Dental Physiology

Smell and Taste

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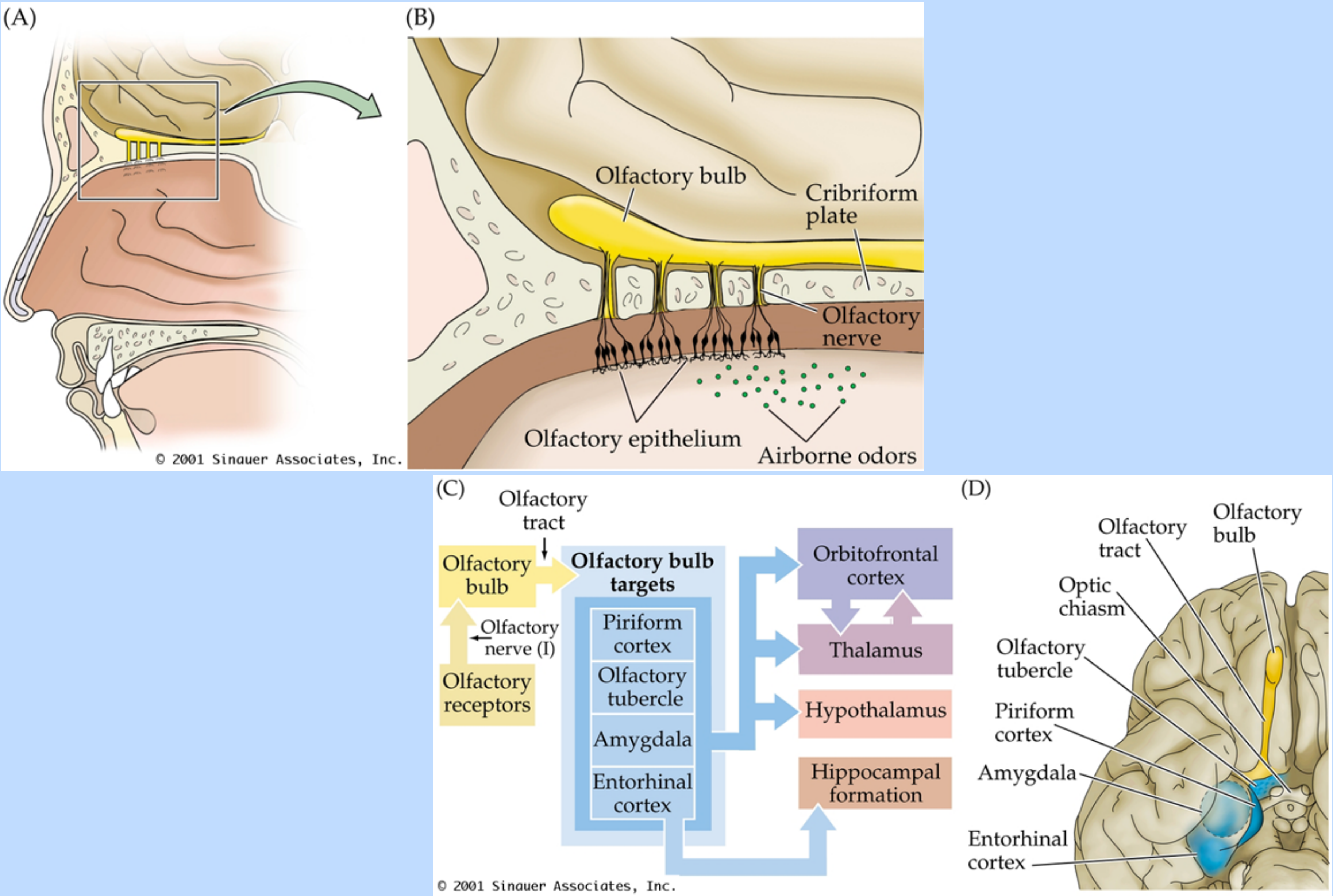
Brain Receives Information From External World via several Senses

- Touch (somesthesis)
- Seeing (vision)
- Hearing (audition)
- Sense of balance (vestibular sense)

Chemical (Chemosensory Triad):

- Taste (gustation)
- Smell (olfaction)
- Chemosensory irritant (Trigeminal)

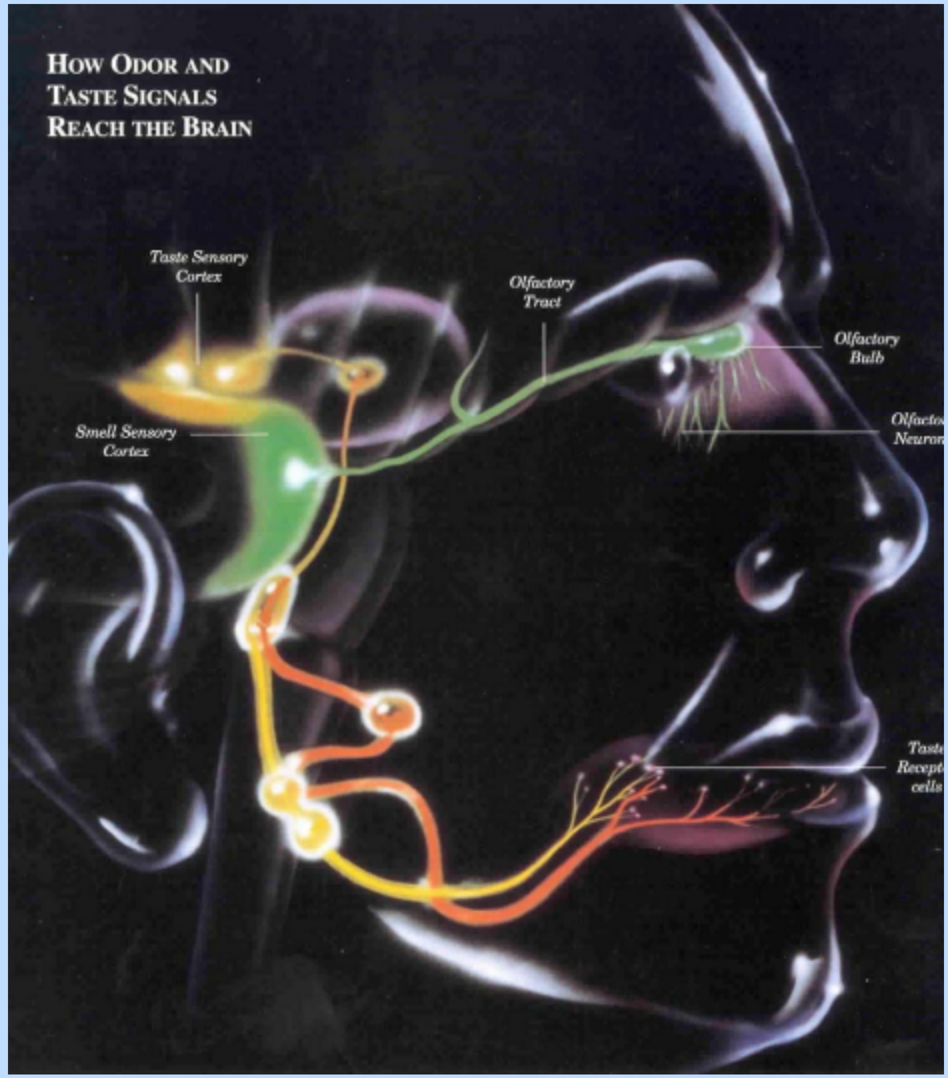
Smell - Olfaction



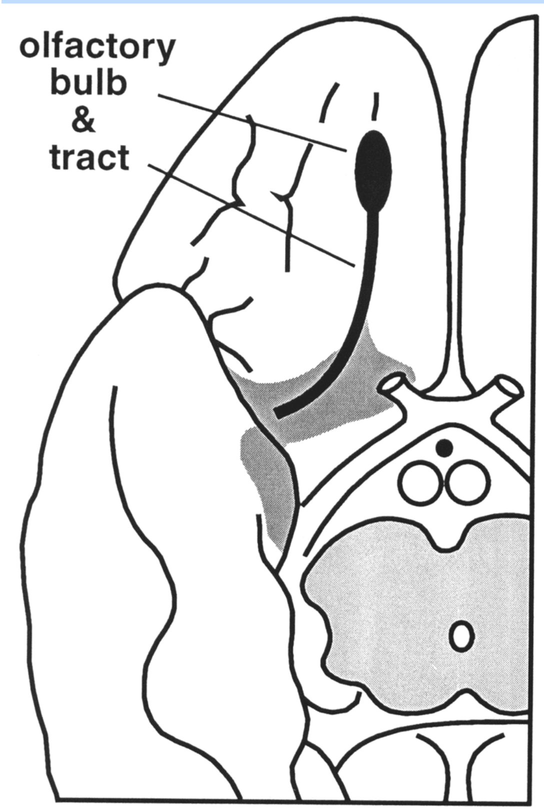
The route of olfaction

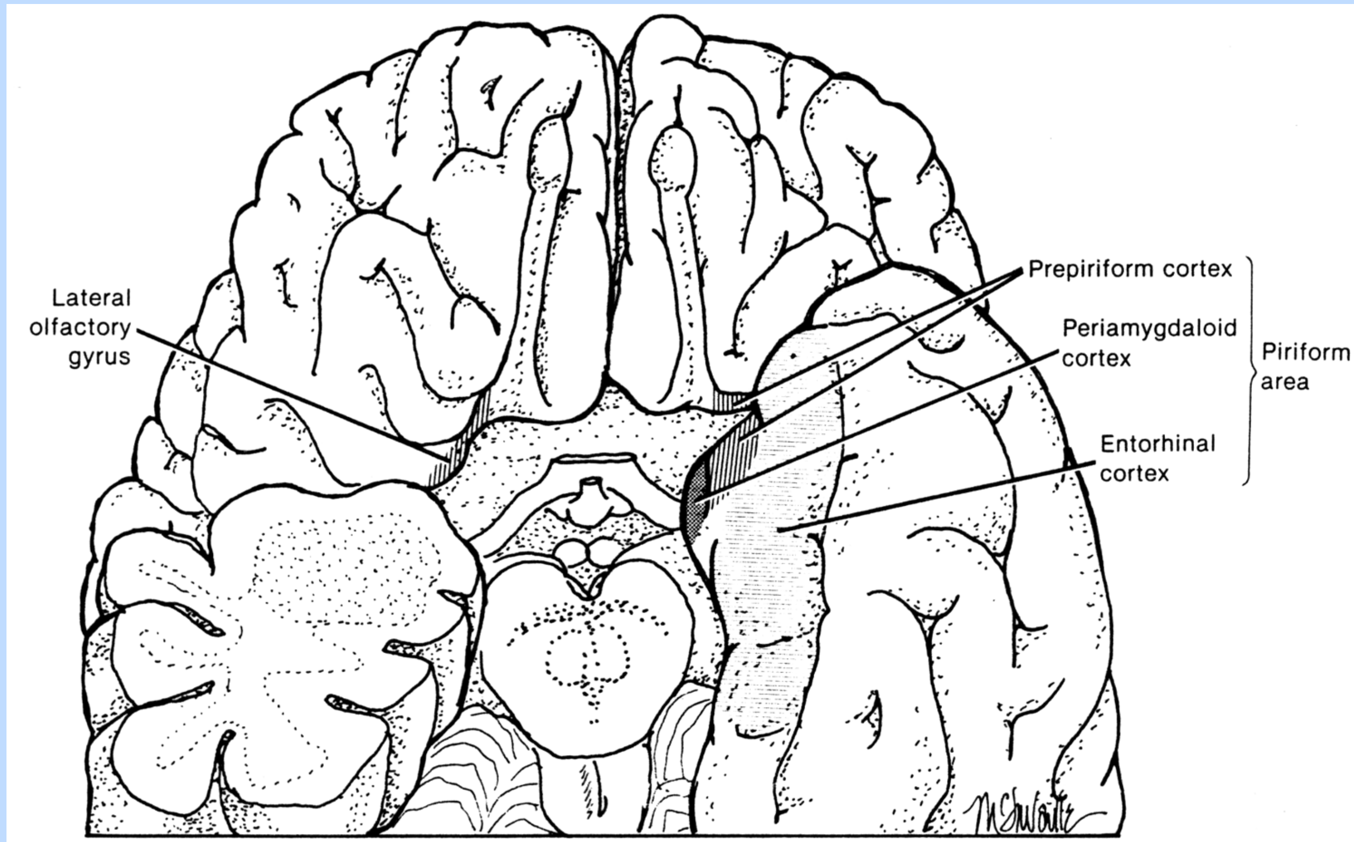
- Starts in the nose, odorants bind to specific receptors found in the olfactory epithelium.
- Olfactory epithelium projects to neurons in the ipsilateral olfactory bulb, which in turn sends projections contra and ipsi to the pyriform cortex in the temporal lobe and other forebrain structures.
- Pyriform cortex is only 3-layered (sometimes called the archicortex), and is considered older than the neocortex.
- Unique among senses in that it does not include a thalamic relay between primary receptors and the cerebral cortex.
- Pyriform cortex relays information via the thalamus to the associational cortex to initiate motor, visceral, and emotional reactions to olfactory stimuli.

Chemical Senses
Olfaction
Taste
Trigeminal
chemosensory
system



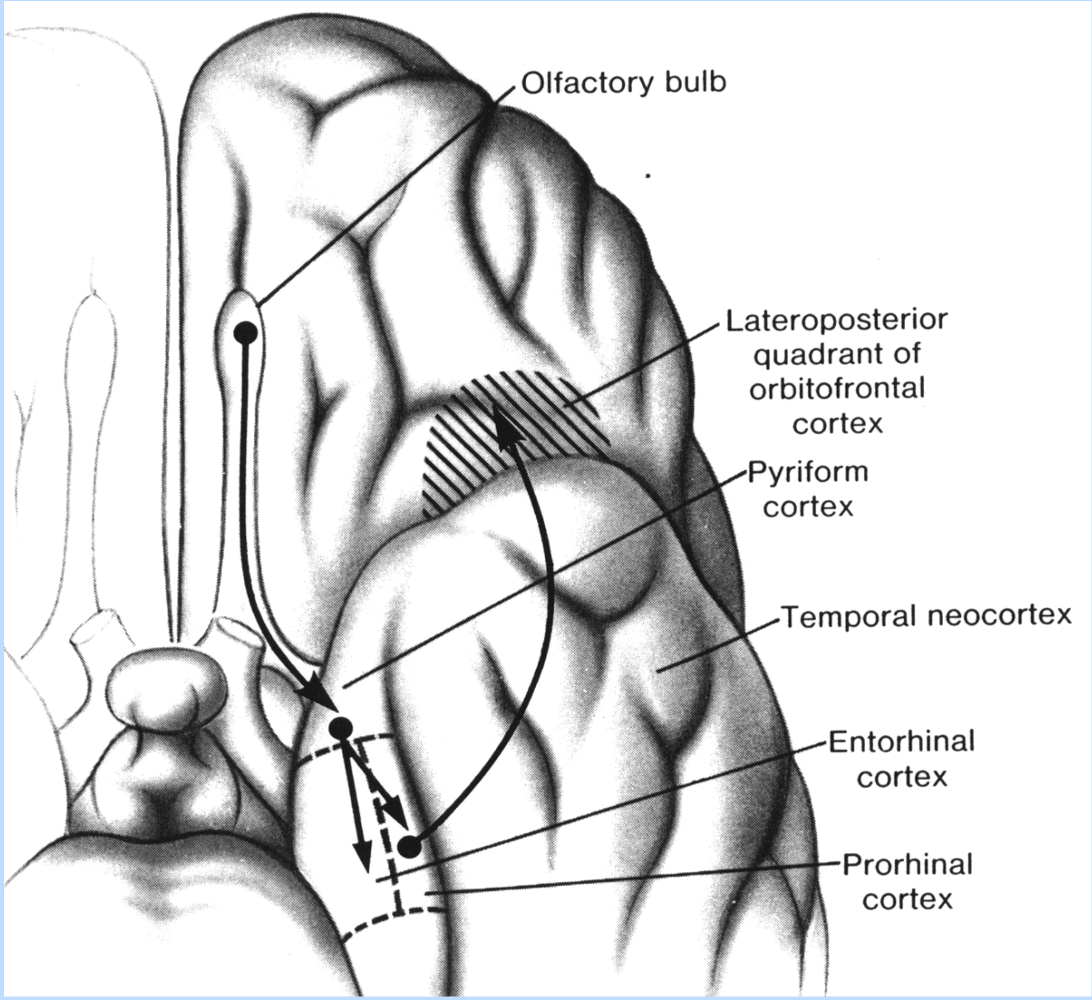
Central projections





Orbitofrontal projections

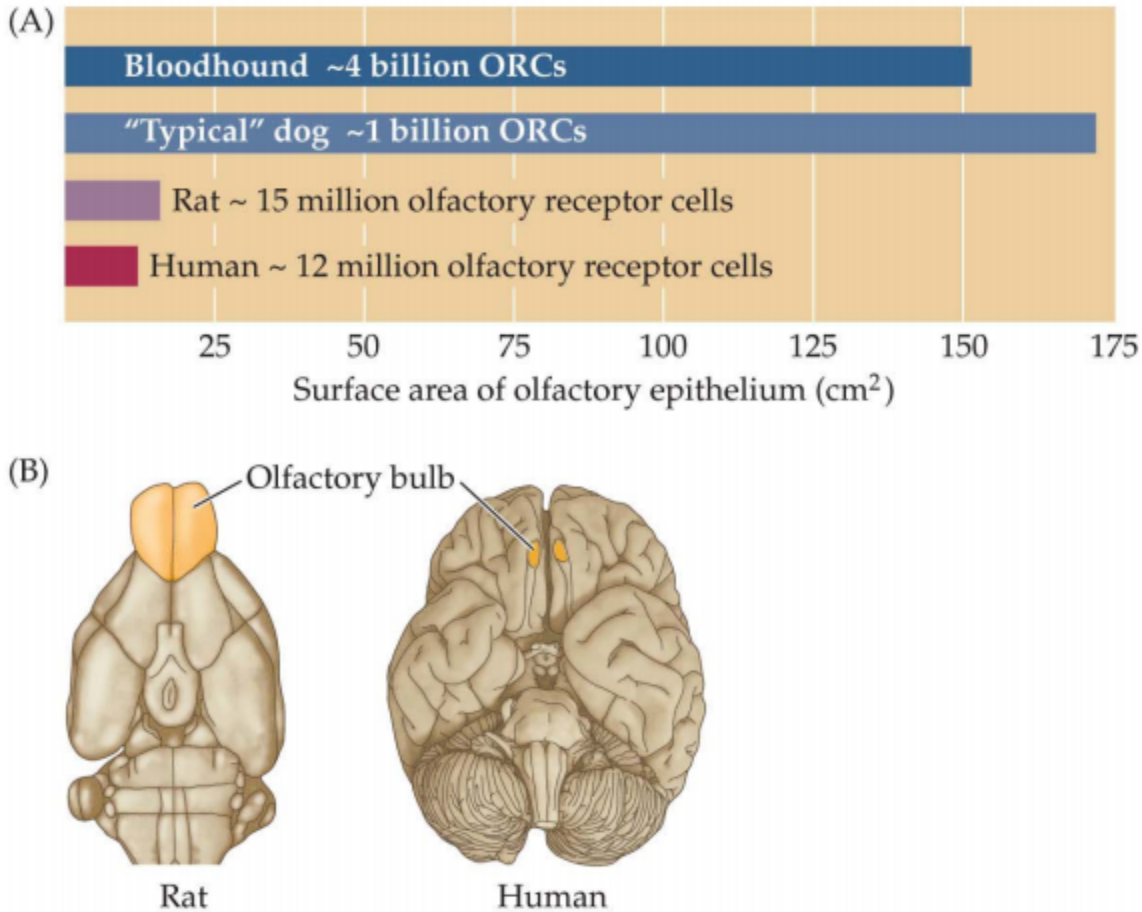
- Orbitofrontal projections are Important for conscious perceptions of odor
- Projections to amygdala, hippocampus, hypothalamus are important for affective, memory and behavioral responses to odors



Of mice and men

- Rats up to 50 times more sensitive to odors than humans
- Dogs can be 10,000 times more sensitive
  - Yet olfactory receptors equally sensitive
  - 1 molecule can stimulate an olfactory receptor
    - Can’t get more sensitive than that!
  - Many more receptors (1 billion compared to 10 million)
    - Decreases # of molecules needed for neural response
- Expertise
  - Wine tasters don’t get more sensitive w/ their nose
  - Better at retrieving labels from memory

Organization of olfactory system



***NEUROSCIENCE*, *Fourth Edition*, Figure 15.2 (Part 1)**

What's the neural code for smell?

- How does the brain know what of hundreds of chemicals are entering the nose?
- Don't really know
- Odor quality
  - Related to physical/chemical properties?
    - e.g., structure of molecule
    - Odotopes in olfactory bulb (OB)
  - Similarly structured molecules smell the same?
    - Not necessarily
  - Differently structured molecules smell different?
    - Not necessarily
- Thus, not easy to relate smell with physicochemical properties of stimulus or OB maps

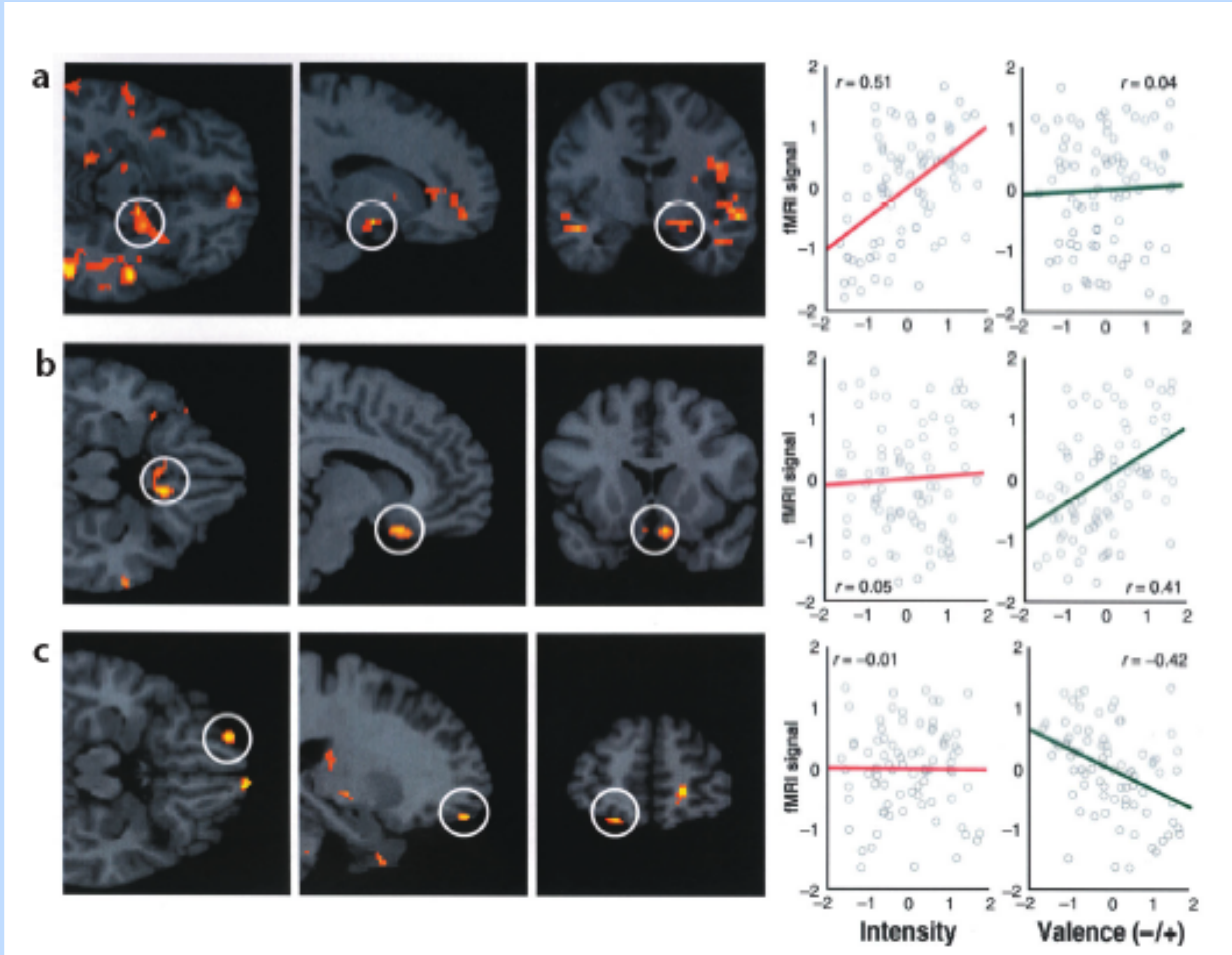
Odor classification

1950's John Amoore:

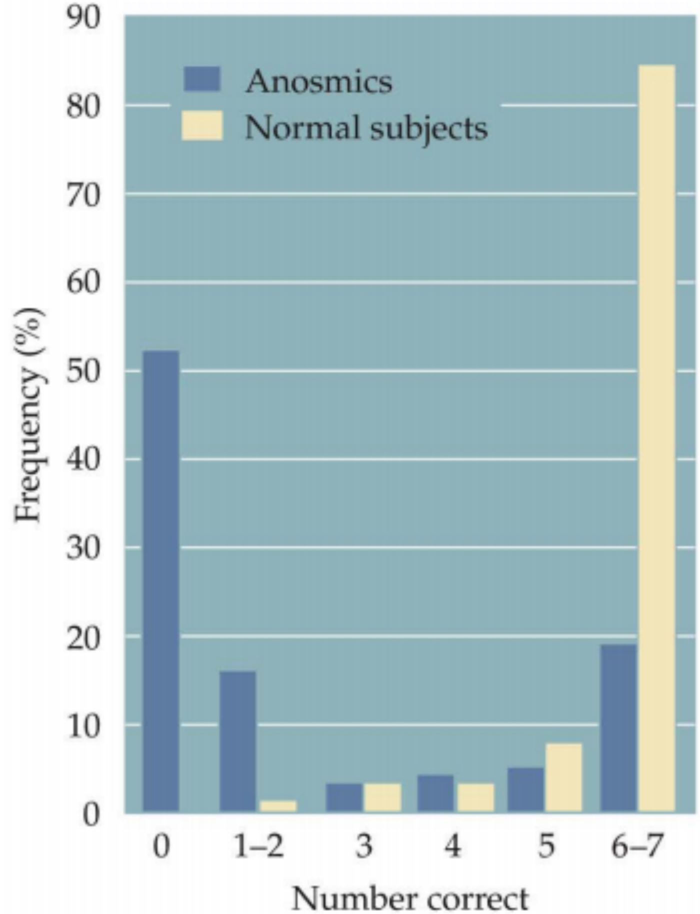
- Pungent
- Floral
- Musky
- Earthy
- Ethereal
- Camphor
- Peppermint
- Ether
- Putrid

What makes a bad smell smell bad?

- Amygdala/ piriform = intensity
- Medial OFC = good
- Lateral OFC = bad

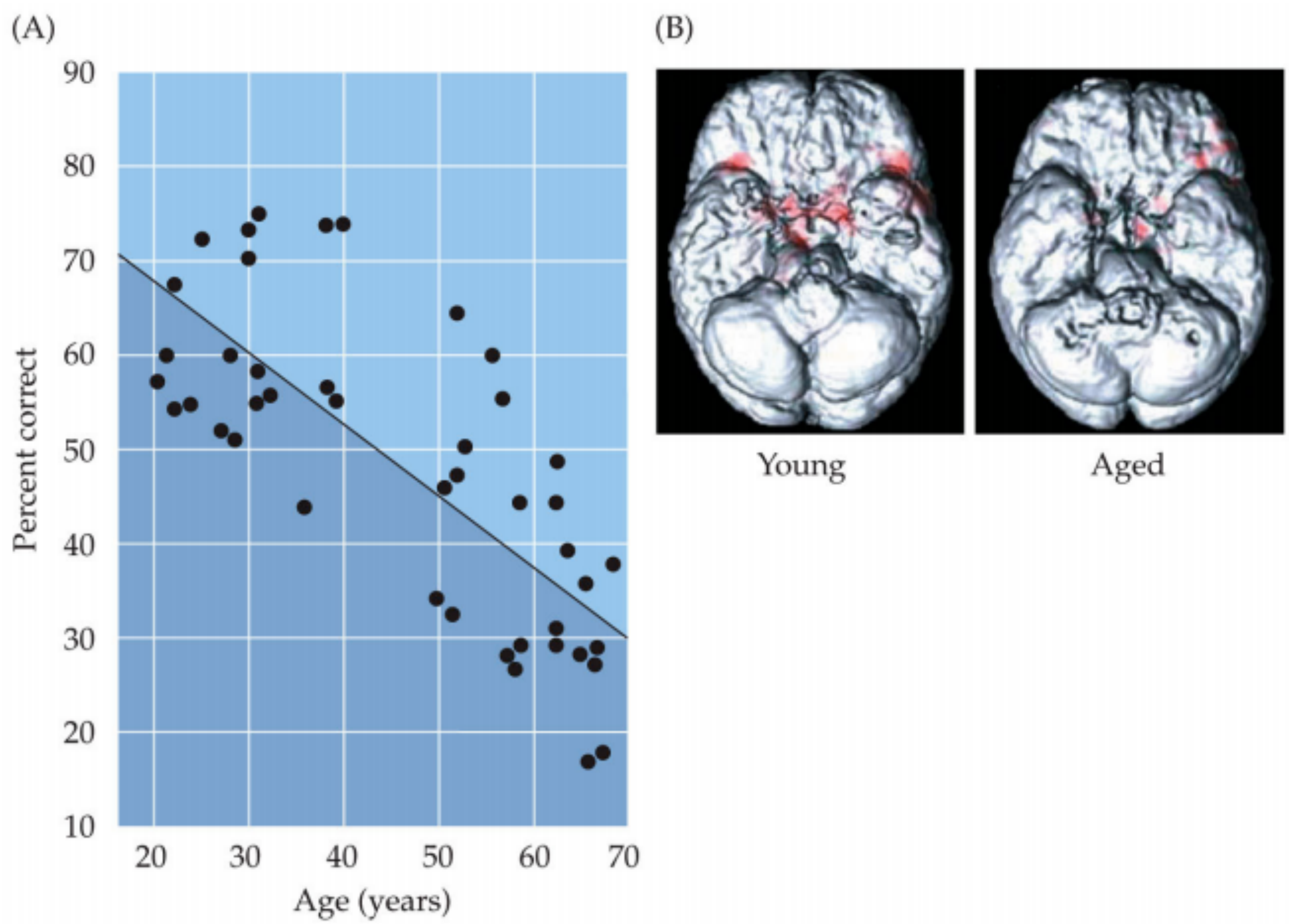


Diseases lacking smell



NEUROSCIENCE, Fourth Edition, Figure 15.3

Aging and odor discrimination



***NEUROSCIENCE*, Fourth Edition, Figure 15.4**

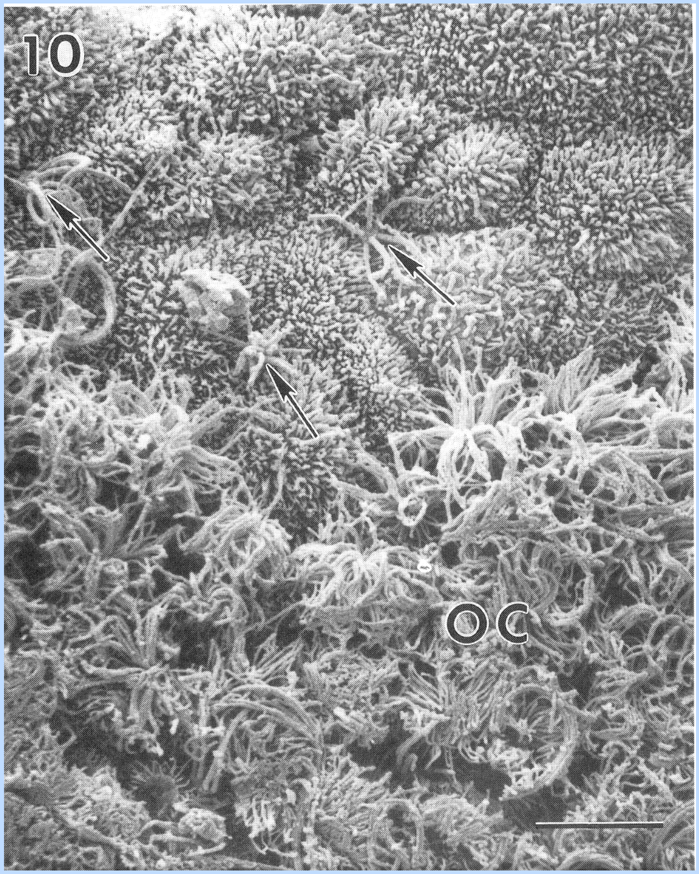
Behavior Pheromones

The vomeronasal organ VNO

- Many species have a specialized structure that recognizes species-specific odorants called pheromones that play important roles in social, reproductive, and parenting behaviors.
- The VNO projects to the accessory olfactory bulb, which in turn projects to the hypothalamus.
- VNOs are not very prominent in humans and there is debate as to whether humans detect pheromones.
- In animals a lesion of the main olfactory projection leaves reproductive behaviors intact, however lesions of the VNO projection severely compromises sexual selection and dominance hierarchies.

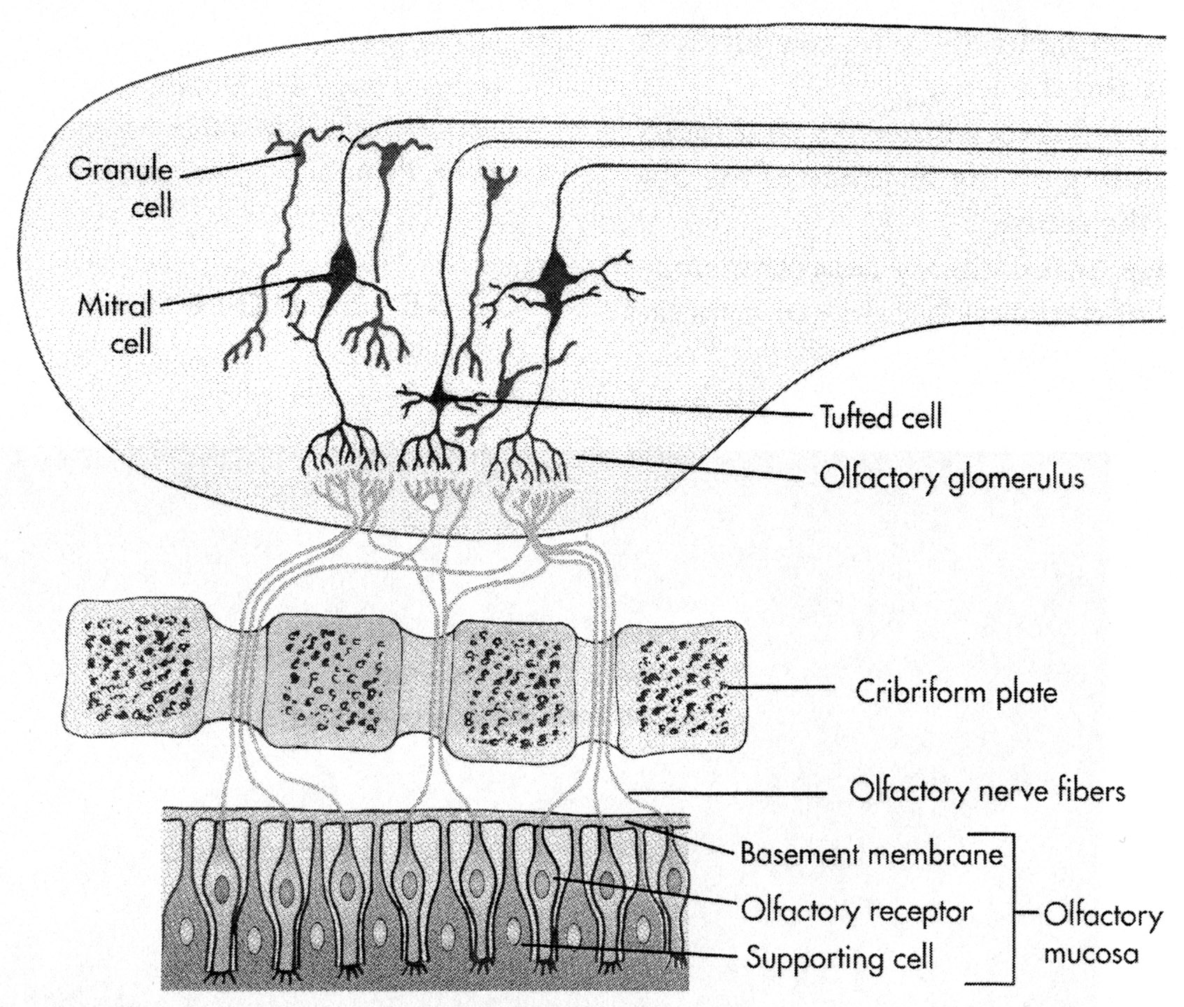
Olfactory epithelium

- Olfactory mucosa
  - Mucus!
  - High in nasal cavity
  - Site of transduction
  - Contains olfactory receptor neurons (ORN)

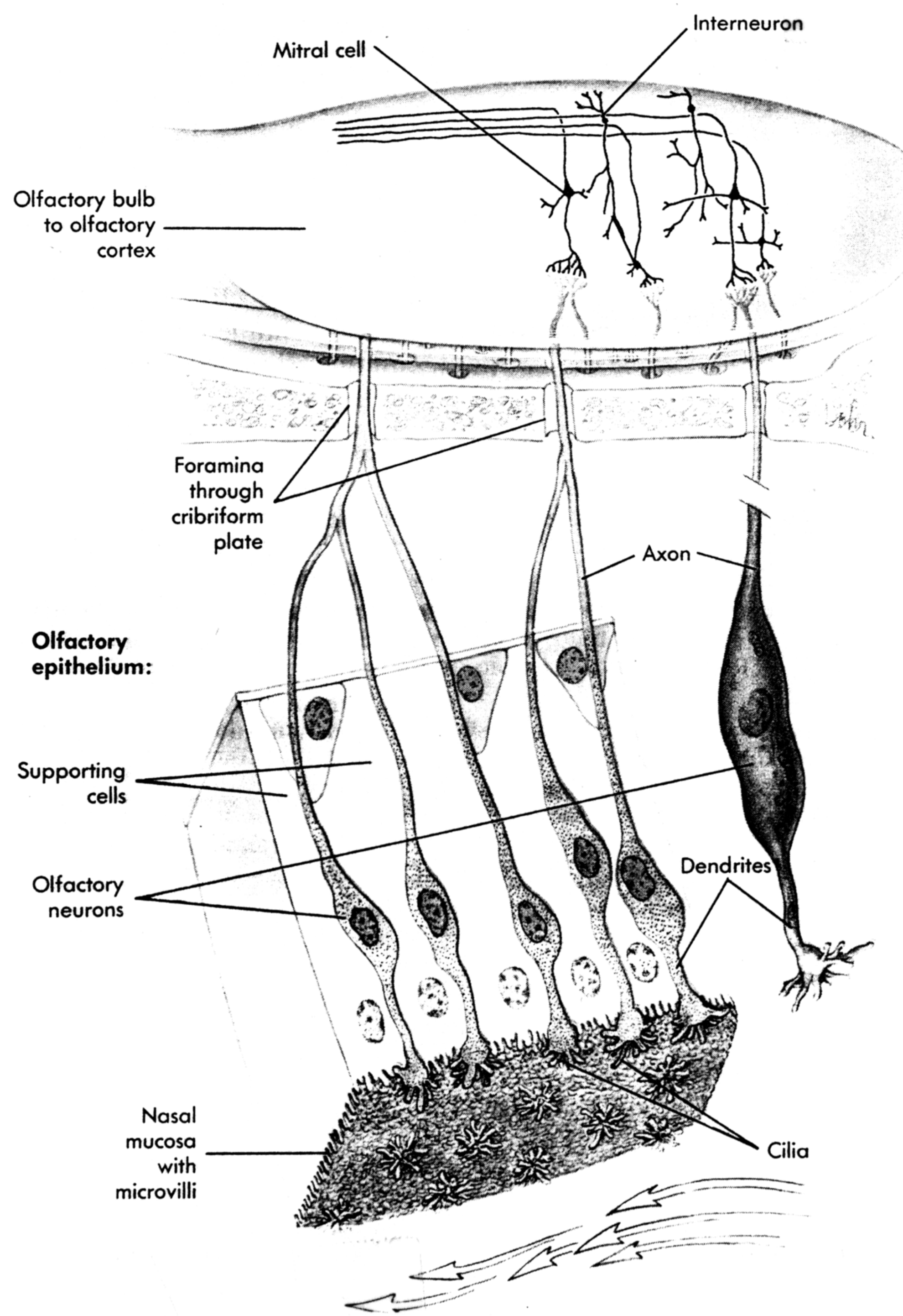


Smell

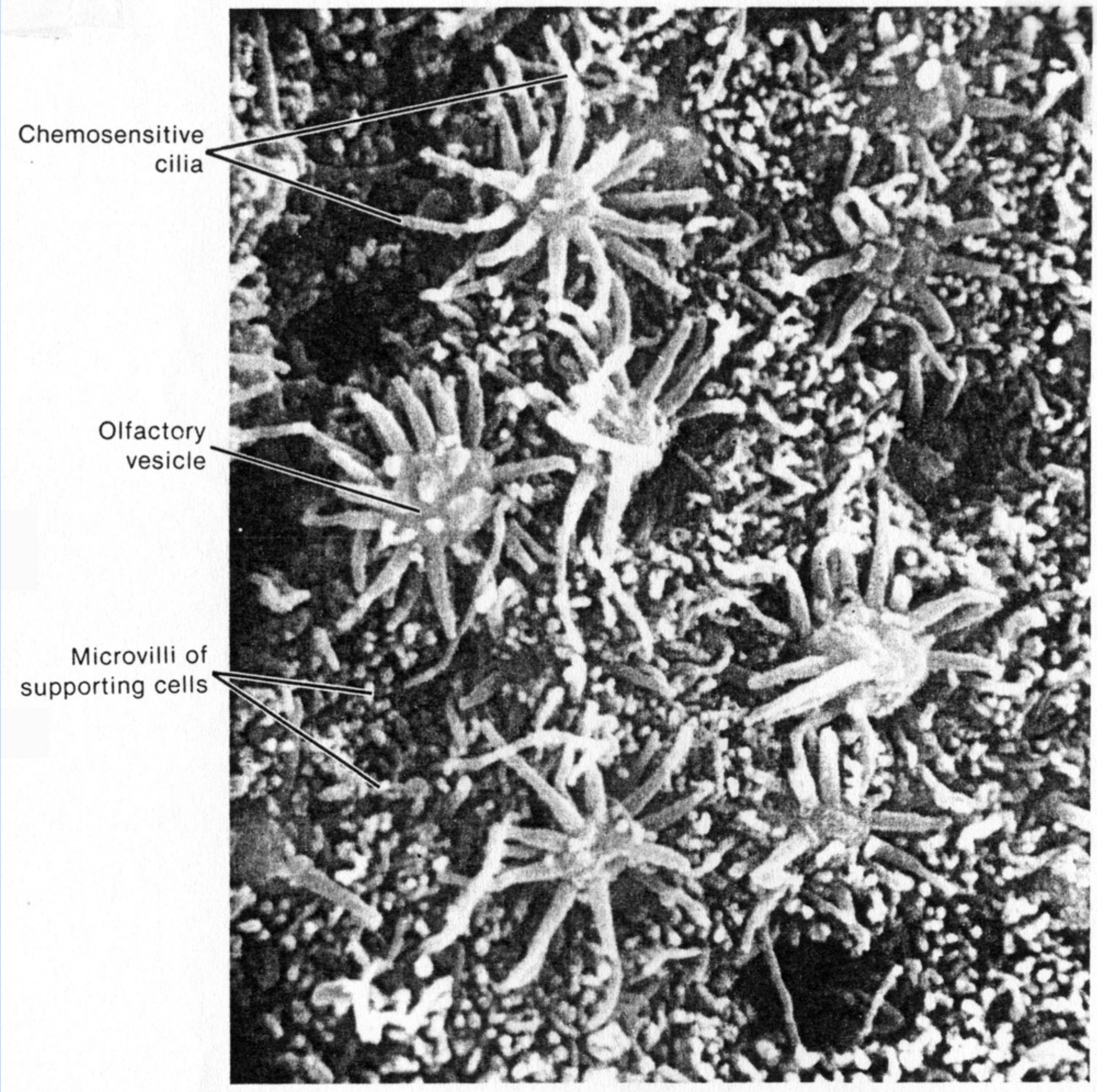
- Receptor location:
  - Roof of nasal cavity
  - Non-motile cilia, vascular
- Receptor cells:
  - Bipolar neurons
  - Odor molecule binding to non-motile cilia
  - Unmyelinated axons travel through holes in ethmoid bone (cribiform plate) to olfactory bulb
- Central relays:
  - Olfactory bulb
  - Temporal cortex
  - Amygdala, hippocampus



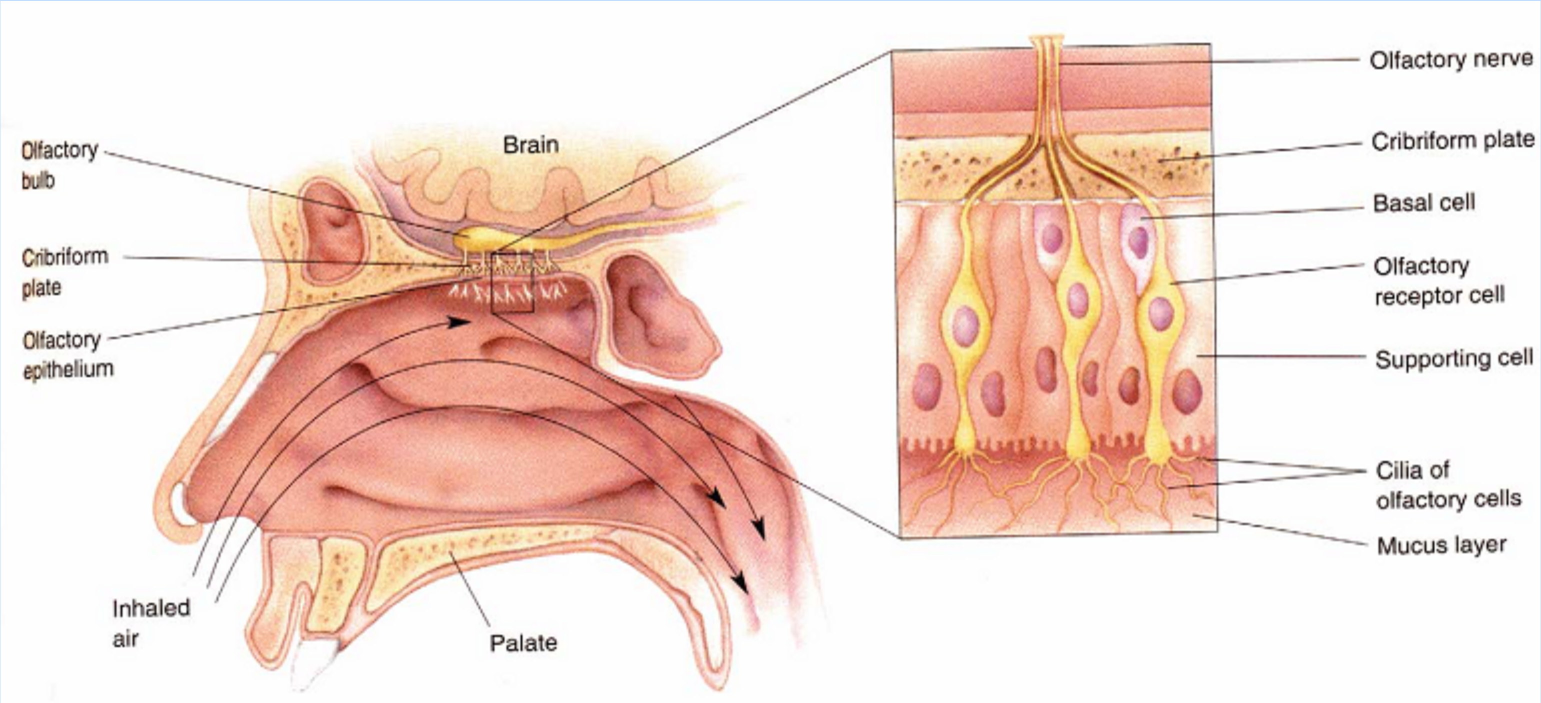
Olfactory mucosa



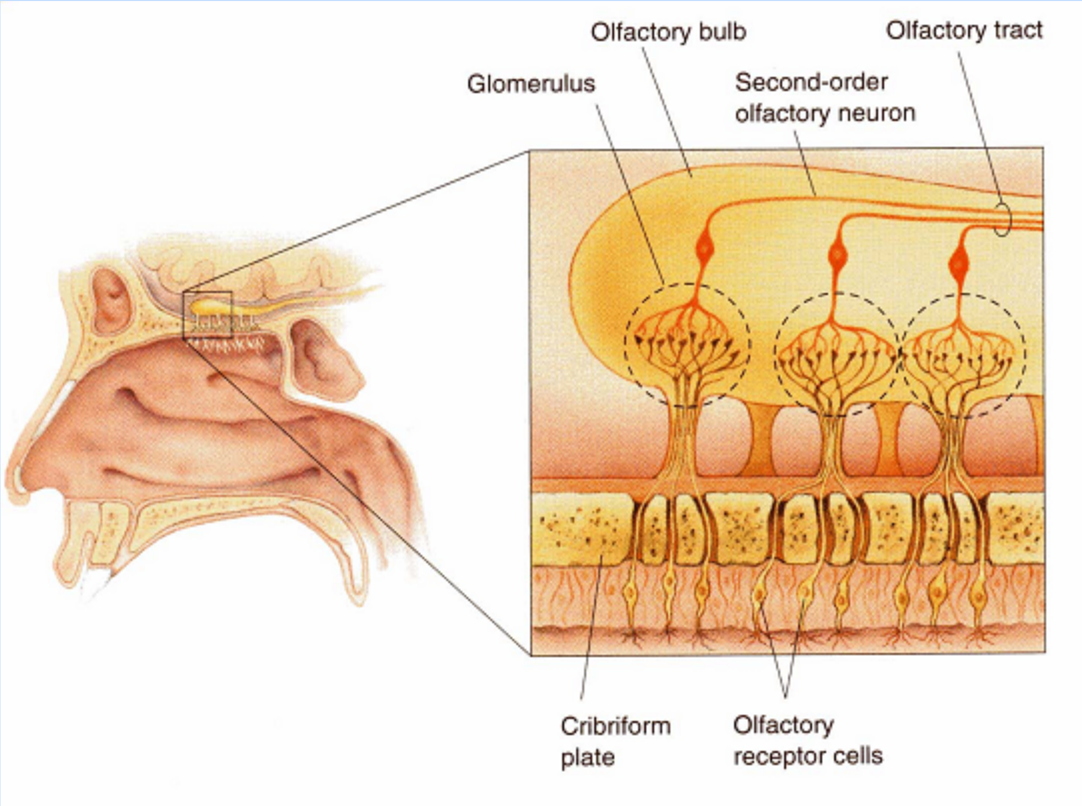
Olfactory cilia



Olfactory organs

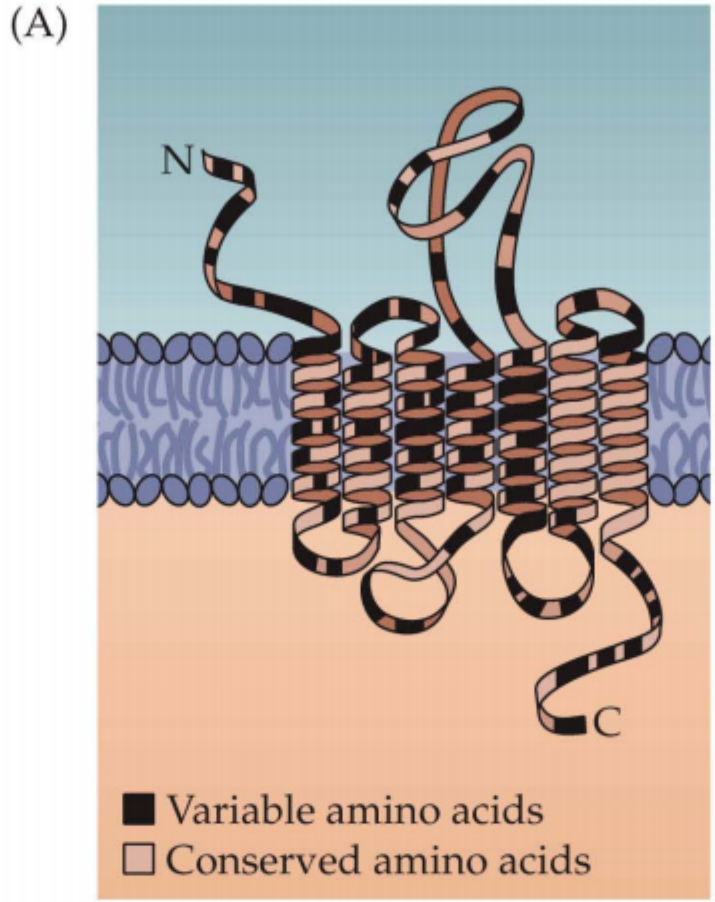


Second order neuron olfactory bulb

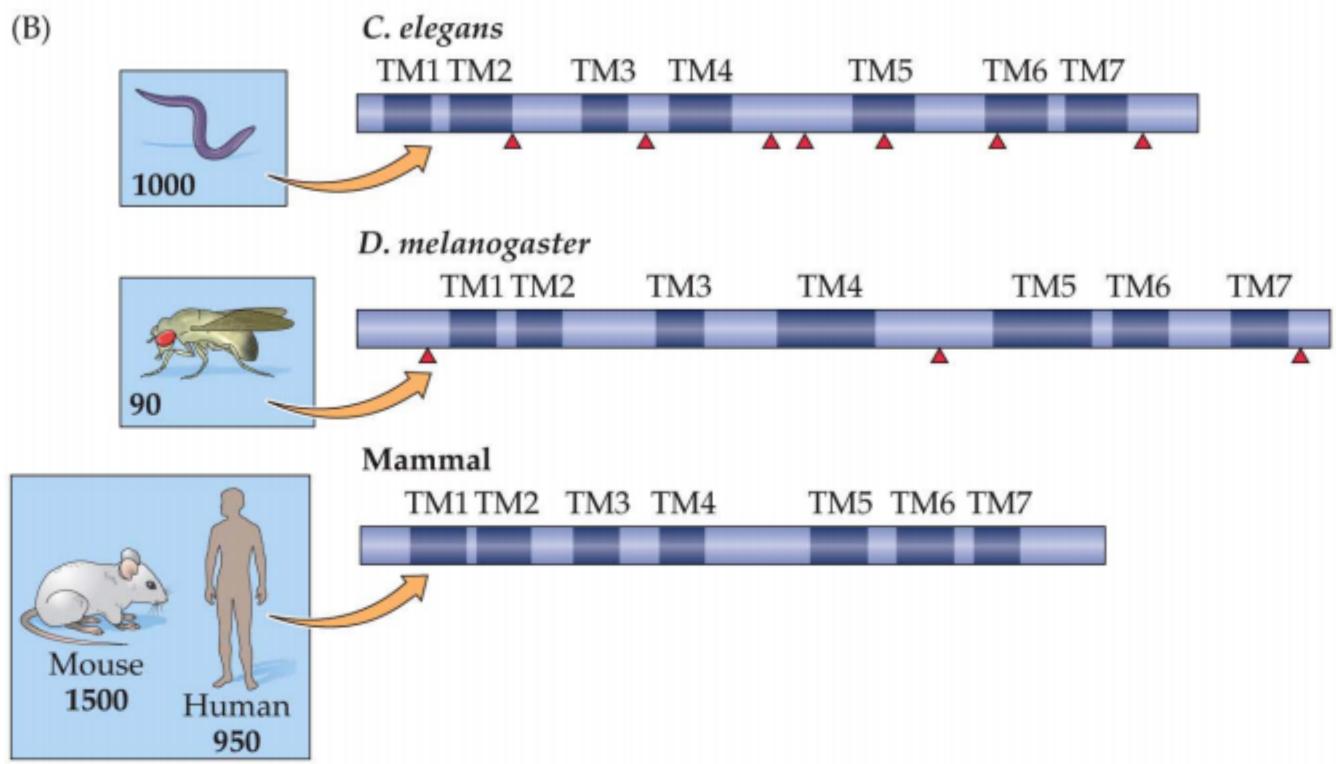


Olfactory receptors

- Discovered by Linda Buck and Richard Axel. Shared nobel prize in 2004.
- They found that olfactory receptors comprise a large GPCR gene family.
- Each olfactory neuron expresses a single olfactory receptor (even inactivates one copy of each allele).
- Each receptor can bind to multiple odorants.
- Each neuron that expresses a given receptor targets to the same glomeruli in the olfactory bulb.

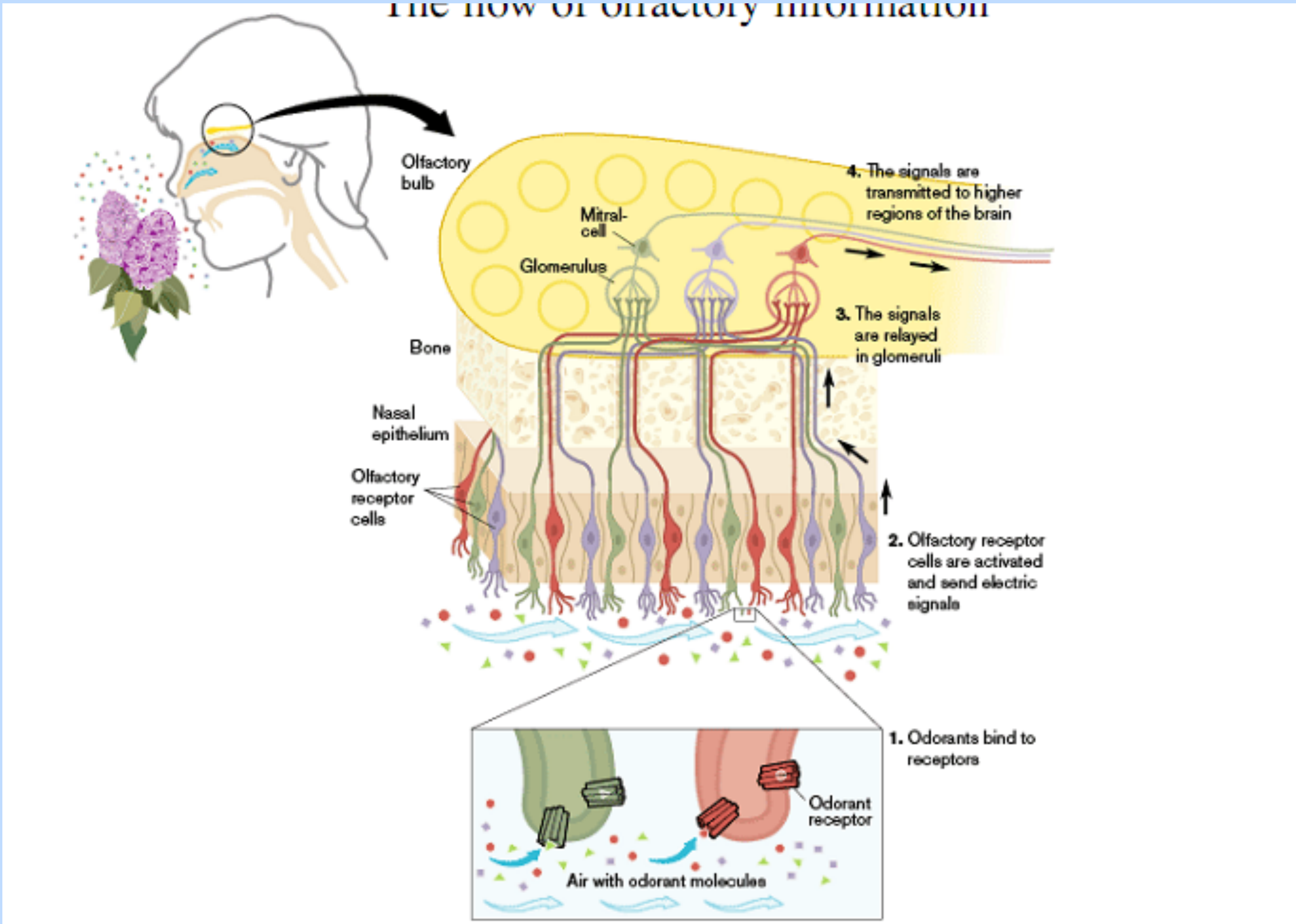


NEUROSCIENCE, Fourth Edition, **Figure 15.7 (Part 1)**



***NEUROSCIENCE*, *Fourth Edition*, Figure 15.7 (Part 2)**

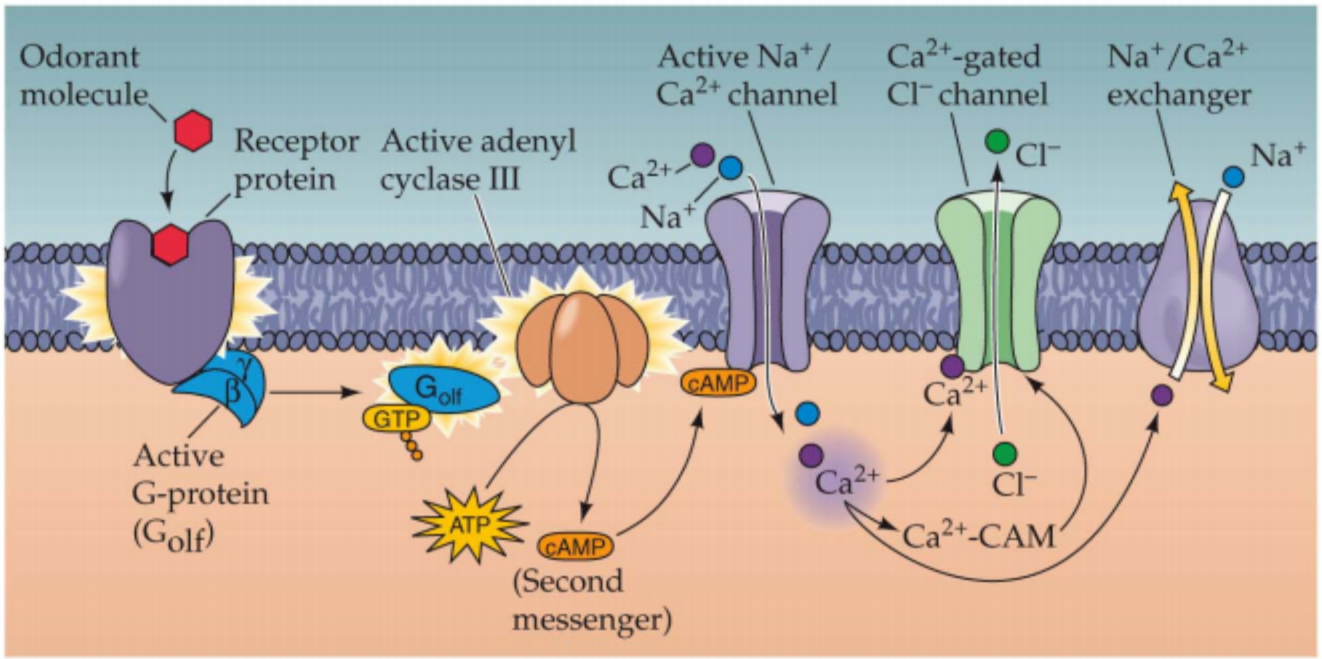
The flow of olfactory information



http://nobelprize.org/nobel_prizes/medicine/laureates/2004/press.html

Olfactory transduction

(A)

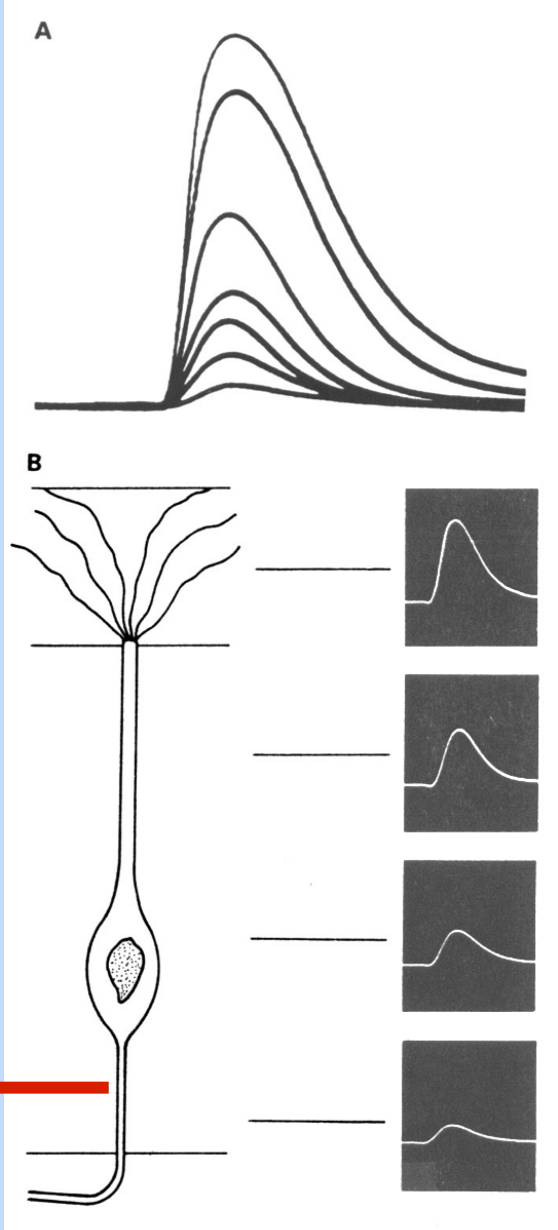


Adaptation comes from calmodulin binding of the Ca2+ and closing Cl- channels and also from being pumped out.

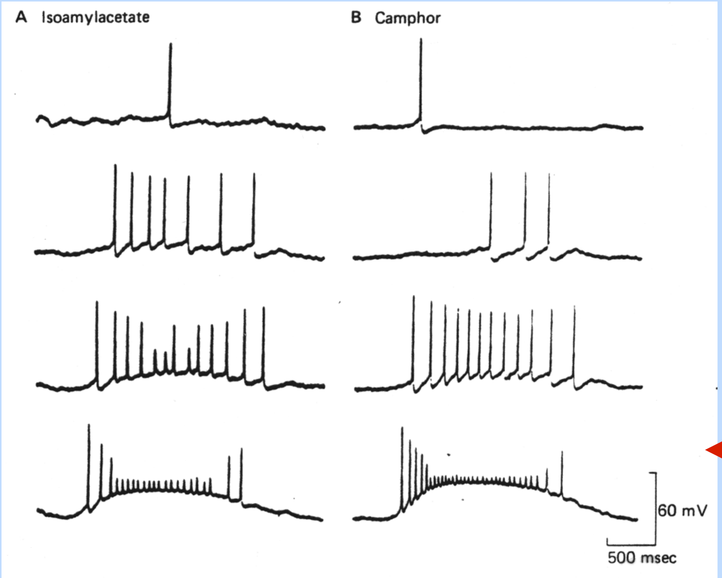
***NEUROSCIENCE*, *Fourth Edition*, Figure 15.9 (Part 1)**

Response to odor molecules

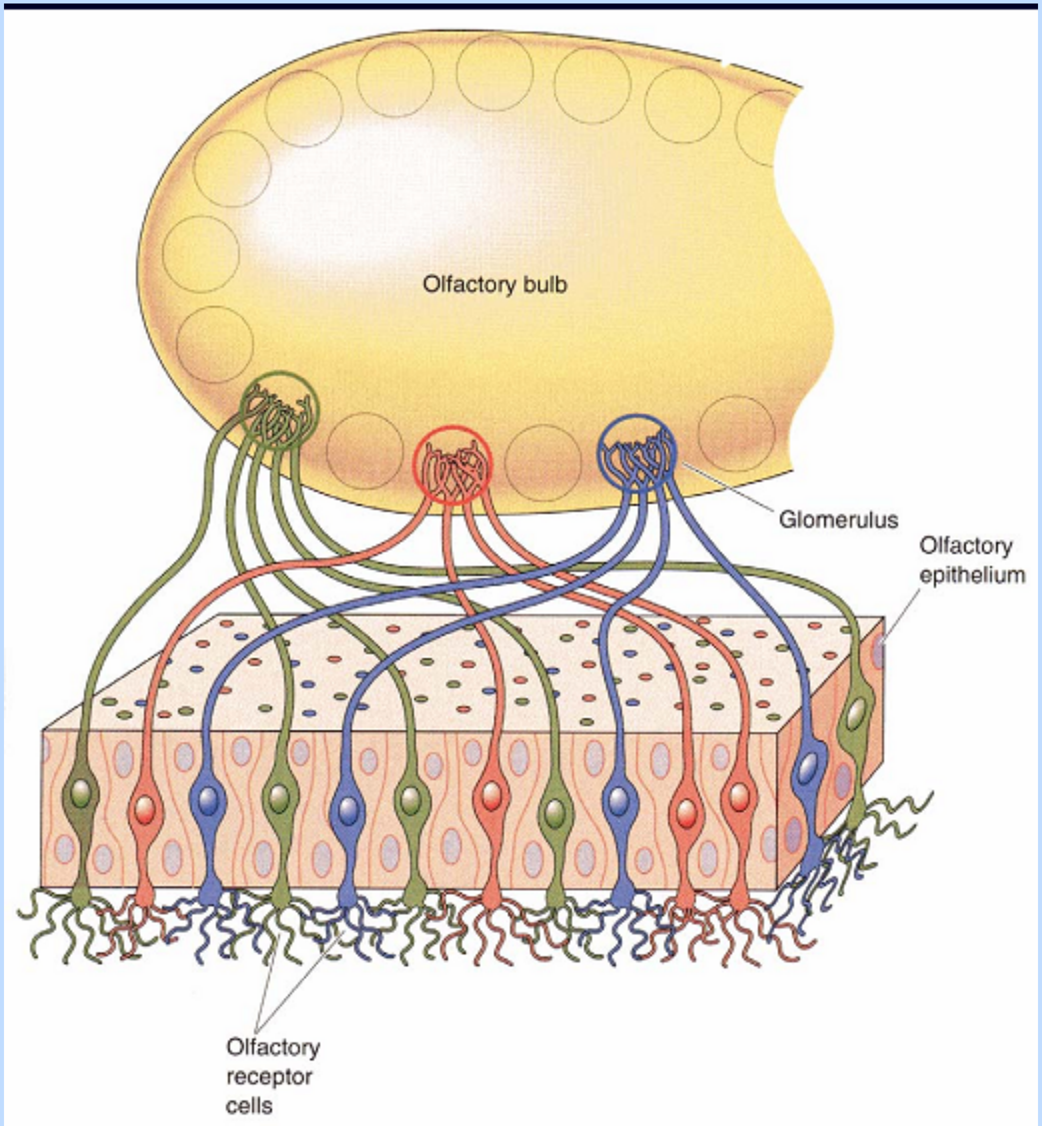
- Odor molecules bind to cilia
  - Receptor depolarizes proportional to odorant concentration
  - Depolarization spreads to trigger action potentials in olfactory axons
- Different cells have different degrees of response to multiple odor molecules



- Action potential frequency increases with the concentration of odorants



One receptor type per glomerulus



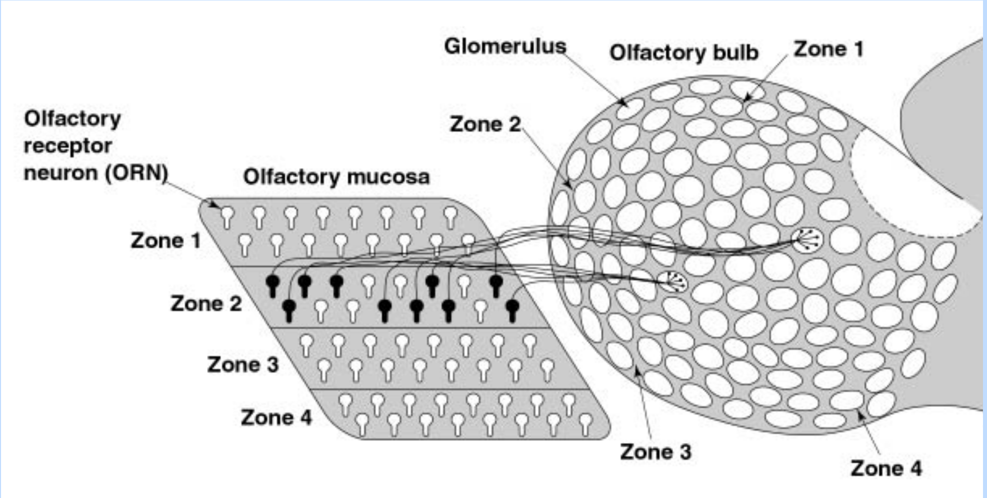
How many receptor types are there?

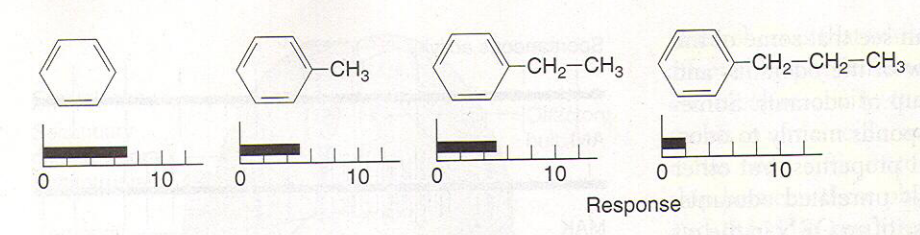
- 1000 different kinds of olfactory receptors (OR)
- 10 million OR neurons
  - 10,000 of each type of OR
  - Each OR neuron has only one type of receptor
  - 1000 neuronal chemical detectors

- Compare to visions 4 receptor types (3 cones, 1 rod)

Mapping onto the bulb

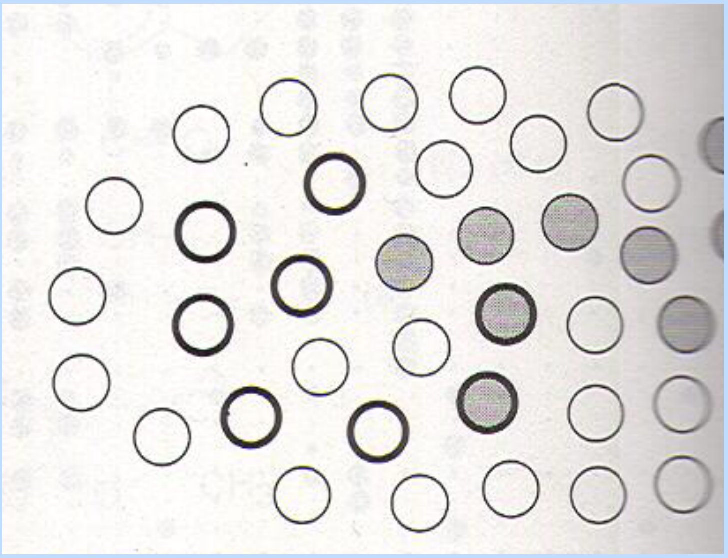
- Similar ORN axons go to similar portions of the bulb
  - Glomeruli (1000-2000)
  - Inputs mainly from 1 ORN
  - Thus, each glomerulus responds to similar compounds
    - Like orientation columns in visual cortex
- Glomeruli coding
  - Similar structure, not smell
  - Odotope maps
    - Mapping of similar chemical features





Distributed coding of smell

- Olfactory code is a complex pattern
- Overlap across 1000 ORN types represents smell quality
- Number of receptors would suggest specificity coding
- Millions of colours can be perceived with 3 cones
- How many odors?



Smell

- Receptor location:
  - Roof of nasal cavity
  - Non-motile cilia, vascular
- Receptor cells:
  - Bipolar neurons
  - Odor molecule binding to non-motile cilia
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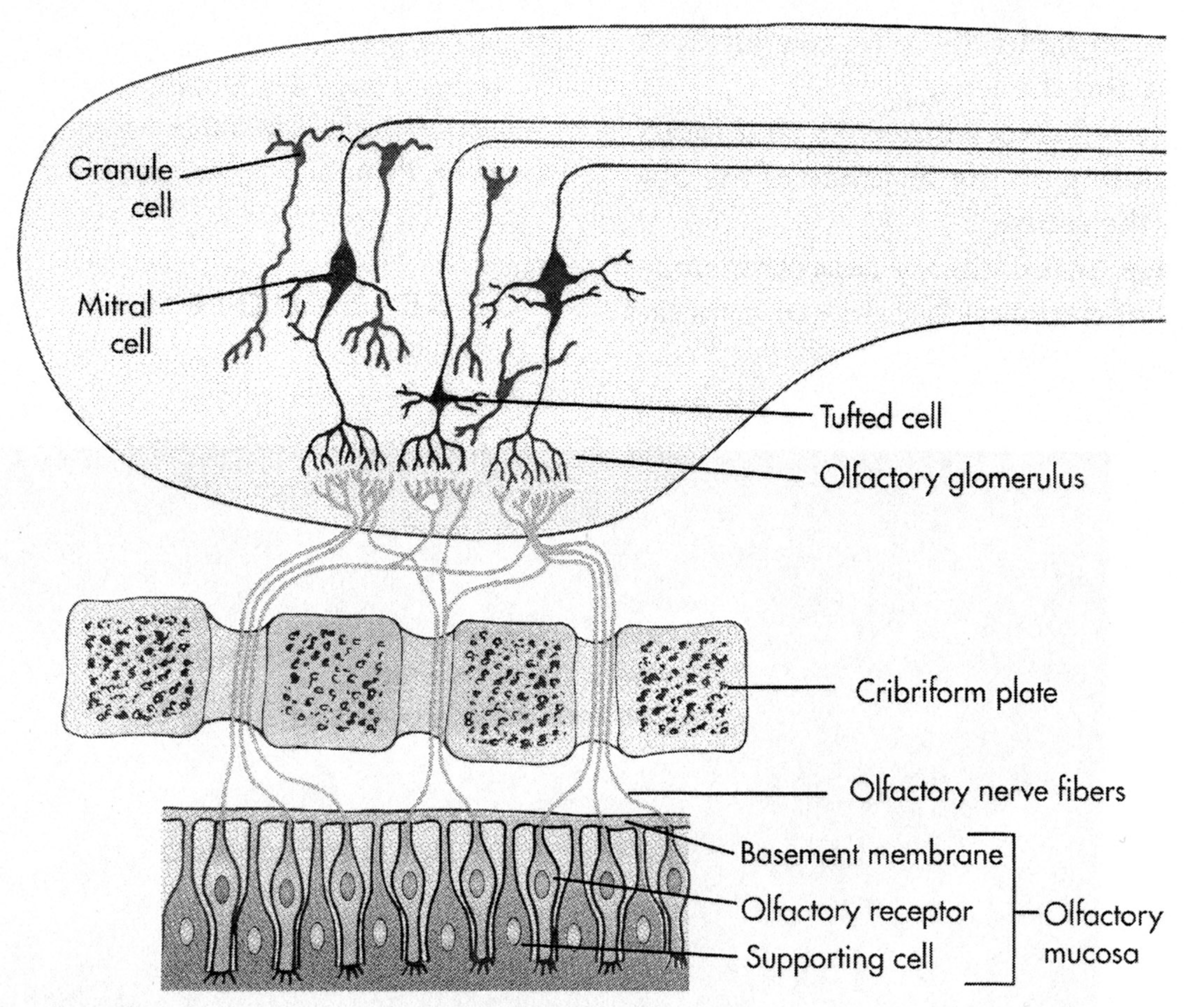


- We now go to the second chemical sense :

- Gustatory response or taste

Gustatory pathway

Connect to cranial nerves

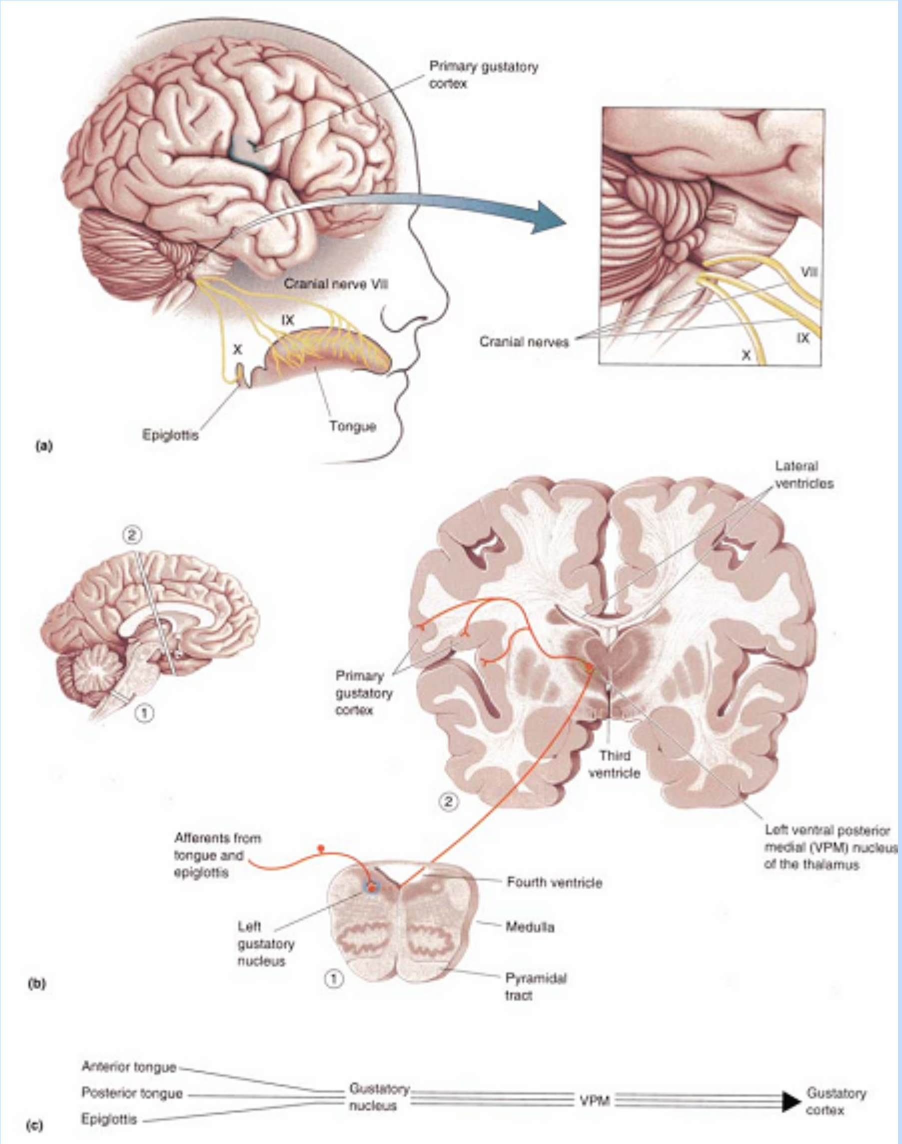
VII	Facial

IX	Glossopharyngeal

X	Vagus

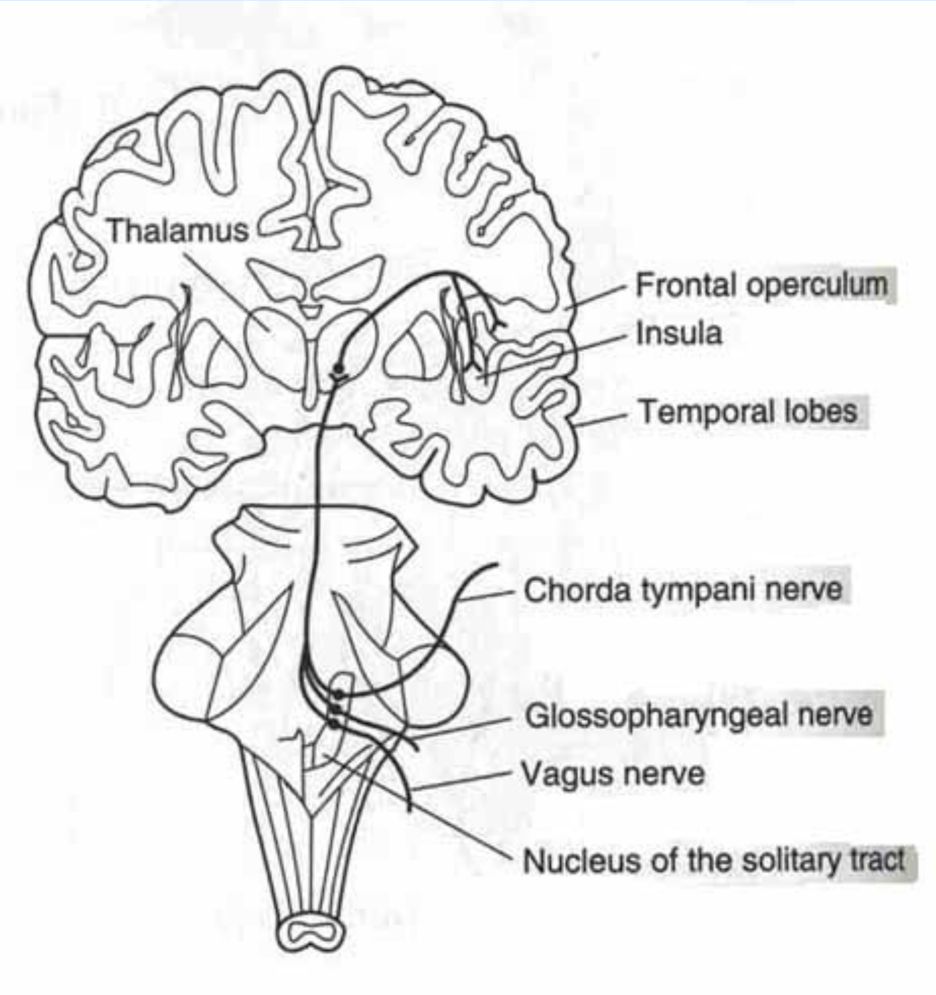
Single tract in Medulla
a.k.a. Gustatory nucleus

Project to
Ventral posterior medial
nucleus of Thalamus



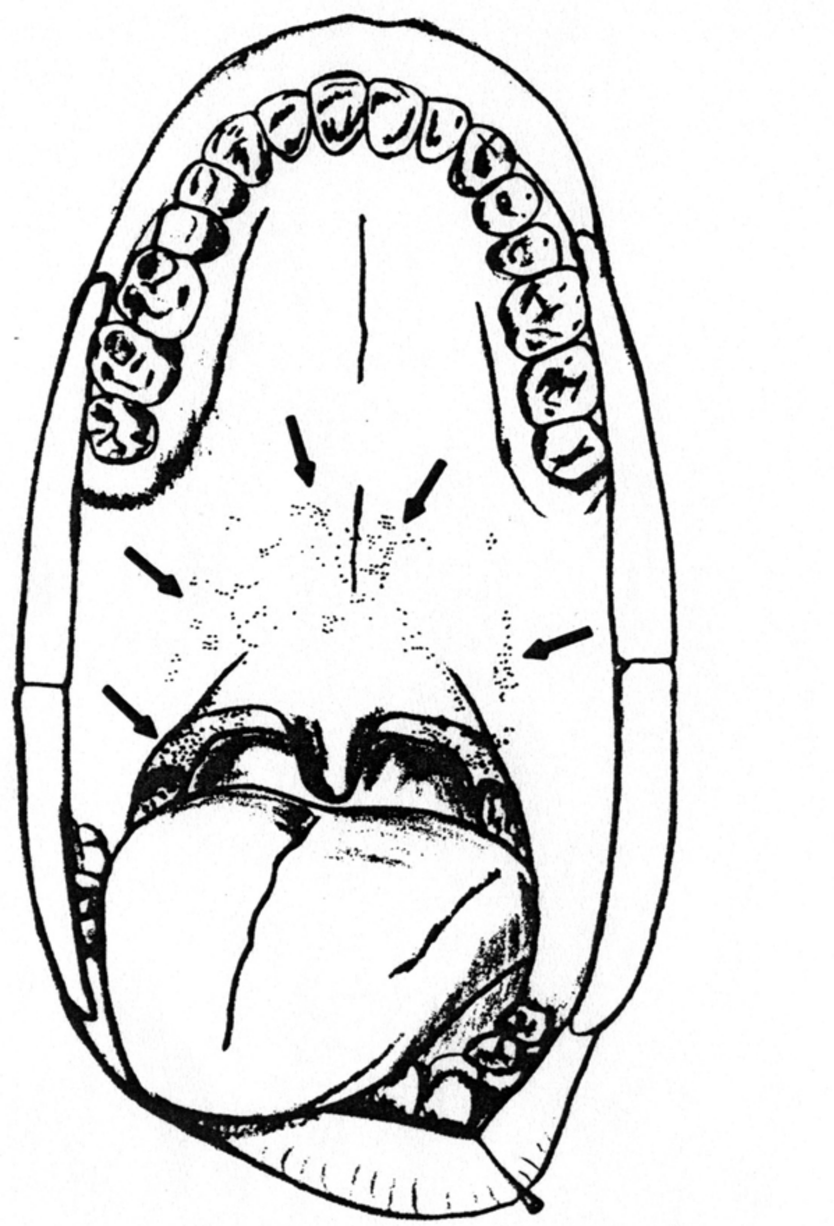
Taste pathway

- Electrical signals carried by 3 pathways
  - Chorda tympani VII
    - Front & side
  - Glosso-pharyngeal IX
    - Back
  - Vagus X
    - Mouth & larynx
- NST (brainstem)
- Gustatory thalamus
- Primary taste areas
  - Insular/opercular cortex
- Secondary taste areas
  - Orbitofrontal cortex



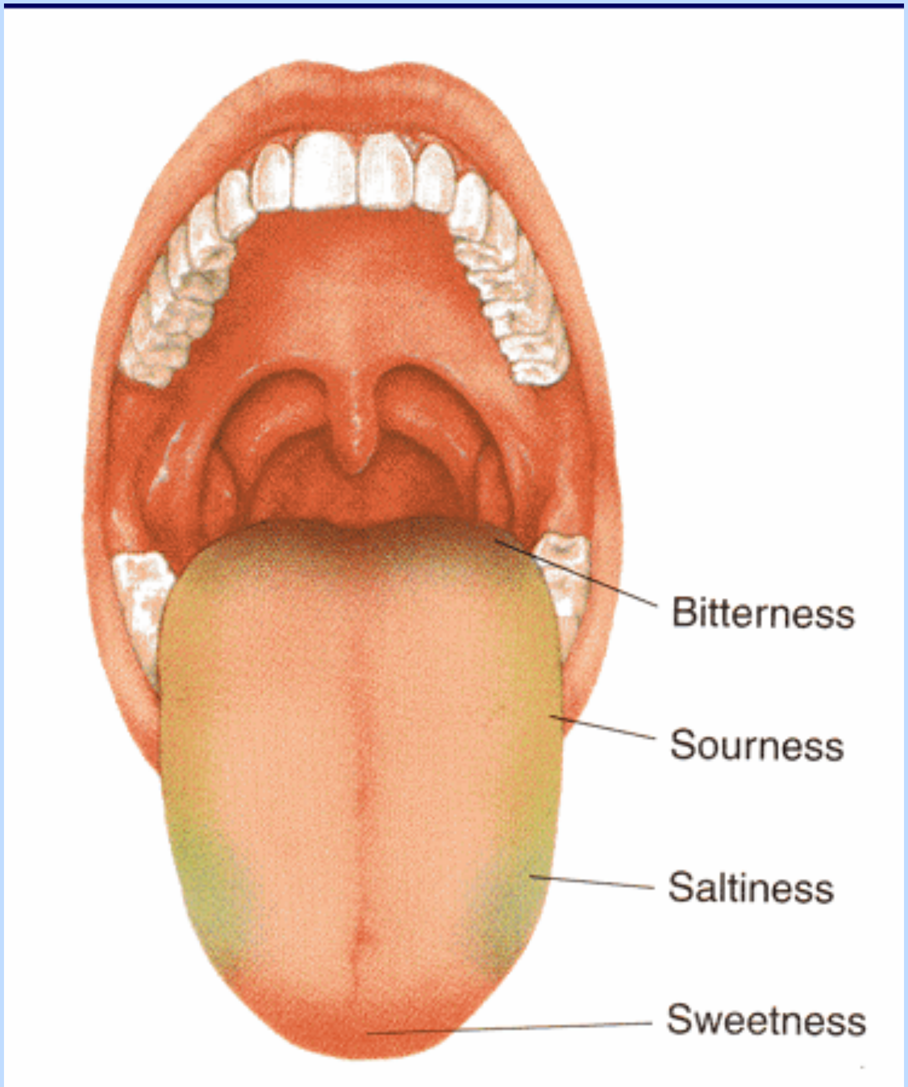
Taste buds on palette

- Taste buds are most dense on the tongue
- Taste buds can also be found on palate and gingiva
  - Often have high sensitivity to sour or bitter
  - Large dental appliances can mask these taste buds
  - May produce patient complaint that food tastes bland



Human soft palate showing locations of taste buds

Regions of Low Threshold

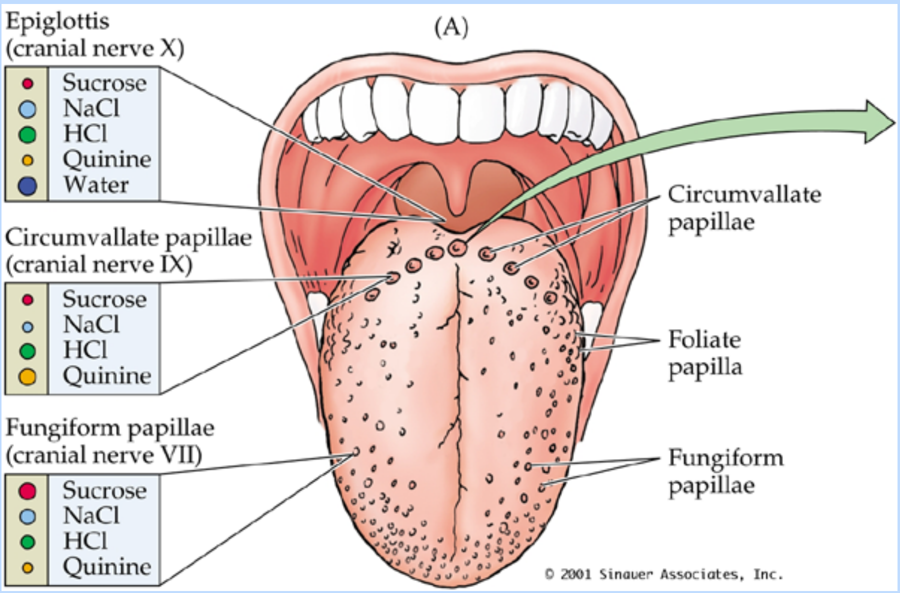


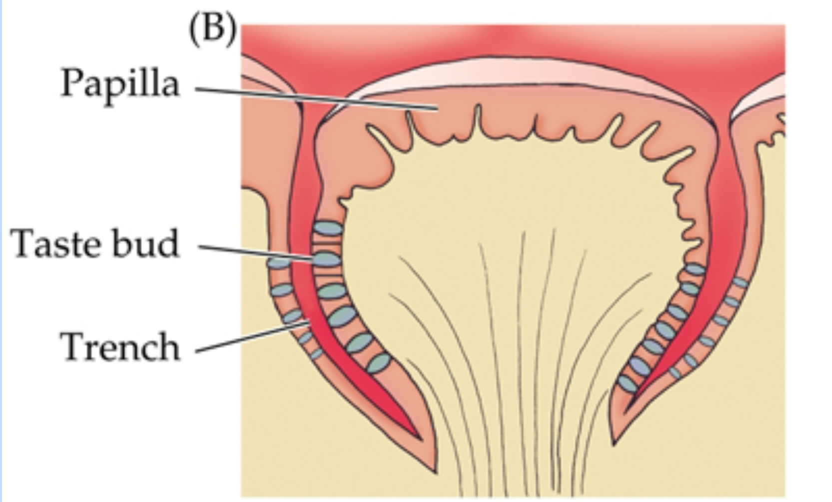
Five Taste Categories

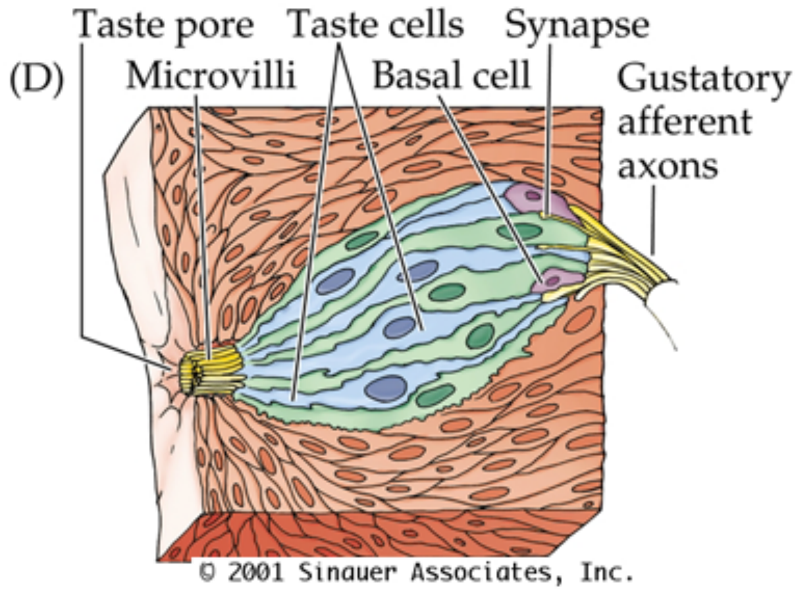
• Saltiness
• Sourness
•Sweetness
• Bitterness
Umami MSG ?

A multitude of tastes come from relative combinations of each of these five types?
Pungency
Astringency
Metallic
Fat

Taste & Viscerosensation

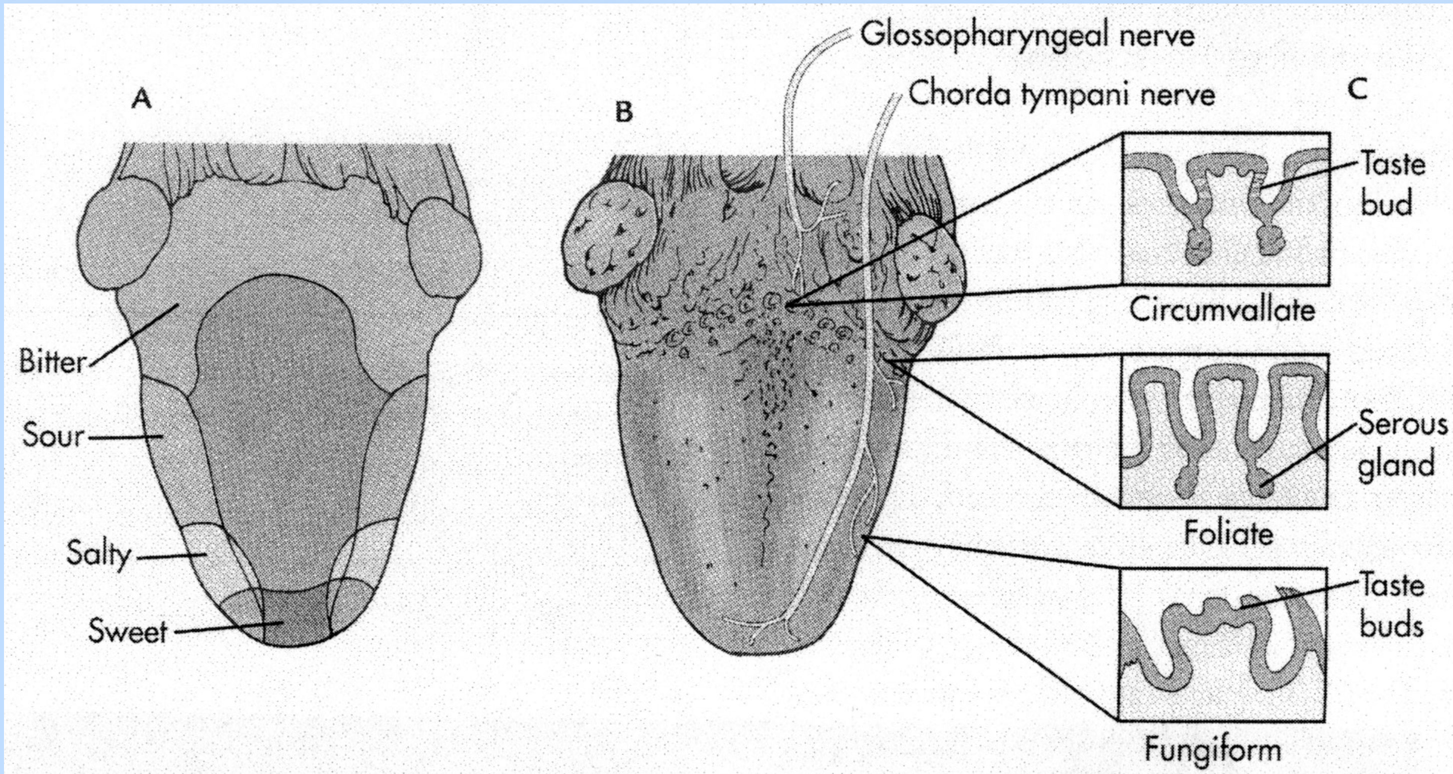






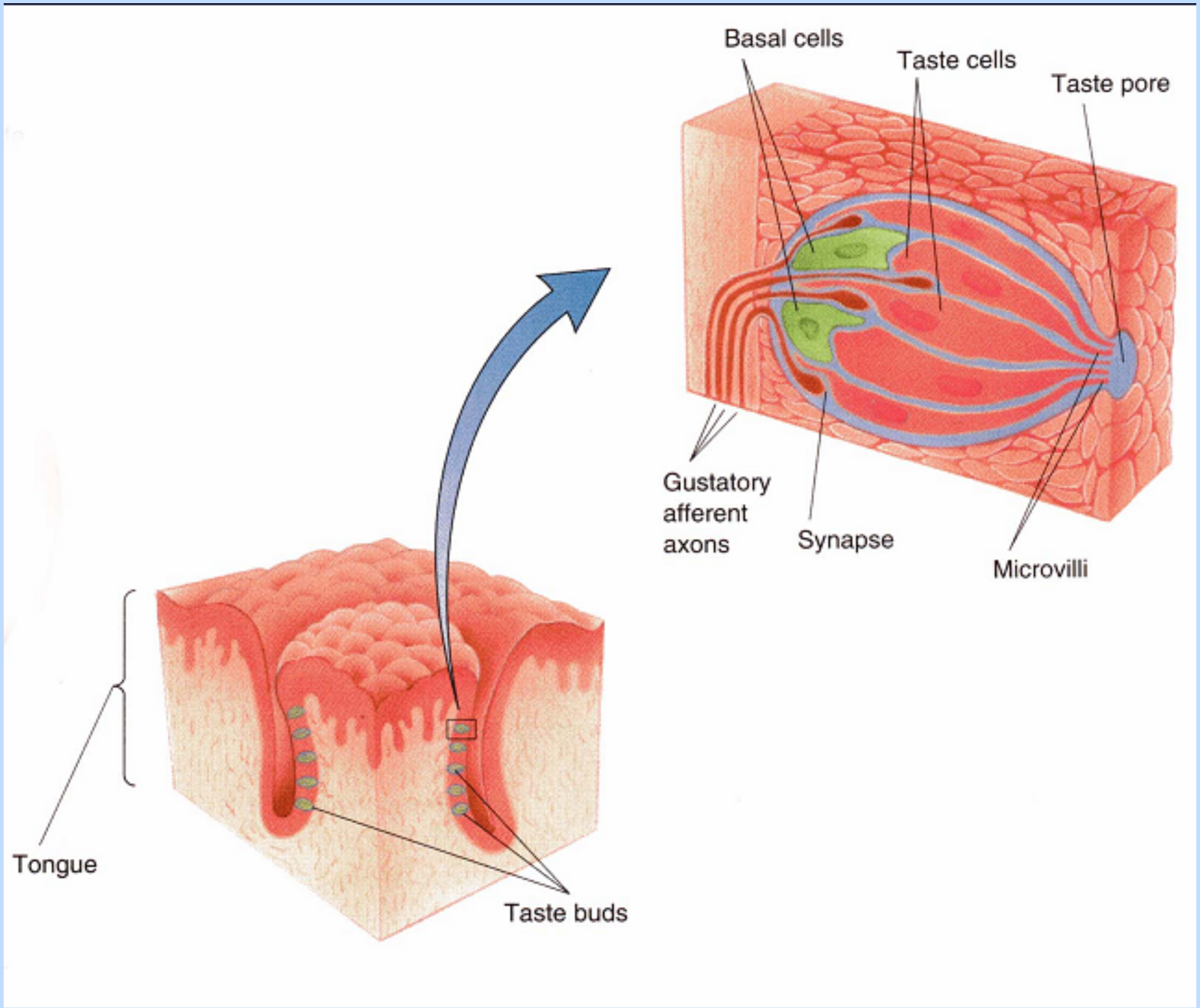
Taste

- Receptor cells are in taste buds
- Most dense on tongue
- Sensitivity varies on tongue for 4 modalities



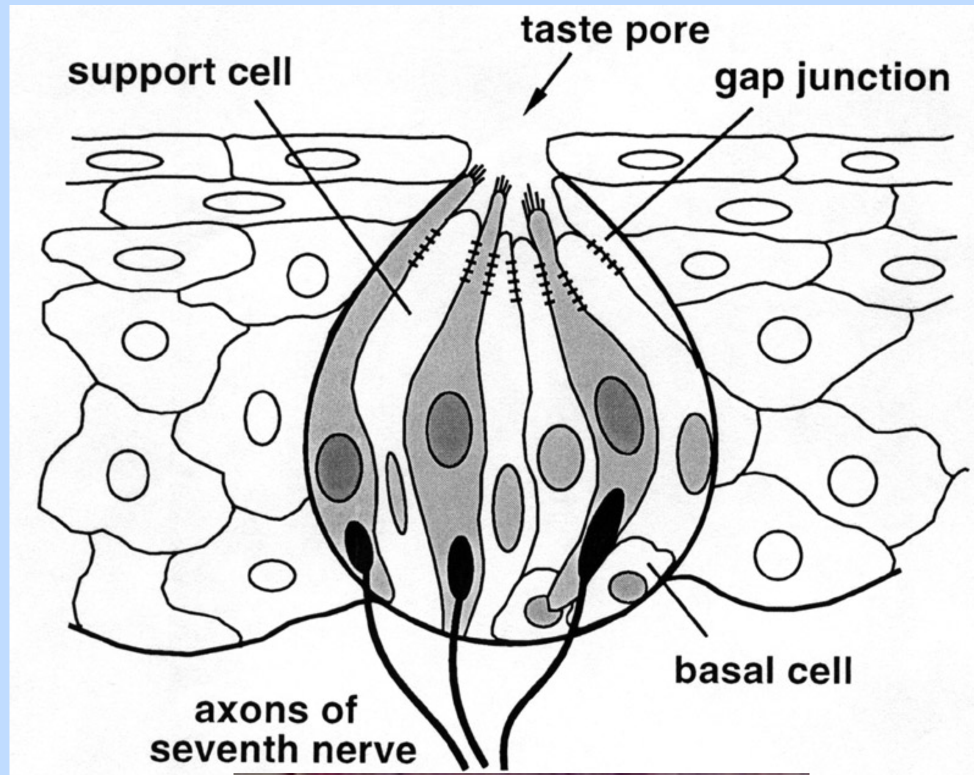
- Innervation:
- Anterior 2/3 of tongue & palate - facial nerve (CN VII)
- Posterior 1/3 of tongue - glossopharyngeal nerve (CN IX)
- Pharynx - Vagus nerve (CN X)

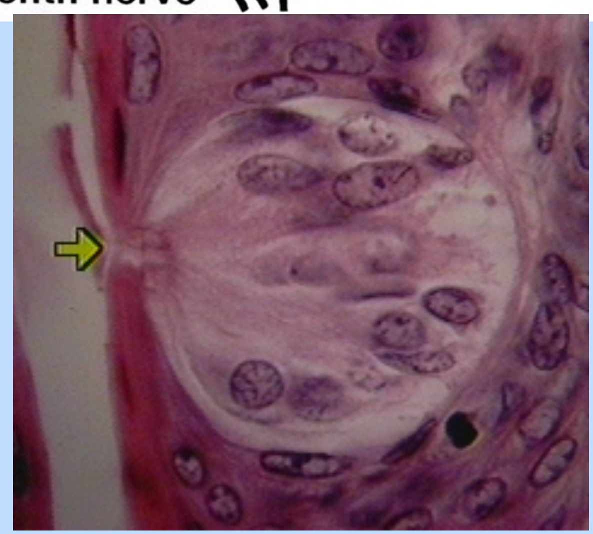
The Taste bud



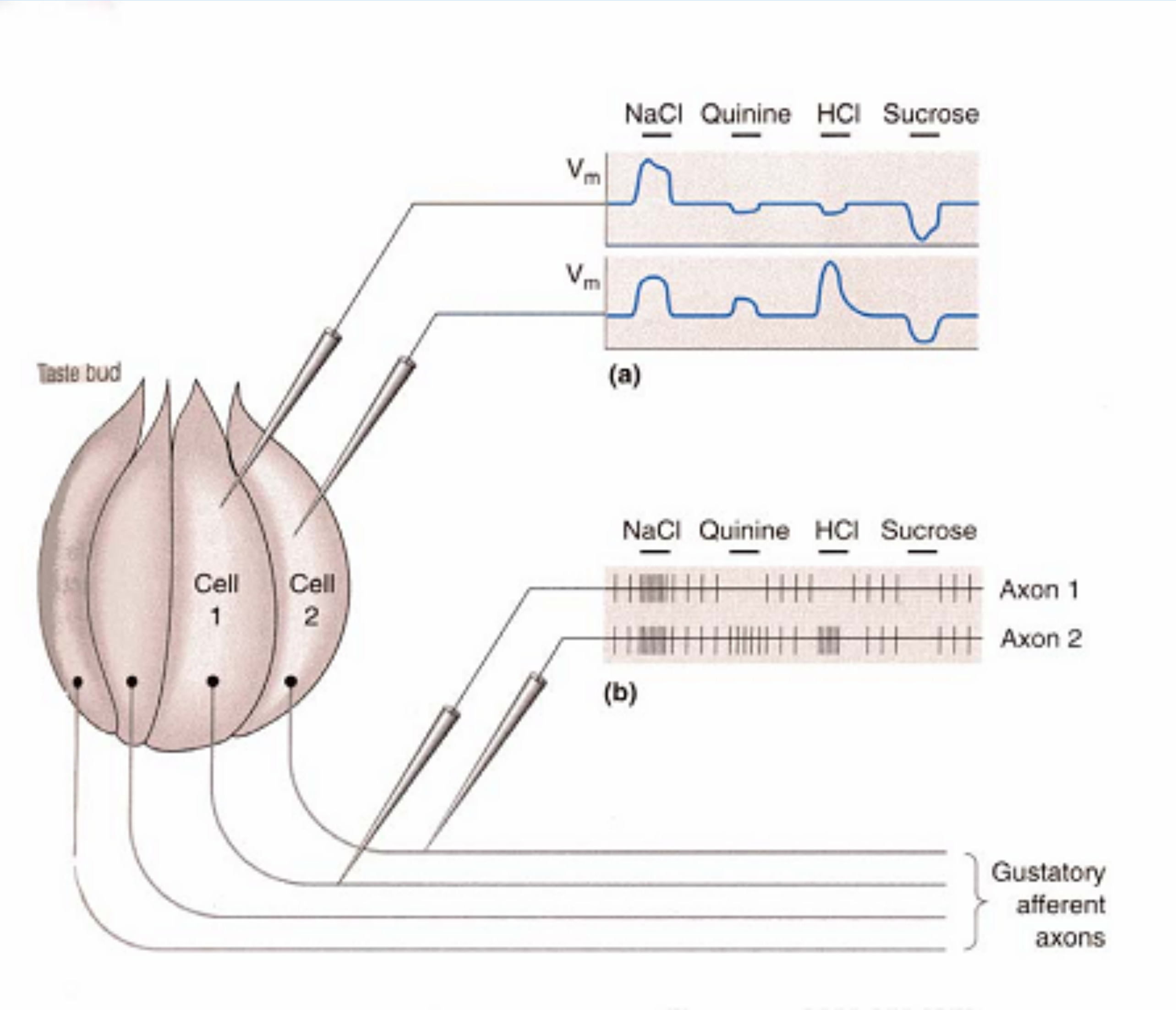
Taste bud structure

- Transducers:
  - Goblet shaped cluster of neuroepithelial cells
  - Chemical binding sites on apical microvilli
- Taste pore:
  - Opening in epithelium allowing disolved molecules to reach apical microvilli
- Tight junctions at apical ends of all surface cells
- Depolarization of taste cells releases transmitter to stimulate afferent axons





Generator Potentials in Taste Cells Lead to Action Potentials in Gustatory Nerve

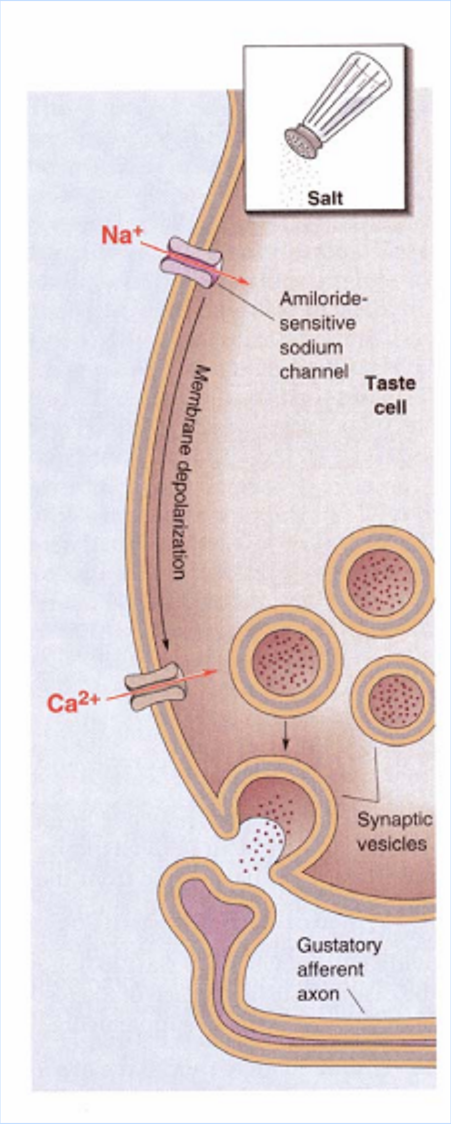


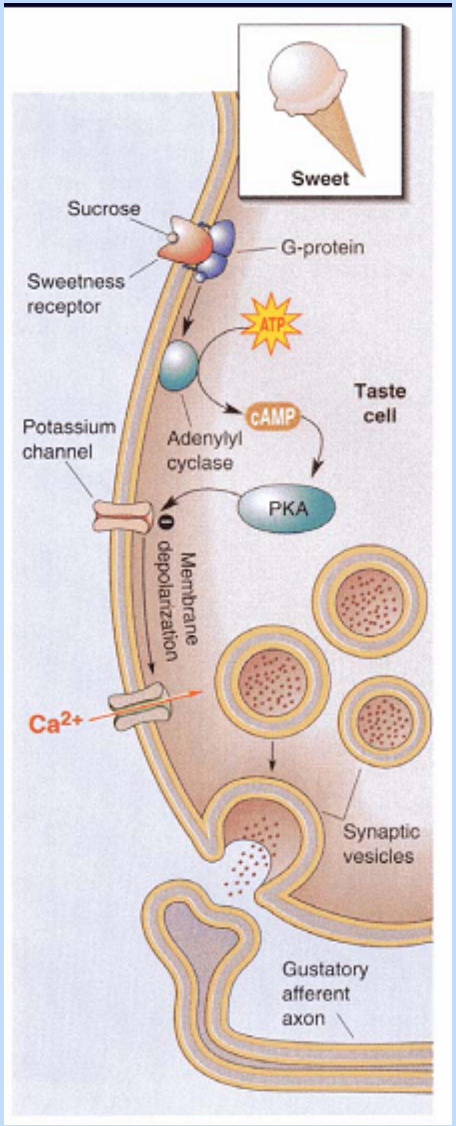
Mechanisms for Production of Generator Potentials

• Chemicals pass directly through
ion
channels
• Chemicals can bind and either
open or
block ion channels
• Chemicals can bind and activate
second
messenger systems

- Direct action by entering ion channel

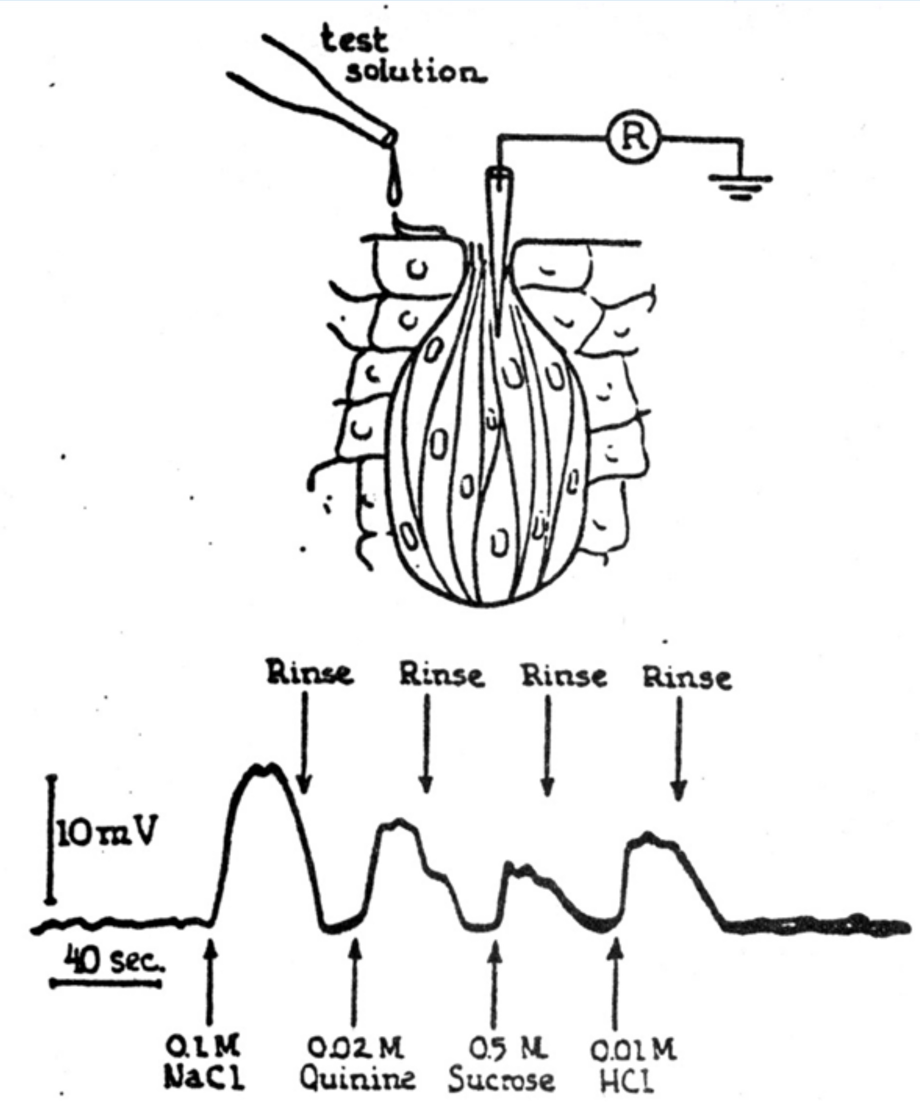
- Binding and activation of second messenger





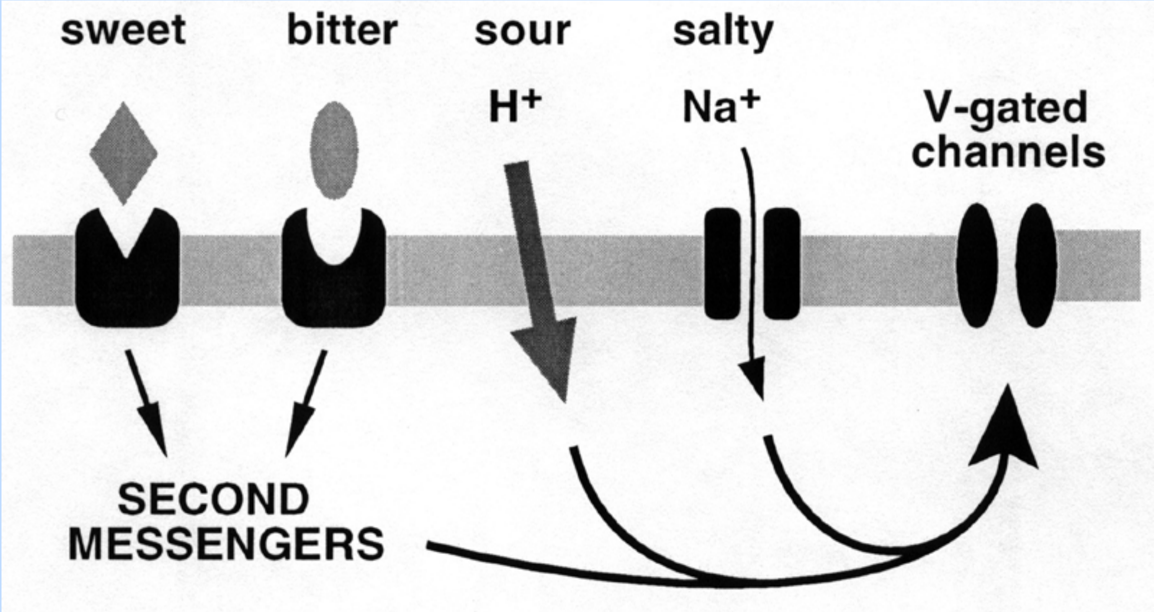
Response to taste chemicals

- Depolarization of taste bud cells is proportional to concentration of dissolved chemicals
- Most receptors respond to all four modalities
  - One modality produces largest response
  - Different cells have different combination of response
- Afferent axons also respond to multiple modalities
  - Firing freq increases with conc.
- Taste axons relay in solitary nucleus of medulla

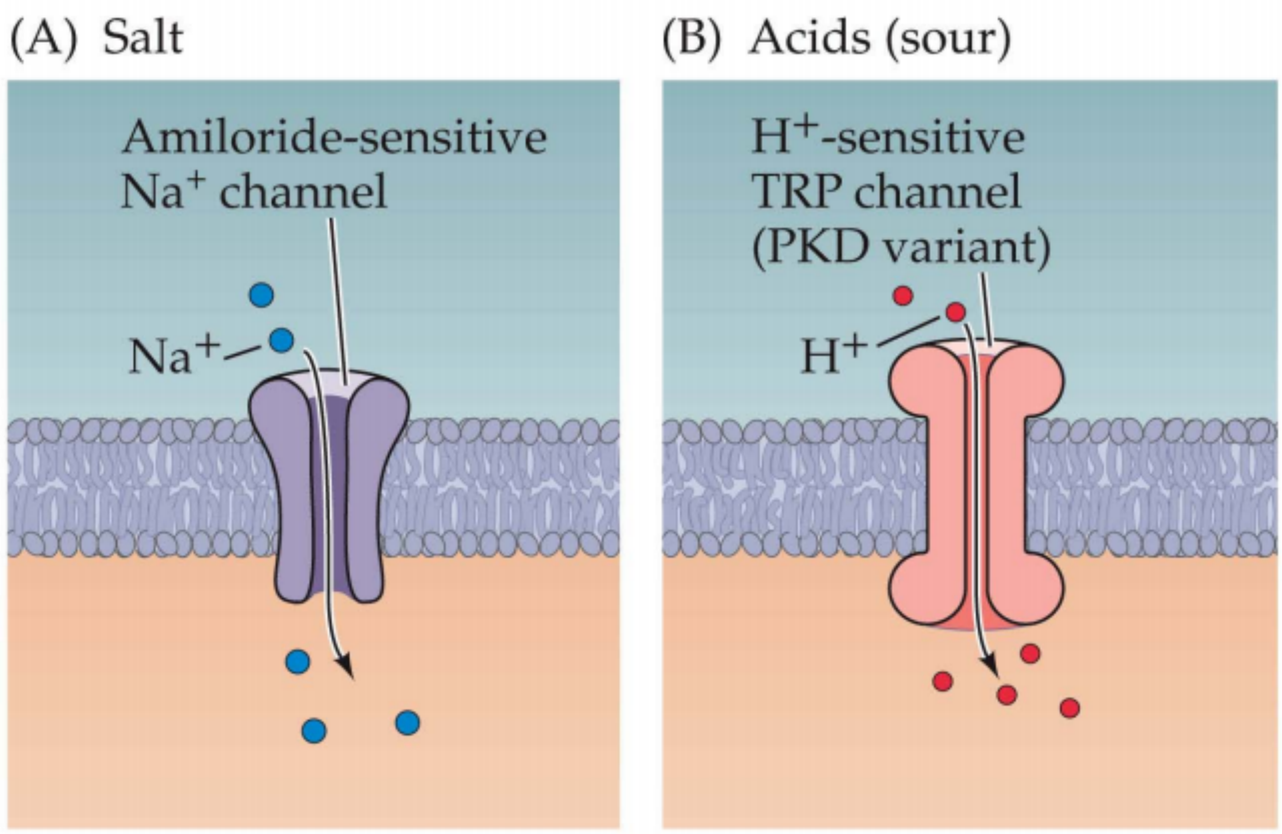


Transduction mechanisms for 4 taste modalities

- Four taste modalities:
  - Salty - molecules often neutral salts
  - Sour - molecules usually produce low pH
  - Sweet
  - bitter
- Each group of chemicals uses a characteristic mechanism of transduction

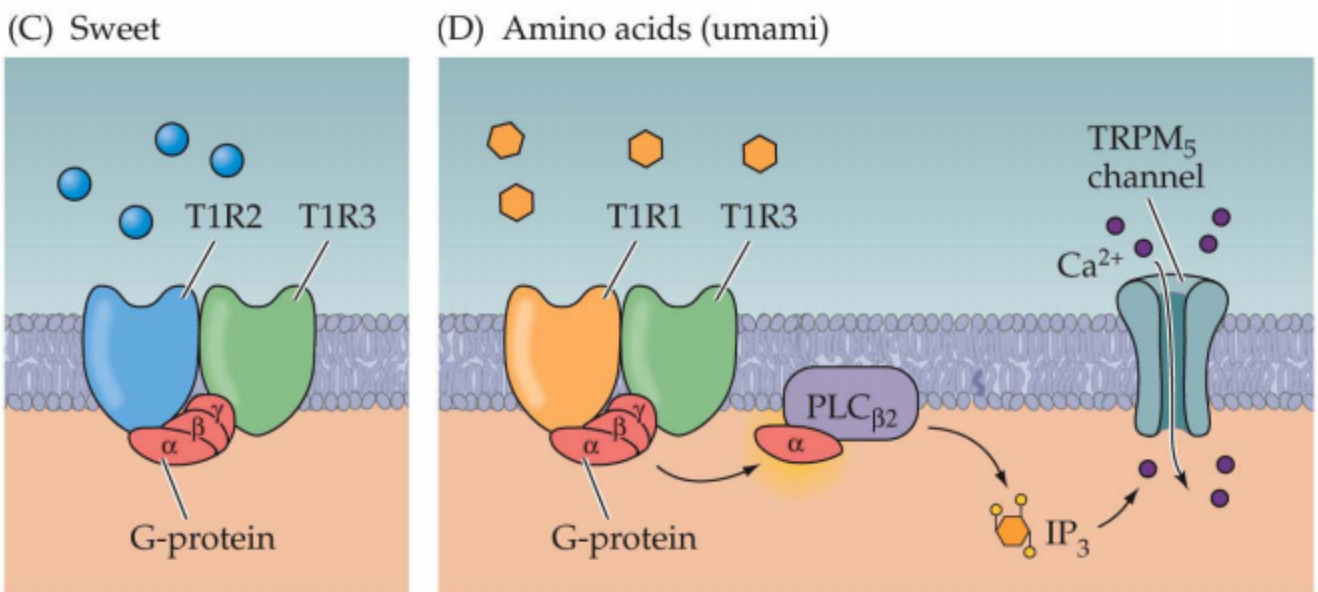


Taste Channels



NEUROSCIENCE, Fourth Edition, Figure 15.18 (Part 1)

Taste Channels



NEUROSCIENCE, Fourth Edition, Figure 15.18 (Part 2)

End