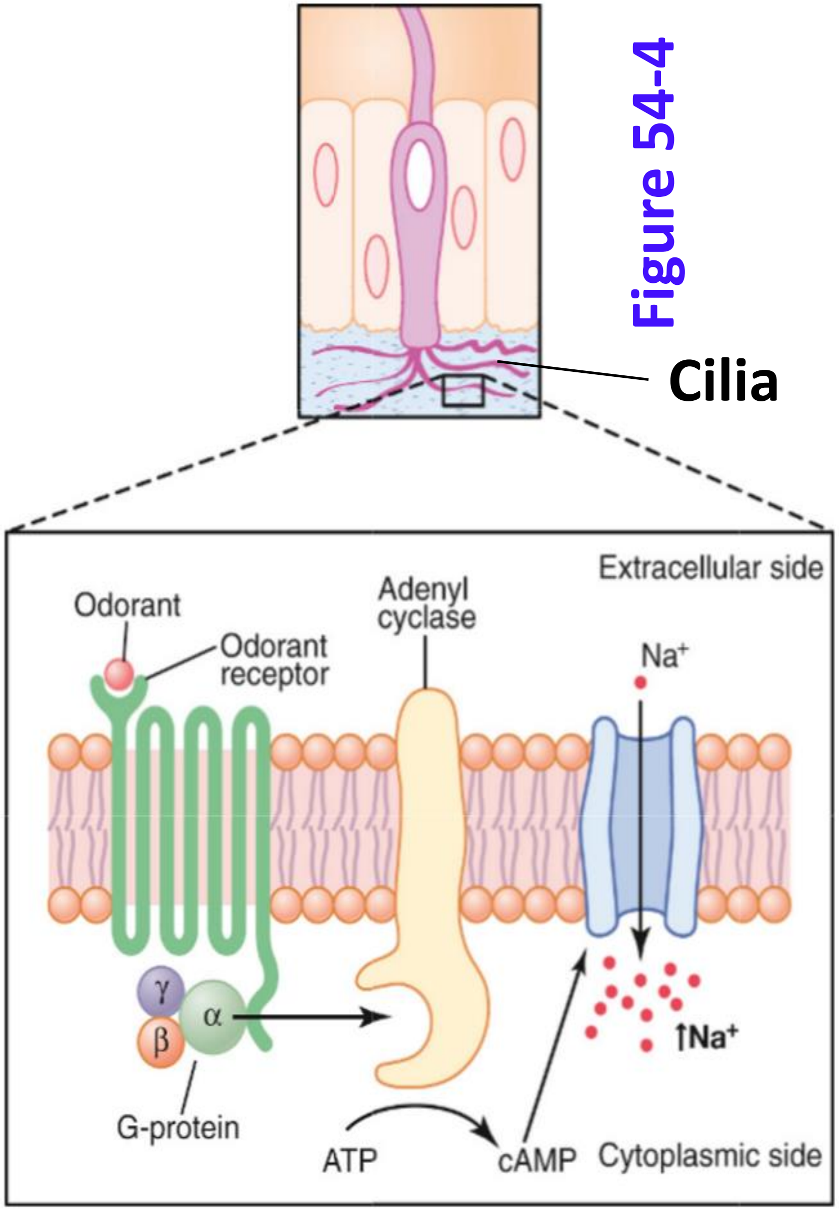


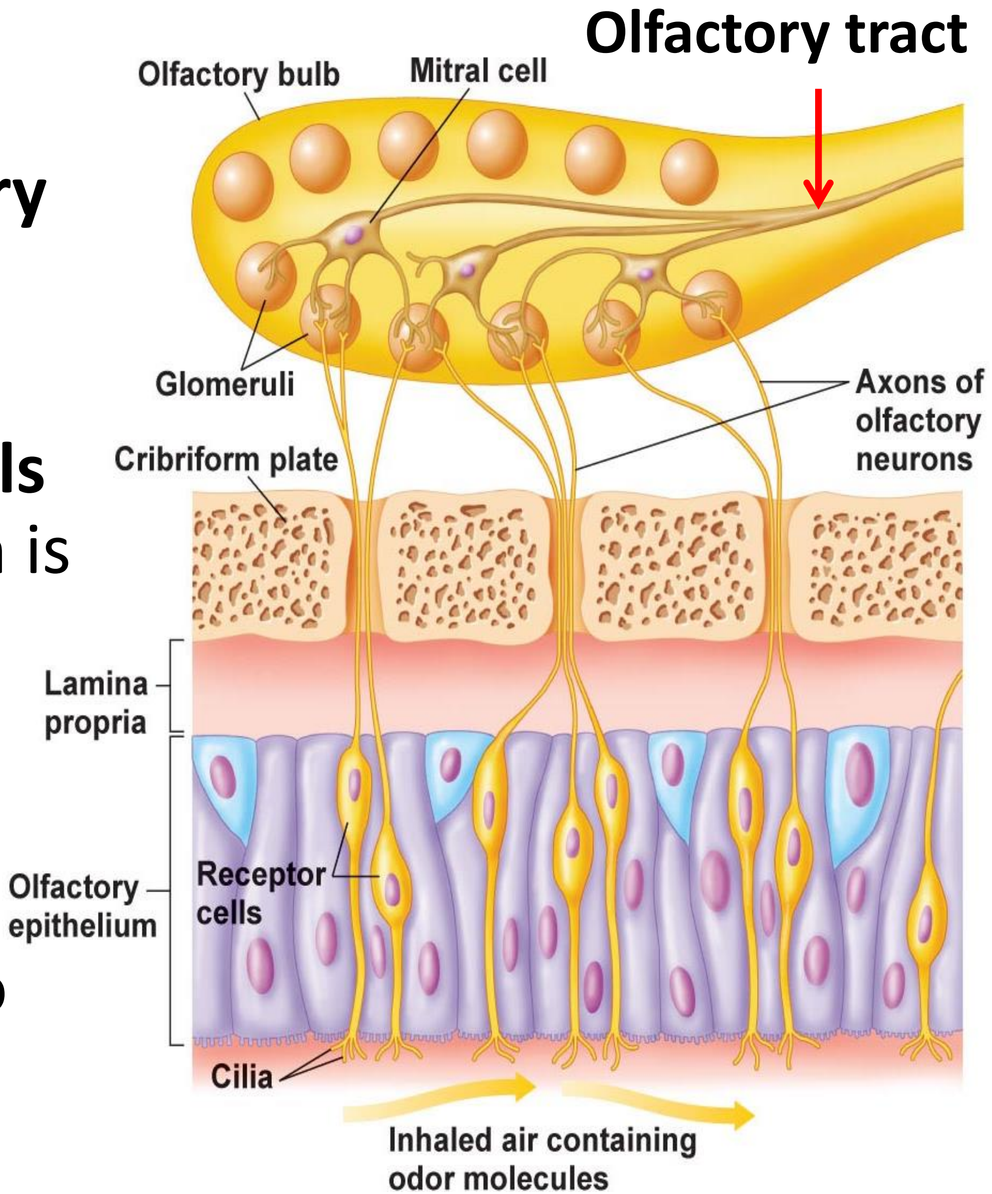
Figure 54-4

Membrane Potential & Action Potential of Olfactory Cells

- The resting membrane potential of olfactory cells is ~ **–55 mV**.
- At this potential, most of the olfactory cells generate **continuous nerve impulses/action potentials** (APs) at a **very slow rate (0.05 to 3 Hz)**.
- Most odorants cause ***depolarization*** and an increase in the rate of APs up to **30 Hz**
- Like other sensory receptors, the rate of olfactory nerve impulses is dependent on of the stimulus strength.

Transmission of Olfactory Signal to Olfactory Bulb

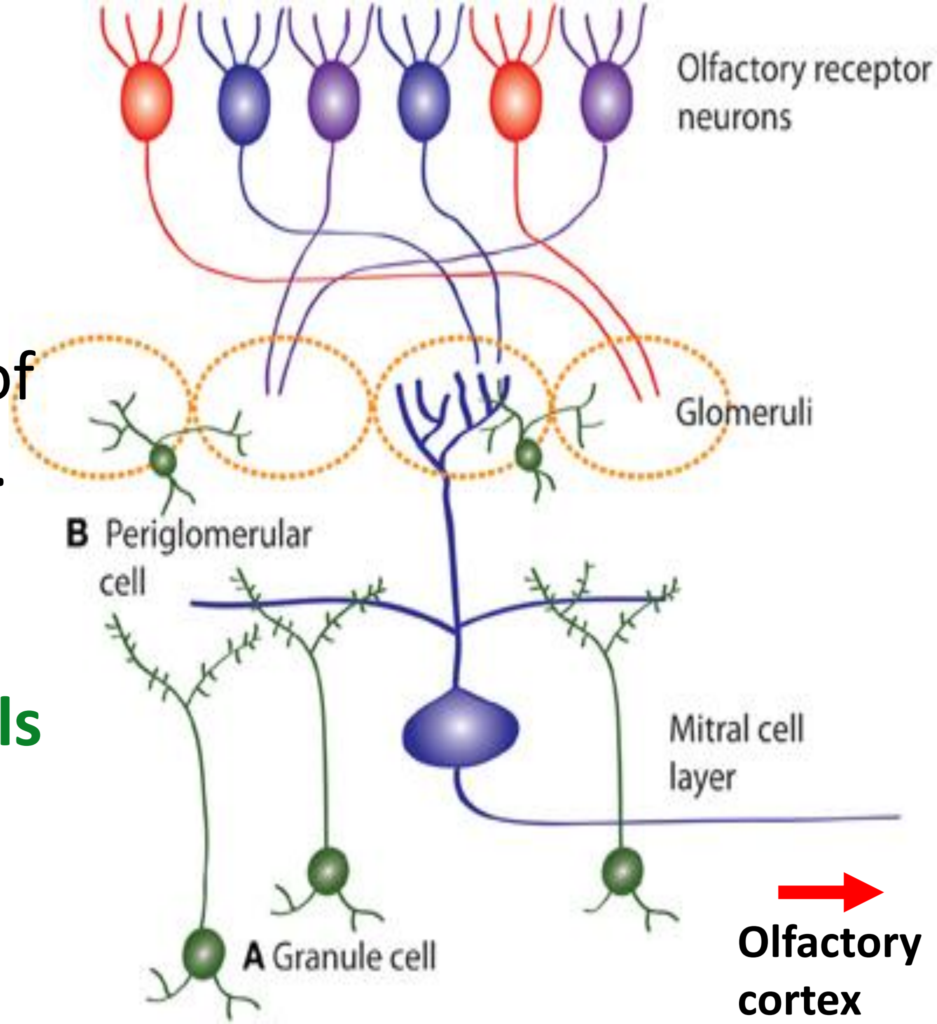
- Axons of the receptor cells penetrate the cribriform plate and form **the olfactory nerve** (**CN I**)
- They synapse on **Mitral cells** in the **olfactory bulb** which is just superior to the cribriform plate
- Axons of Mitral cells travel along the **olfactory tract** to reach the **olfactory cortex** and the **limbic system**



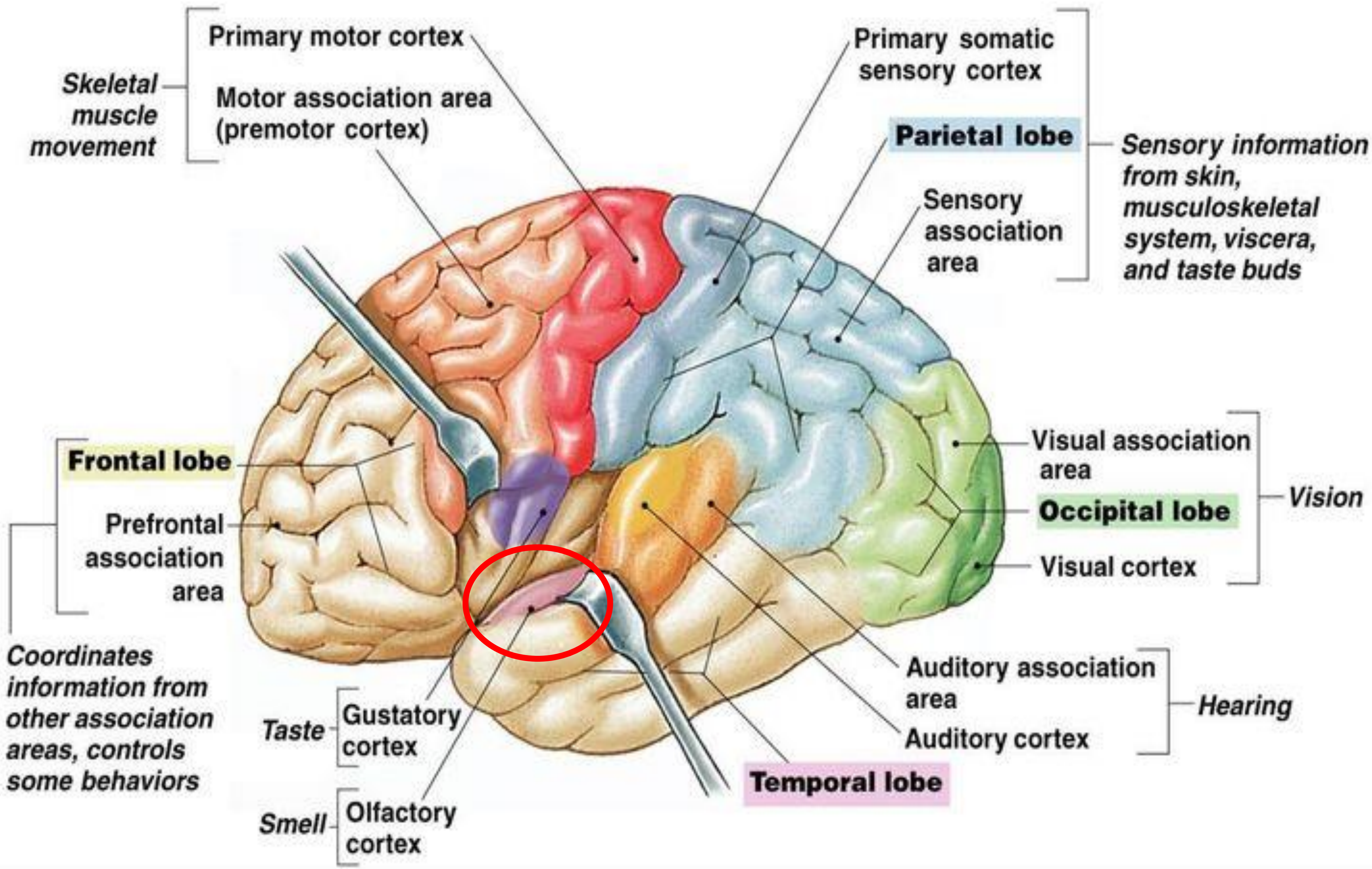
Olfactory Glomeruli

- Olfactory receptor neurons express **one type of odor receptor**
- Receptor neurons with the same receptor type project to the **same glomerulus**
- They synapse with dendrites of **mitral cells** in the **glomerulus**.
- Mitral cells project to the olfactory cortex.
- **Granule & Periglomerular cells (inhibitory interneurons)** modulate mitral cell activity.

Each glomerulus represents a single odorant receptor



Olfactory Cortex



Neuronal Connections of the OS-1

- **The olfactory tract divides into 2 pathways:**
  1. *The medial olfactory area:*
     - Consists of nuclei anterior to the **hypothalamus**
     - Concerned with **basic behavior** e.g. responses to the smell of food (**salivation**)

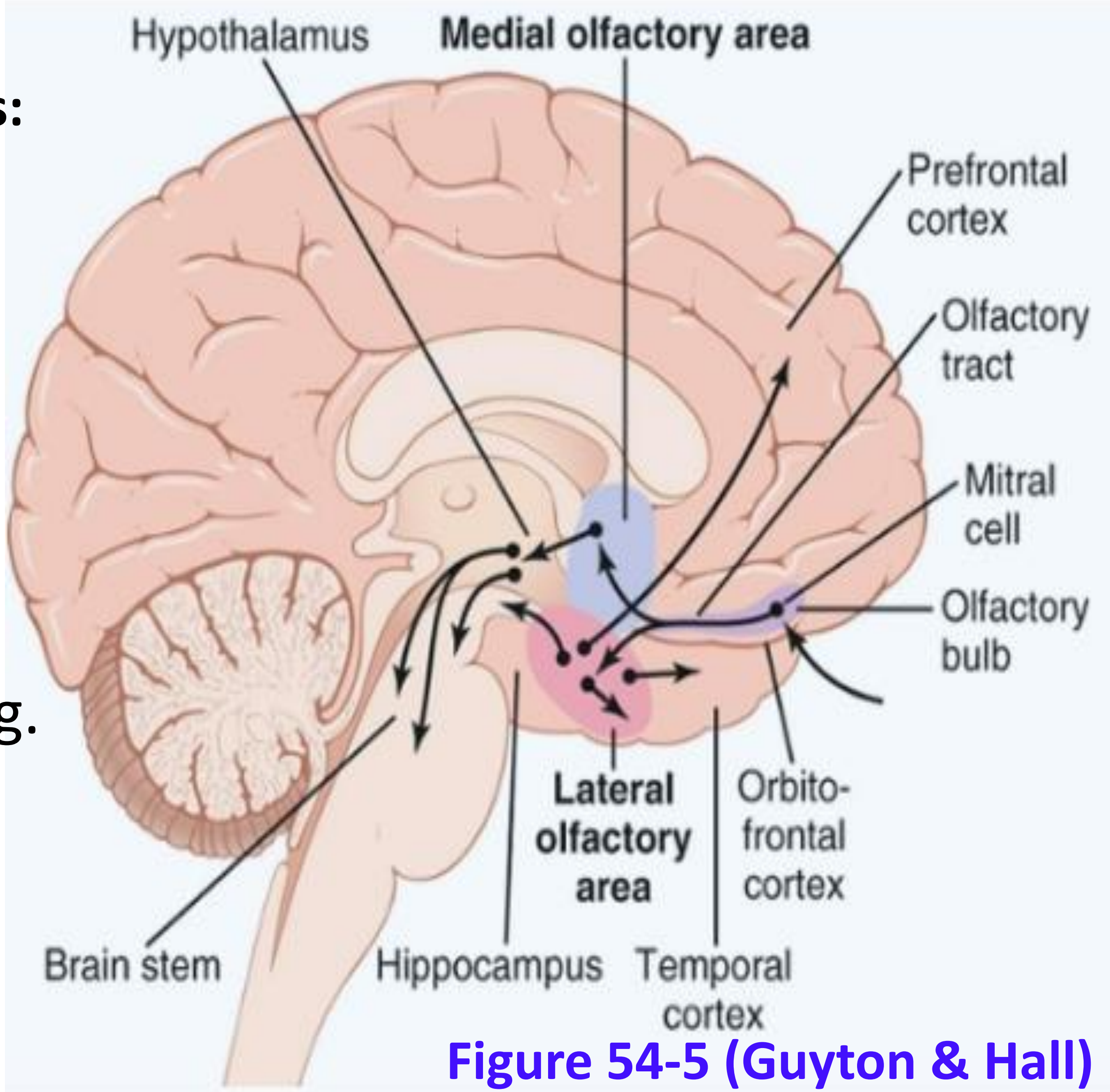


Figure 54-5 (Guyton & Hall)

Neuronal Connections of the OS-2

- **The olfactory tract divides into 2 pathways:**
  - **2.** ***The lateral olfactory area:***
    - Provide inputs to **all portion of the limbic system** e.g. hippocampus

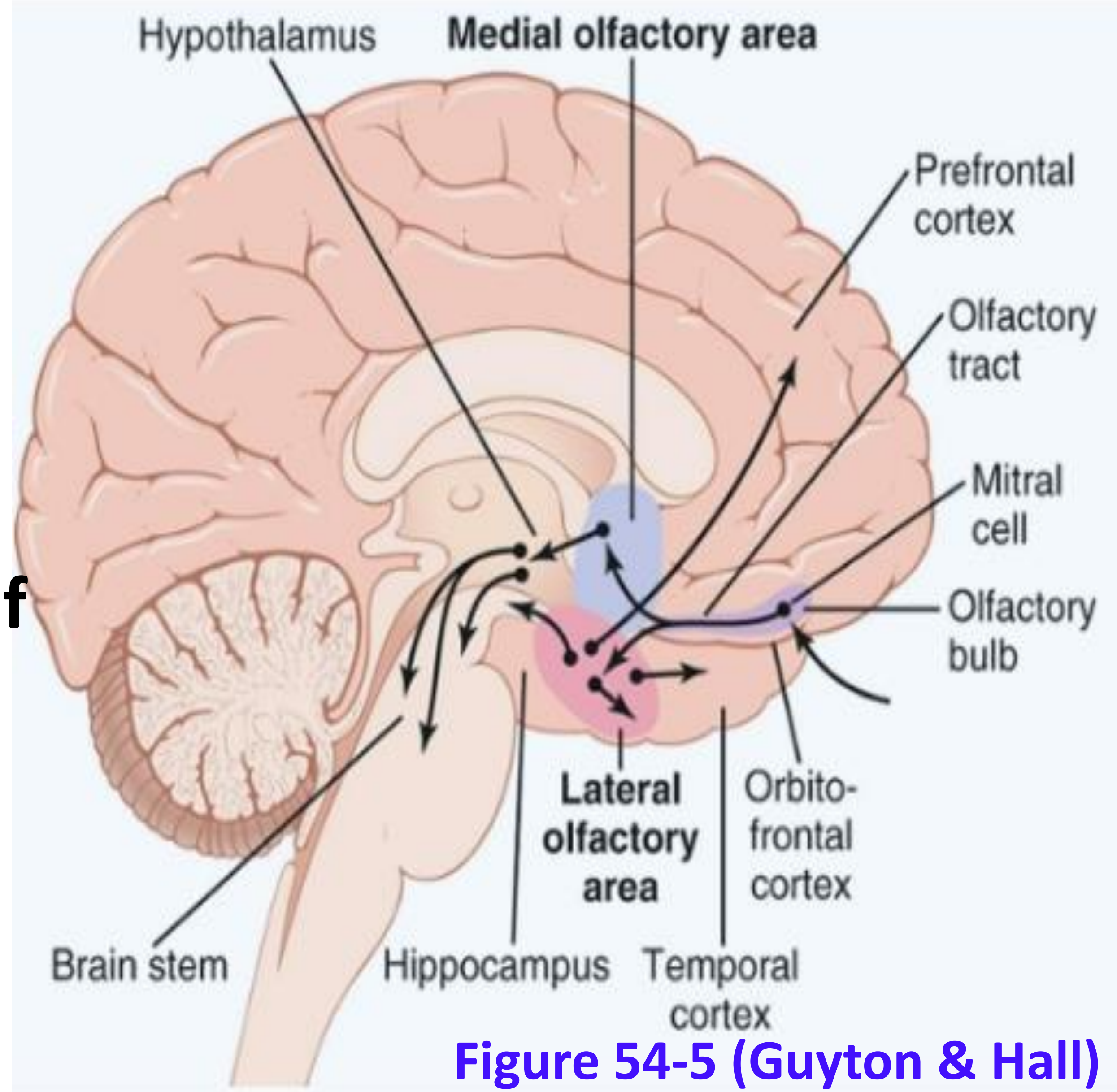
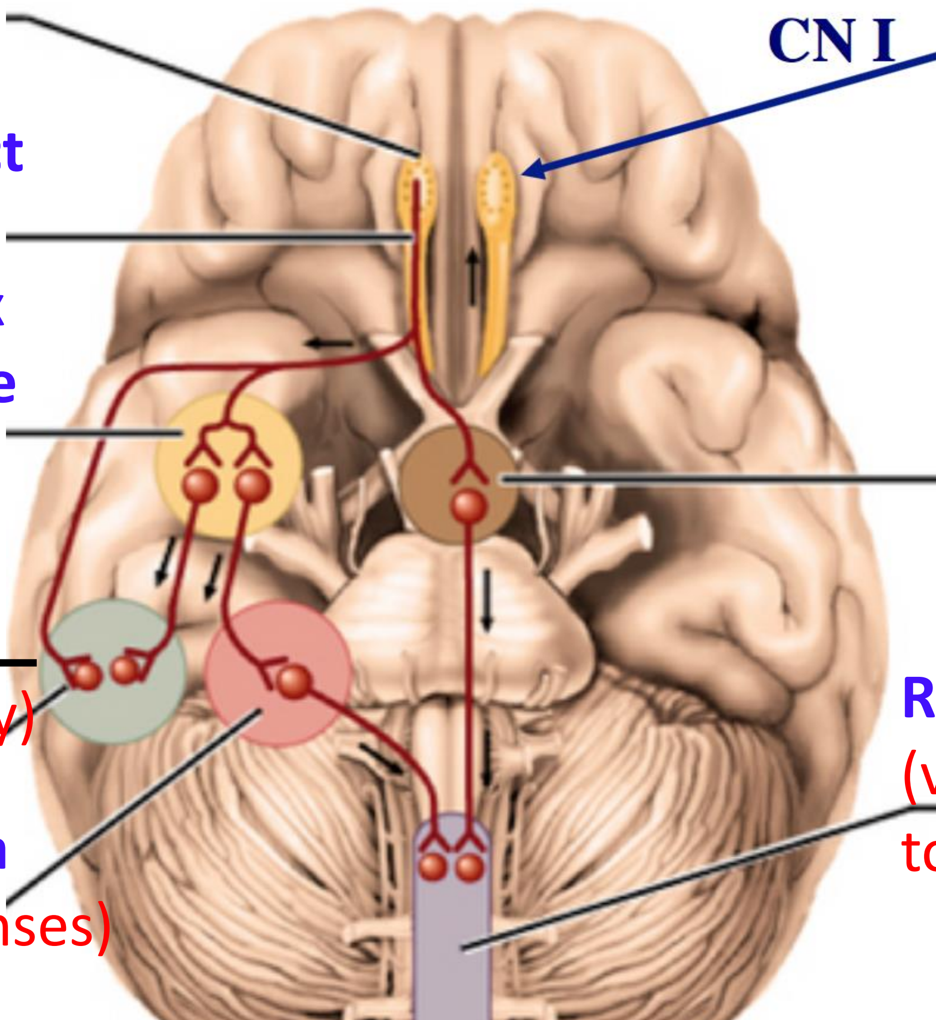


Figure 54-5 (Guyton & Hall)

Olfactory Projection Pathways



Smell Sensations Adapt Rapidly

- Olfactory receptors adapt about **50 %** in the first **second** or so
- After that, they adapt very little and very slowly.
- Smell sensations adapt almost to **extinction** within a **minute** or so (from experience)
- The additional **psychological adaptation** occurs in the CNS
- Centrifugal (efferent) nerve fibers pass from the brain backward and terminate on the ***granule cells*** ***(inhibitory neurons)***.
- After onset of an olfactory stimulus, the CNS quickly develops strong **feedback inhibition** to suppress relay of the smell signals

Pathophysiology of Smell

- **Anosmia**: loss of smell sensation
- **Hyposmia**: decreased ability to smell
  - Vitamin A deficiency
- **Dysosmia**: distorted identification of smell
  - **Parosmia** - Altered perception of smell in the presence of an odor, usually unpleasant
  - **Phantosmia** – Perception of smell without an odor present
  - **Agnosia** - Inability to classify or contrast odors, although able to detect odors
- **Hyperosmia:** increase in smell sensation

What causes smell disorders?

Common causes of smell disorders are:

- Aging
- Sinus and other upper respiratory infections
- Smoking
- Growths in the nasal cavities
- Head injury
- Hormonal disturbances
- Exposure to certain chemicals (e.g. insecticides) and medications, including some common antibiotics and antihistamines
- Parkinson's disease or Alzheimer's disease.

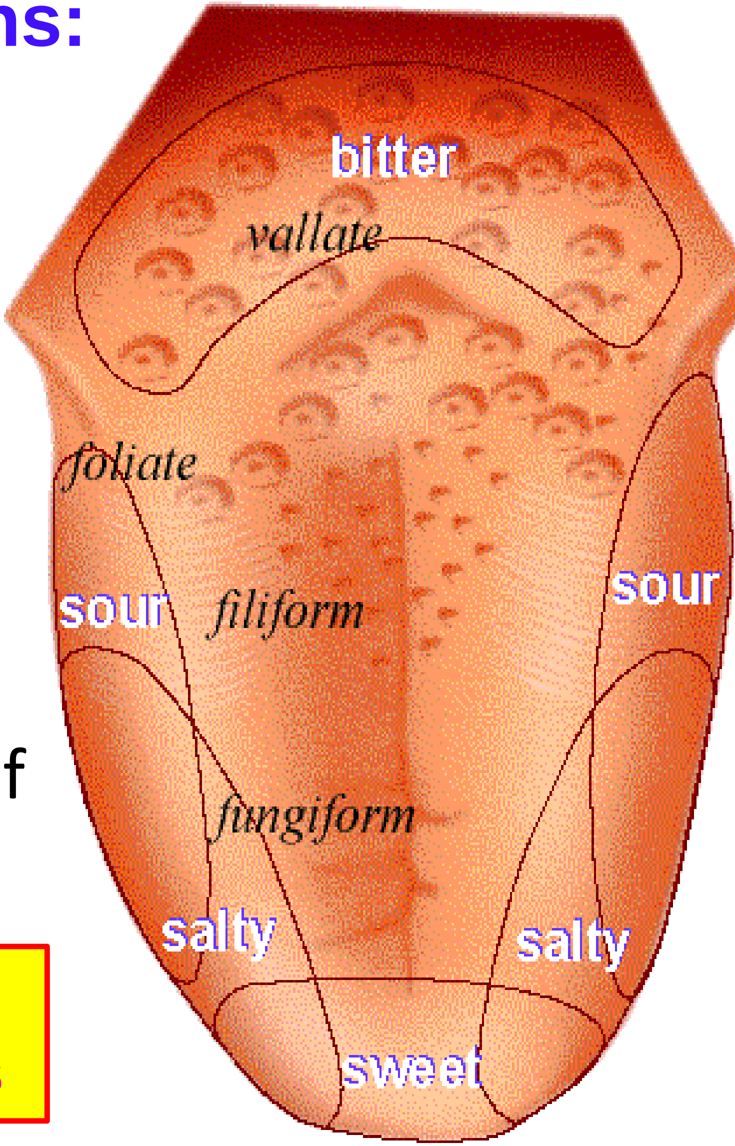
Taste (Gustation)

Taste Sensations

Five established taste sensations:

1. **Sweet:** sugars
2. **Sour:** acids (free H ions)
3. **Bitter:** alkaloids, other substances
4. **Salty:** chemical salts (NaCl)
5. **Umami:** glutamate-“meat taste”

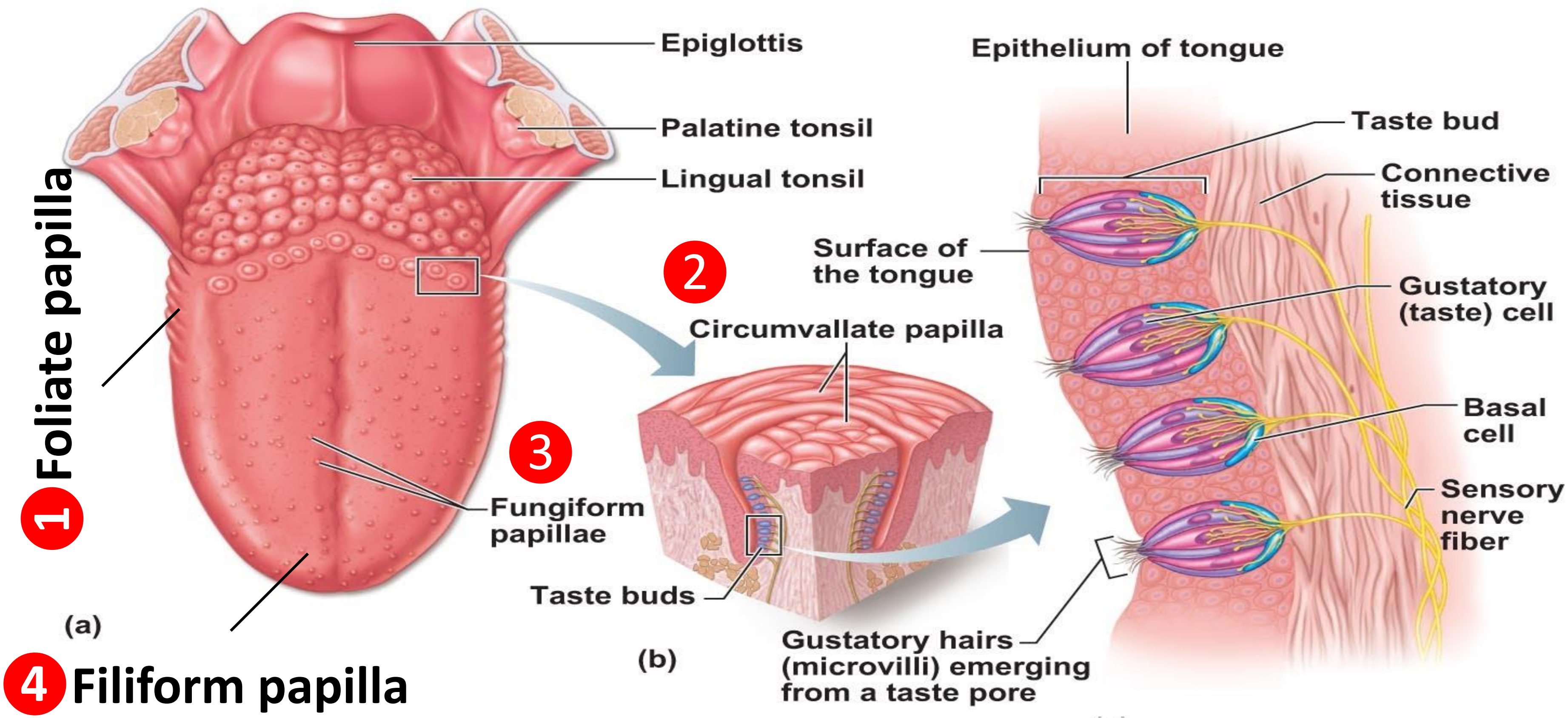
- **Myth**: these tastes are detected by different regions of the tongue!
- **Fact:** can be detected by any area of the tongue and other mouth parts



These sensations are detected by taste receptors found in Taste Buds

What are Taste Buds? 1

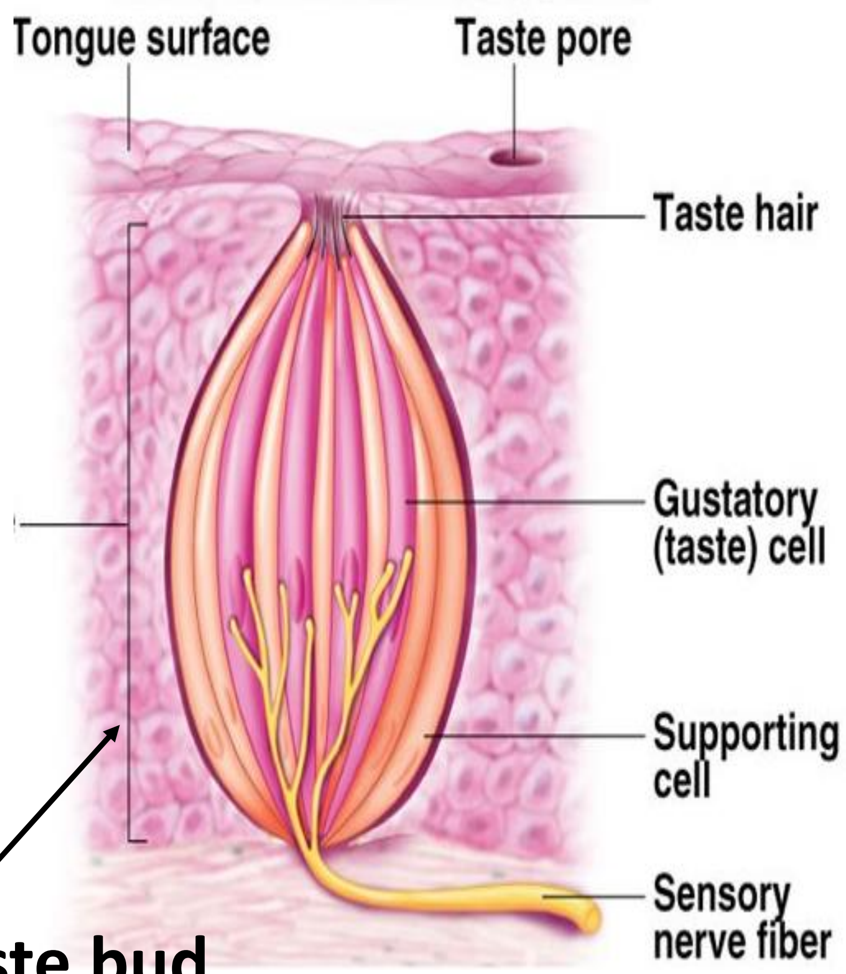
- Are **barrel-shaped** structures that contain **taste receptors**
- They are found in small protrusions (bumps) called **papillae**
- **Four types of papillae**: (1) Foliate, (2) Circumvallate, (3) Fungiform, and (4) Filiform (**no taste buds**)



What are Taste Buds? 2

Taste bud consists of:

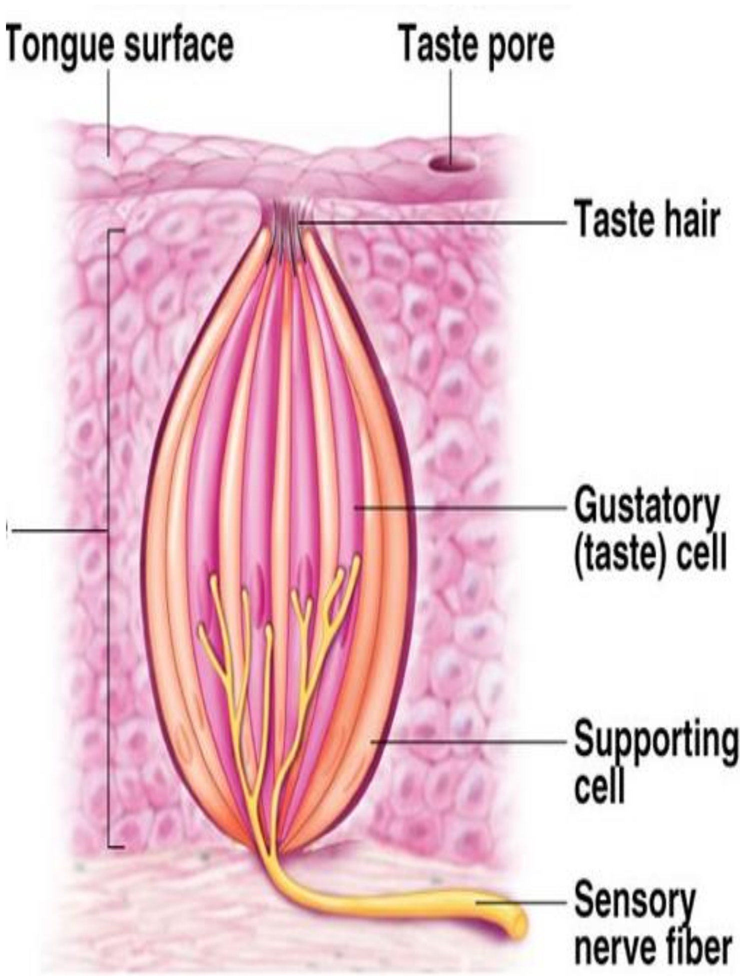
- Taste pore
  - Opening through which **fluids** come into contact with taste receptor cells
- Taste receptor cells **(~50 cells)**
- Supporting cells
- Endings of afferent fibers



Taste bud

What are Taste Receptor cells?

- Are modified epithelial cells with surface folds called **microvilli** (hairs) (**life span is ~10 days**)
- Are NOT neurons (**unable to generate action potentials**)
- Able to be depolarized upon stimulation and **generate receptor potentials**
- Make chemical synapses with the endings of afferent fibers of cranial nerves (**VII, IX and X**)



Plasma membrane of microvilli contain receptor sites that bind selectively with chemical molecules in saliva

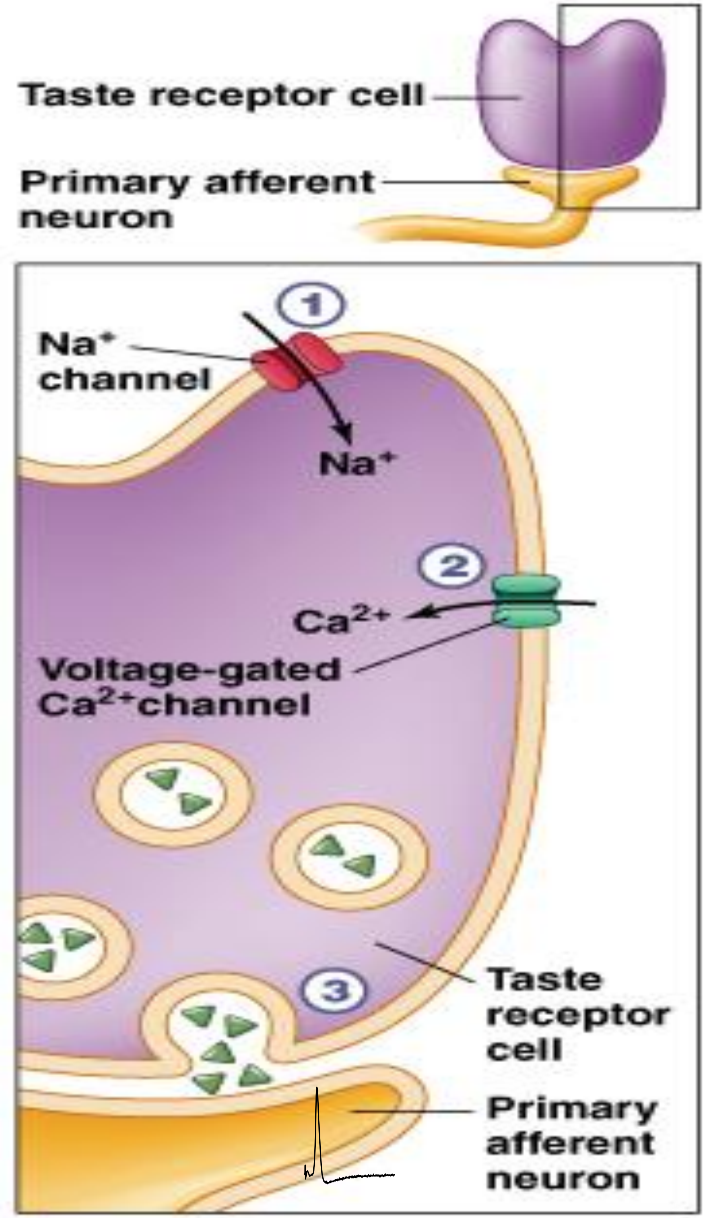
Taste Transduction: 1. Salty

❶ **Na^+** from salty food enter the cell through **Amiloride-sensitive (epithelial) Na^+ channels** in microvilli

❷ Entry of Na^+ into the cell causes **depolarization** which opens **voltage-gated Ca^{2+} channels**

❸ Influx of **Ca^{2+}** causes neurotransmitter release which is needed for signal transmission to the **post-synaptic afferent neuron**.

Amiloride = K^+-sparing diuretic



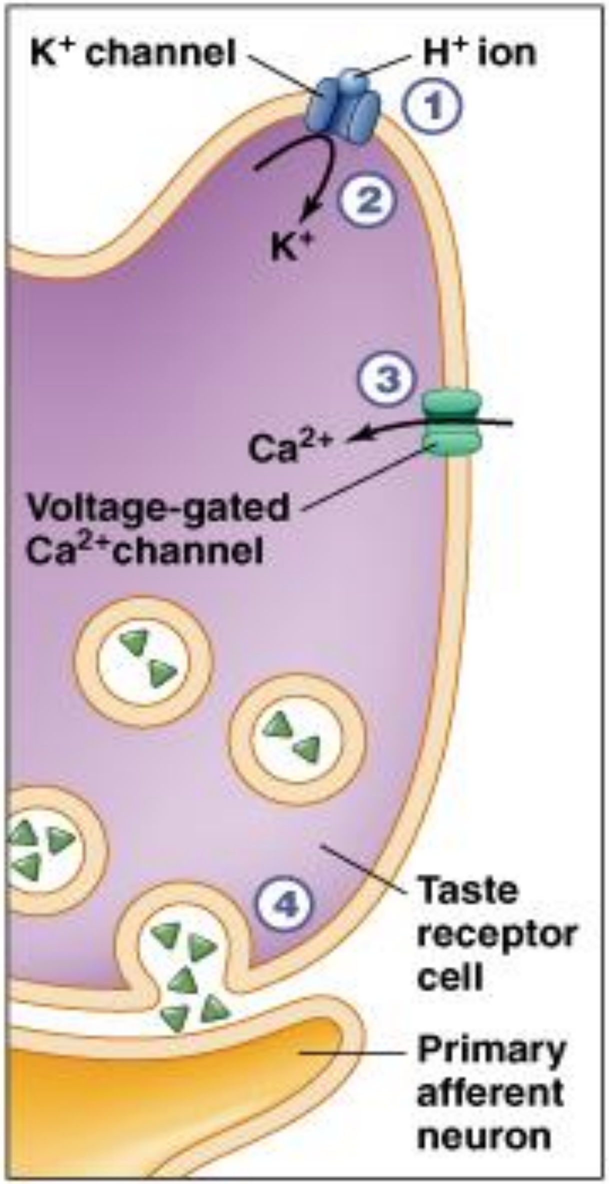
Taste Transduction: 2. Sour

1 **H^+** ions from sour food block **K^+ channels** in the microvilli .

2 This blockage prevents **K^+** from leaving the cell

3 This causes **depolarization** which opens **voltage-gated Ca^{2+} channels**

4 Influx of **Ca^{2+}** causes neurotransmitter release which is needed for signal transmission to the **post-synaptic afferent neuron.**



Taste Transduction: 3. Sweet

1 A sweet molecule binds to a **G-protein-coupled receptor** causing conformational change.

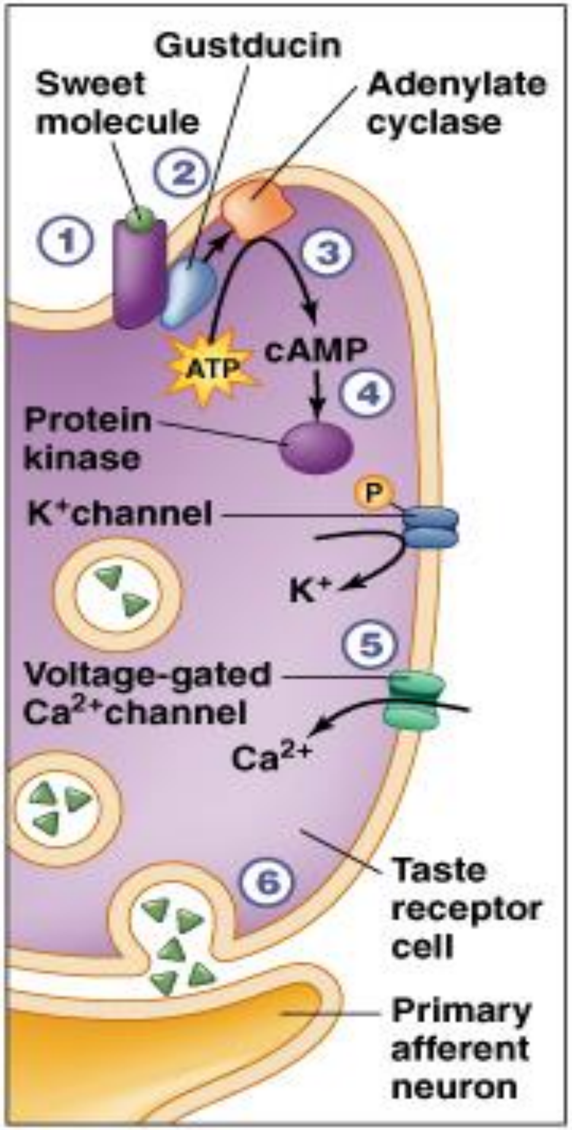
2 This activates the protein **Gustducin** which in turn activates **Adenylate cycalse**

3 This enzyme catalyzes conversion of ATP into cAMP.

4 The cAMP activates a protein kinase causing closure of K^+ channels

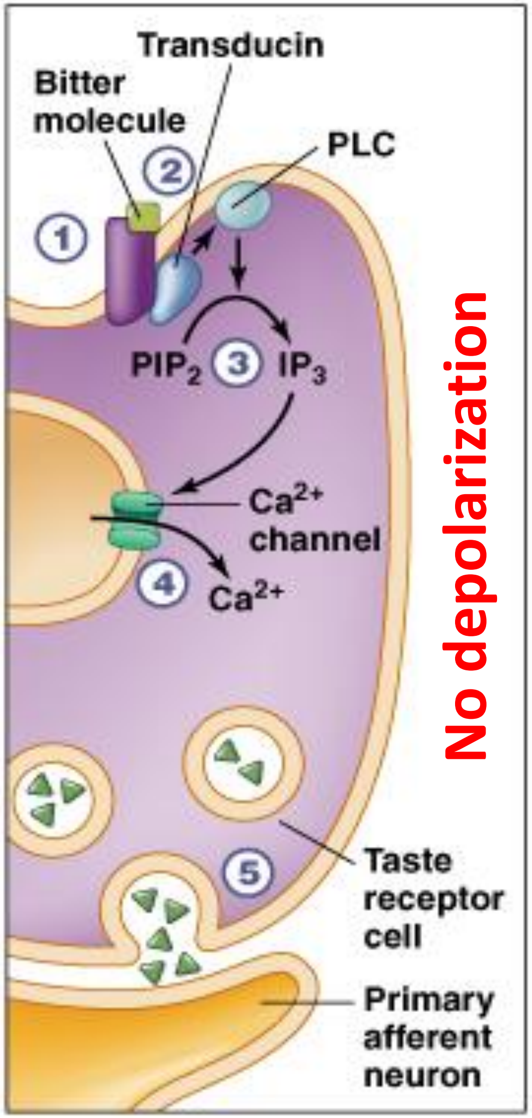
5 This causes **depolarization** which opens voltage-gated Ca^{2+} channels

6 Influx of Ca^{2+} causes NT release



Taste Transduction: 4. Bitter

❶ A bitter molecule binds to a **G-protein-coupled receptor** causing conformational change.
❷ This activates the protein **Transducin** which in turn activates phospholipase C (PLC)
❸ This enzyme catalyzes conversion of **PIP_2** (phospholipid) into second messenger **IP_3**
❹ **IP_3** causes **Ca^{2+}** release from intracellular stores
❺ Release of **Ca^{2+}** causes NT release which is needed for signal transmission to the **post-synaptic afferent neuron.**



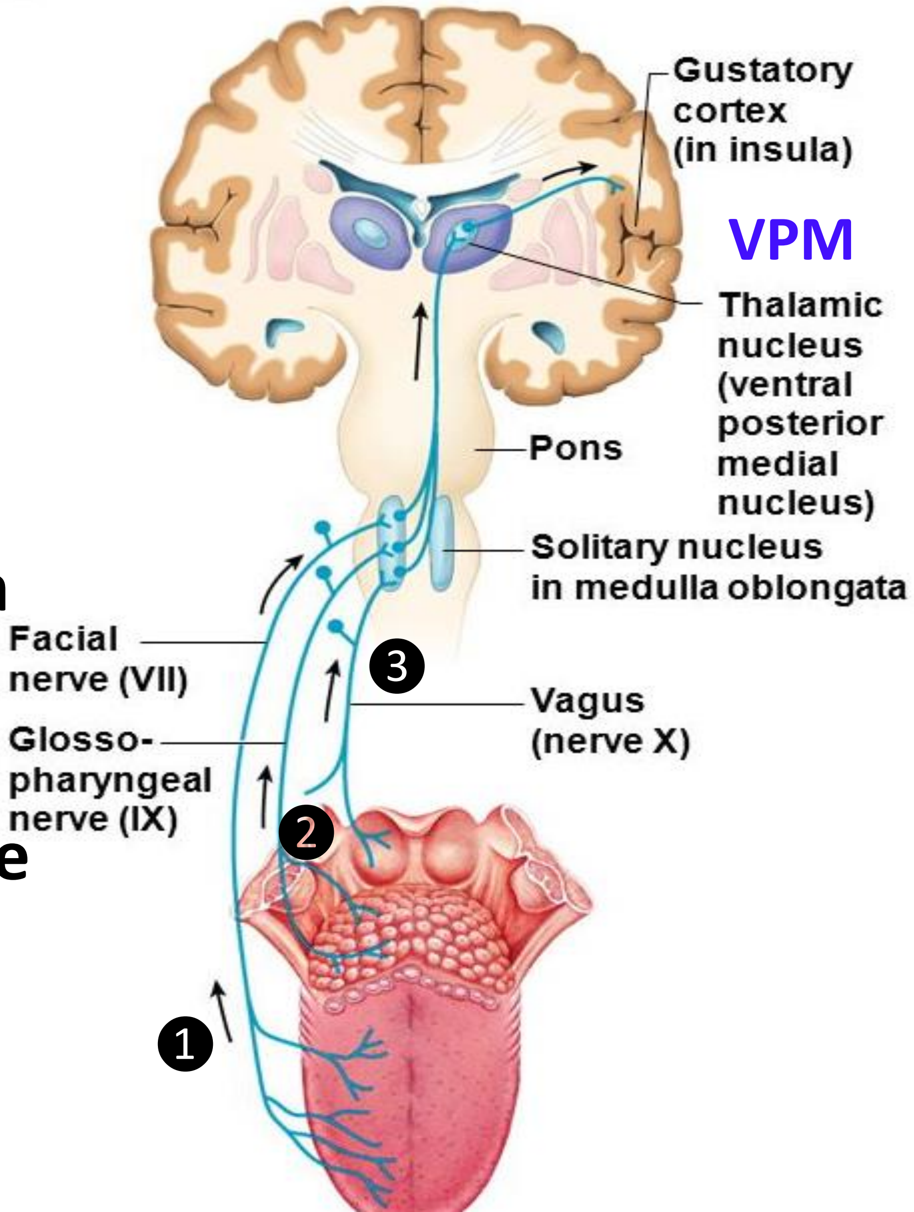
No depolarization

The Taste Pathway-1

❶ Taste impulses from anterior **2/3** of tongue pass in cranial nerve (CN) **VII**

❷ Impulses from the posterior 1/3 of tongue and other posterior parts of mouth are transmitted by CN **IX**

❸ Few taste signals from **base** of the tongue and other posterior parts are carried by Vagus nerve (**CN X**)

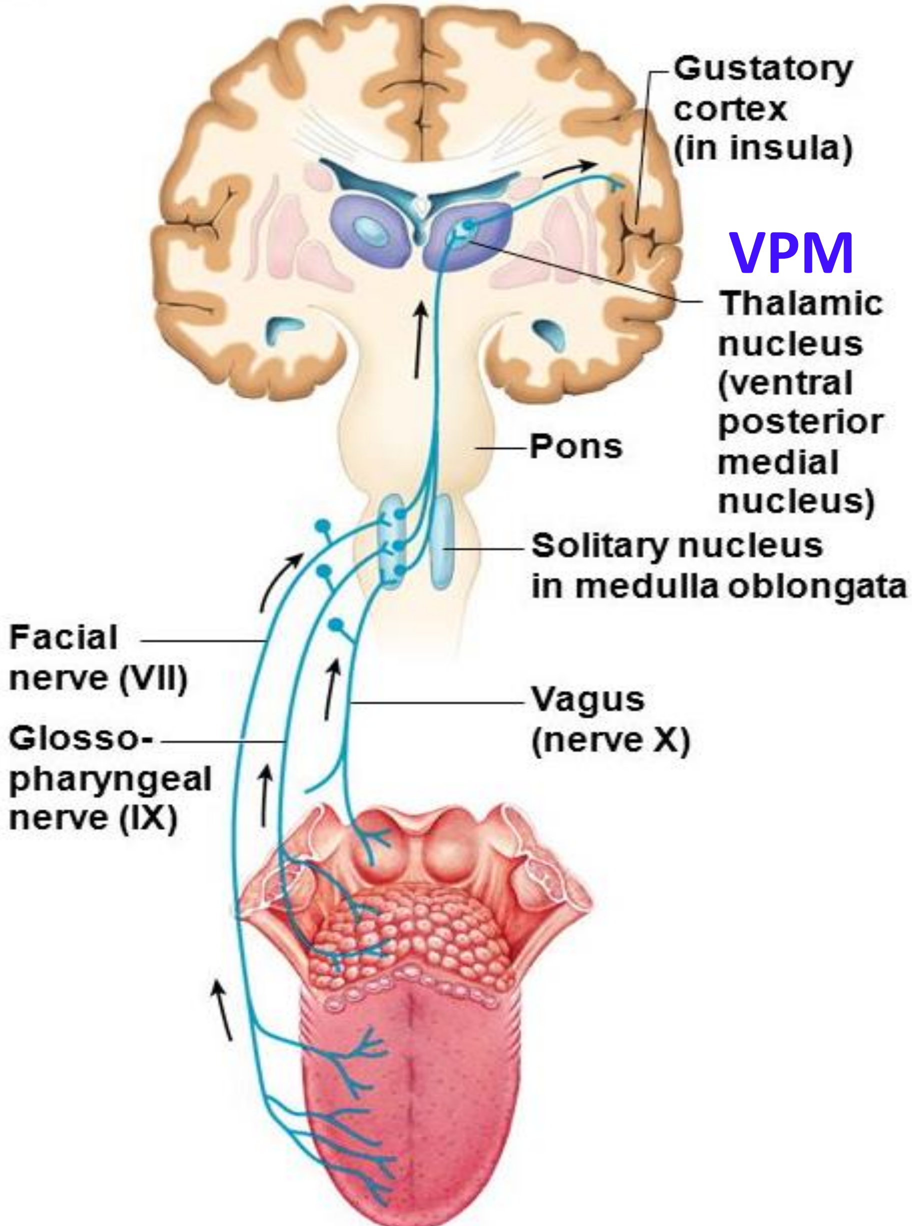


The Taste Pathway-2

- **First order neurones** synapse in in the **nucleus of tractus solitarius** (TS) in the medulla

- **Second order neurones** from TS cross the midline to ascend in the medial lemniscus to the **VPM** of the thalamus

- **Third order neurons** from VPM nucleus project to the gustatory cerebral cortex



Pathophysiology of Taste Sensation

- **Ageusia** (complete loss of taste)
- **Dysgeusia** (disturbed taste)
- **Hypergeusia**
- **Hypogeusia:** it can be caused by many diseases, and drugs such as penicillamine
- Taste sensation can be modified by **Meraculin** (from Miracle fruit):
  - When Meraculin applied to tongue

makes **acids** taste **sweet!!**


Thank You
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Any Questions