Sensation, Part 2
Gleitman *et al*. (2011), Chapter 4

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Psych 9A / Psy Beh 11A
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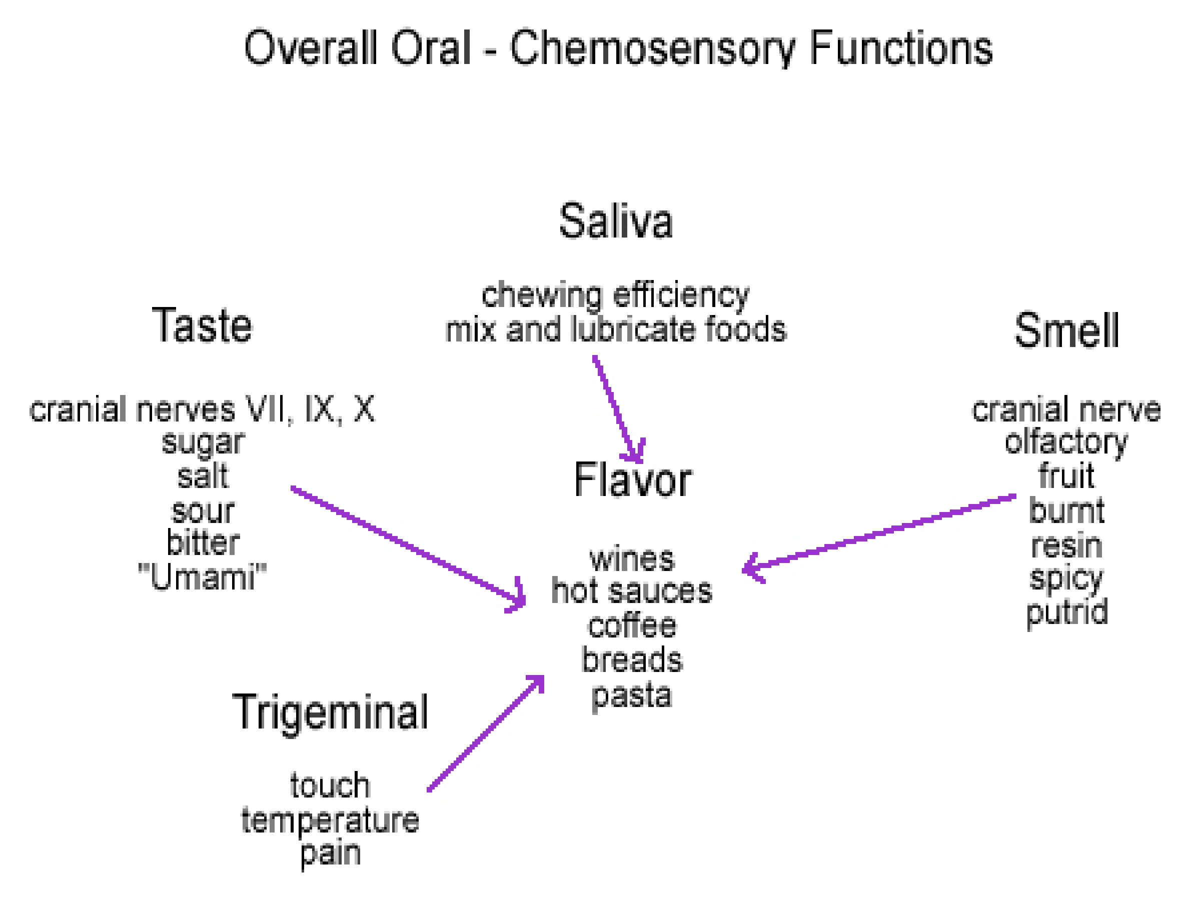
Smell

- The sense of *smell* is triggered by
  - receptors in *olfactory epithelium*
  - send signals to *glomeruli* in olfactory bulb and beyond to olfactory cortex
- Smell has many functions.
  - find food and avoid predators
  - providing a means of communicating
    - *pheromones*

Olfaction – the sense of smell

also an important contributor to “flavor”



M.O.Hutchins

Olfactory system overview

odorant molecules

↓

olfactory receptor neurons
(olfactory epithelium)

↓

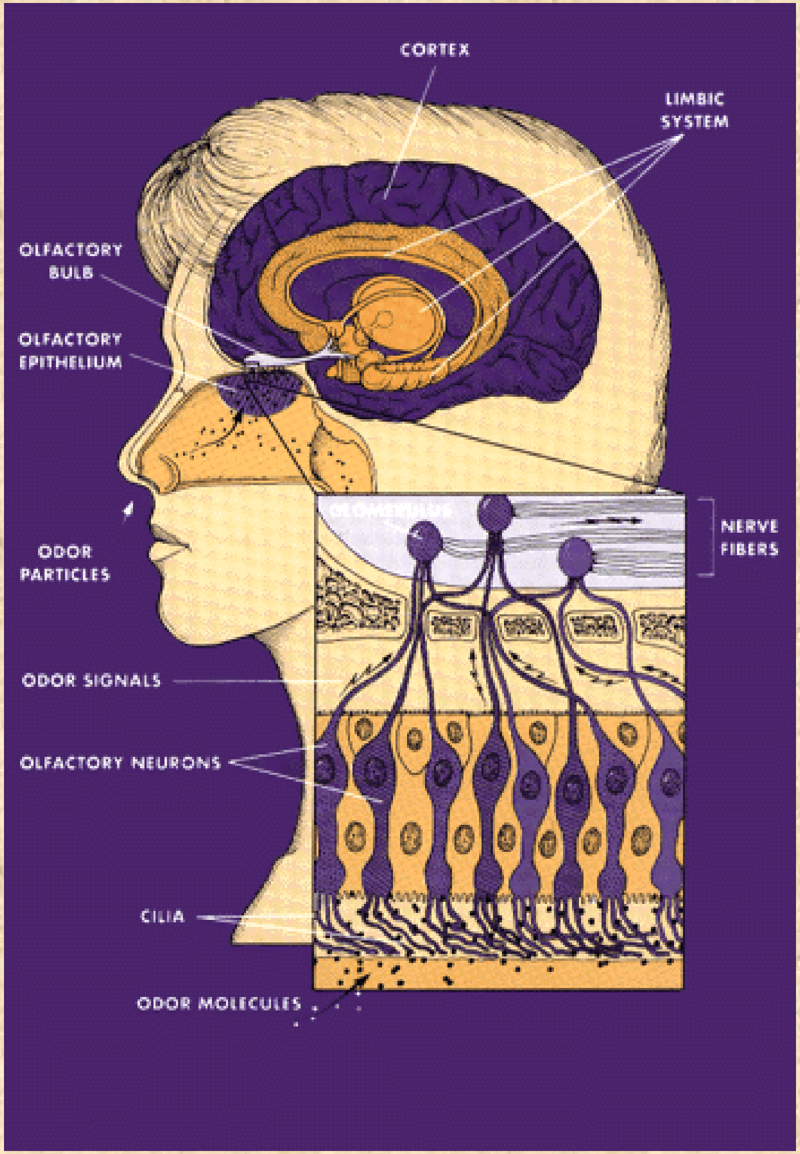
mitral cells
(olfactory bulb)

↓

mitral cell axons
project via the olfactory tract

↓

piriform cortex, thalamus, etc.



Peripheral olfactory system anatomy

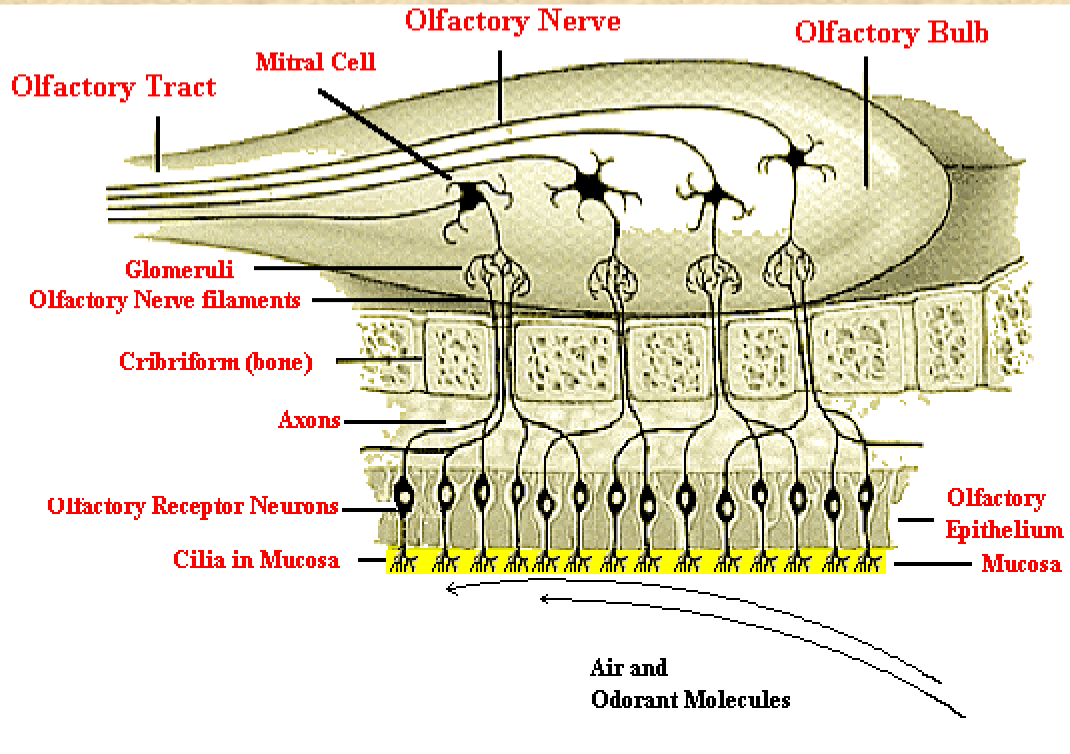
Humans have about 6 million olfactory receptor neurons

Each has a specific kind of membrane protein receptor for sensing odorant molecules

Each olfactory receptor neuron extends to the mucosa via its olfactory rod

Olfactory cilia protrude from the end of each rod

Humans: 6-8 cilia per rod
Dogs: 100-150 cilia per rod



Leffingwell

Olfactory stimuli: odorant molecules

Go to this site and click on the name of the odorant molecule for more information:

http://www.flavornet.org/flavornet.html

Transduction

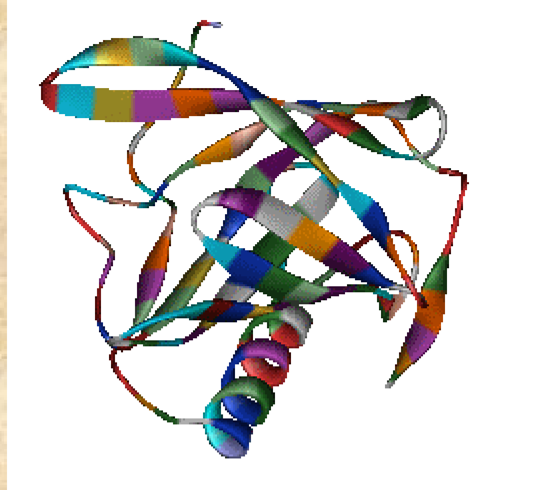
Odorant molecules are effectively "dissolved" in air – are *volatile*

They must contact receptor neuron cilia in the mucosa for transduction to occur

The mucosa is watery

Many odorant molecules are repelled by water (**hydrophobic**)

Olfactory binding proteins bind to odorant molecules and let them dissolve in the watery mucous



Leffingwell

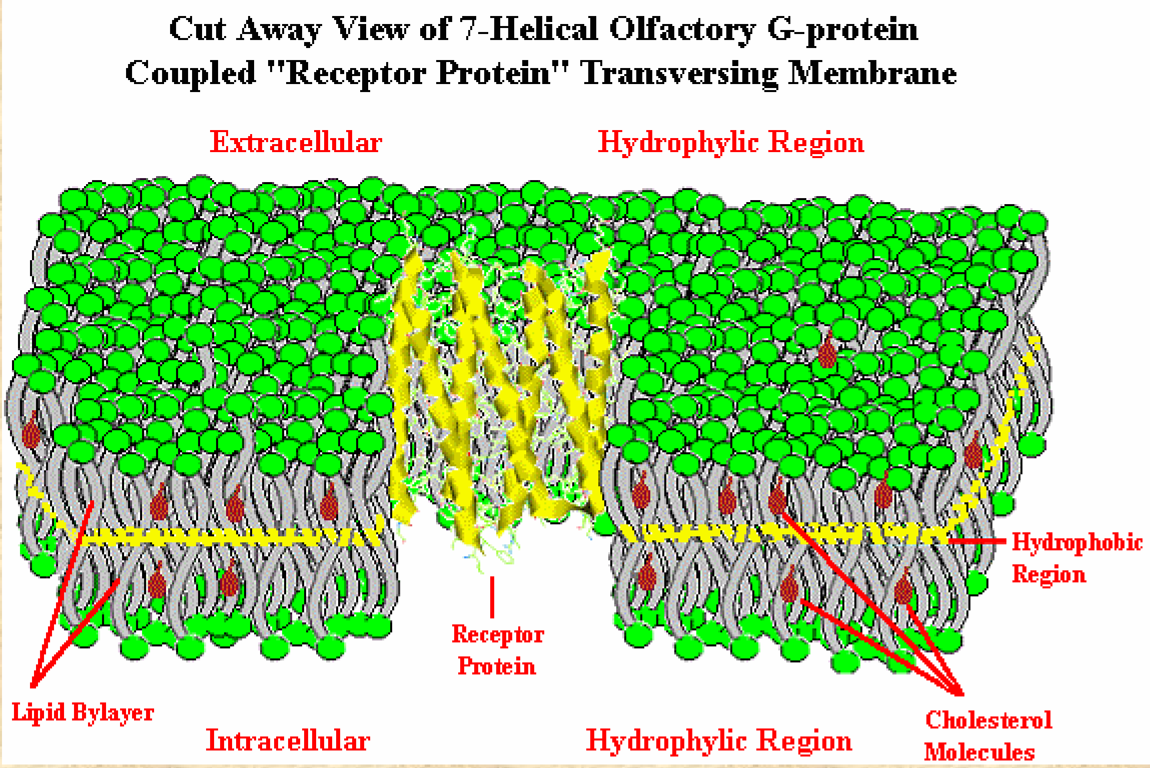
Human OBP IIa (partial structure)

Transduction

Receptor proteins are embedded in cilia outer membranes

An odorant molecule, accompanied by its olfactory binding protein, contacts an appropriate receptor protein molecule in a lock-and-key fashion

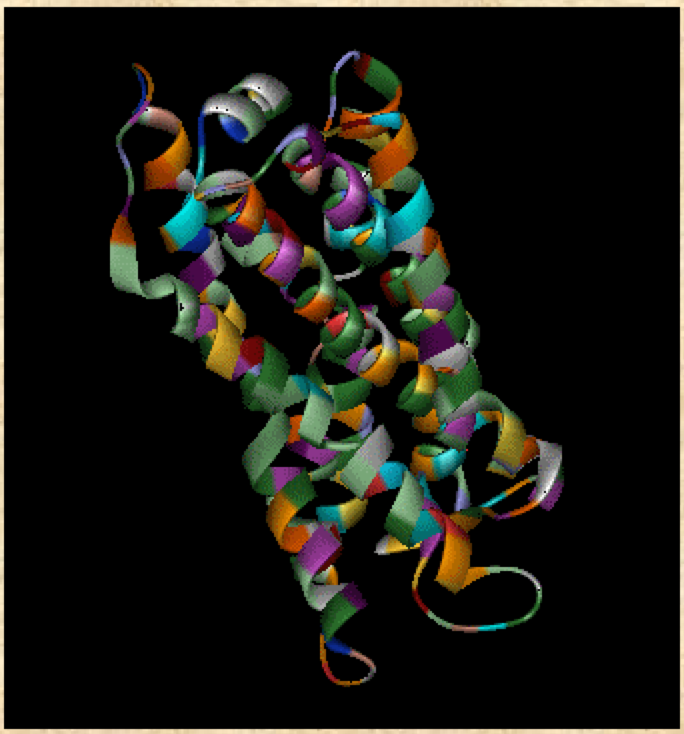
These receptor molecules are called "**G-coupled protein receptors**" for reasons made clear shortly...



Leffingwell

Transduction

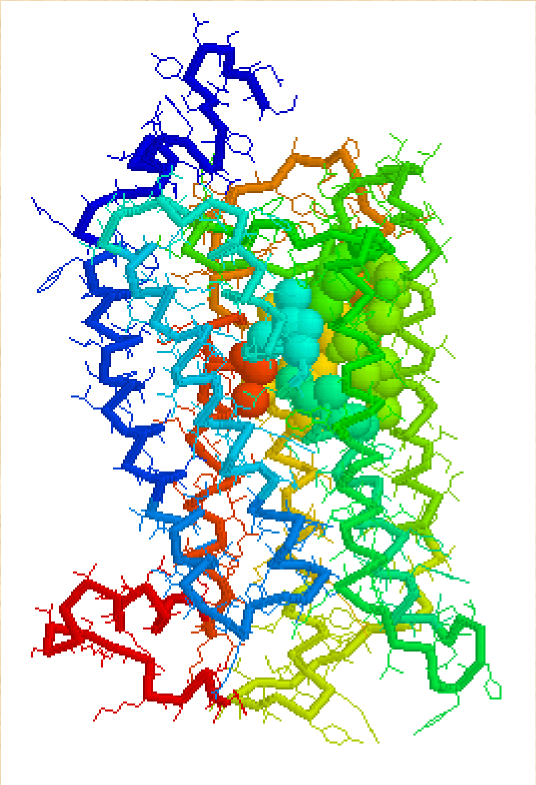
Human olfactory receptor protein OR1.01.05 shown in a way that emphasizes multi-helical structure (Leffingwell)



The same receptor protein displayed in a way that distinguishes constituent amino acids

Transduction

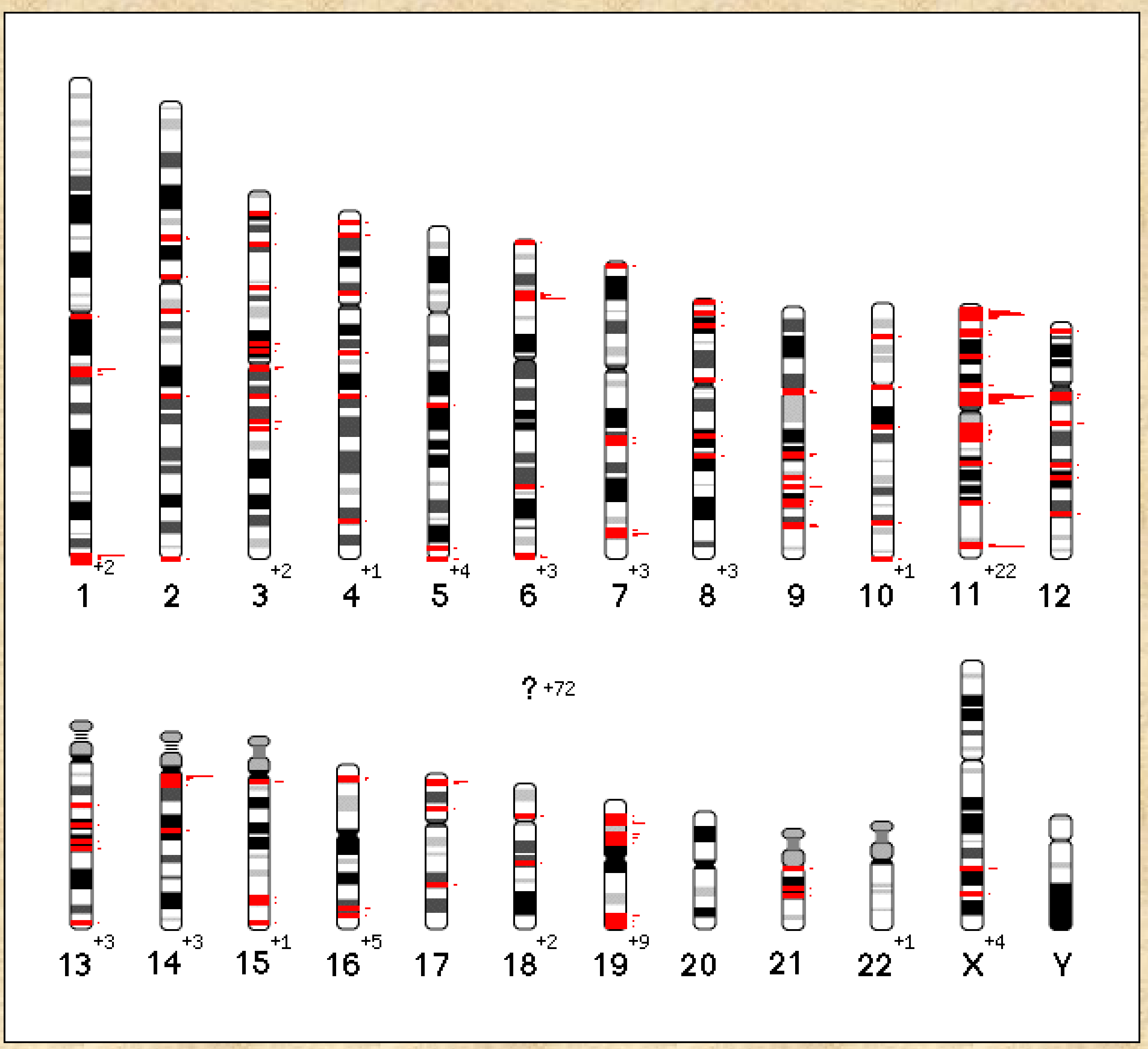
The shape and electrochemical properties of a receptor protein determine which odorant molecules will “fit” and initiate transduction



Binding cavity in Human OR1.04.06 (skeleton) with odorant molecule (spheres) within (Leffingwell)

There are
on the order
of 1000 different
olfactory
receptor
proteins.

The largest
family of genes
in mammals
code for these
various receptor
proteins...



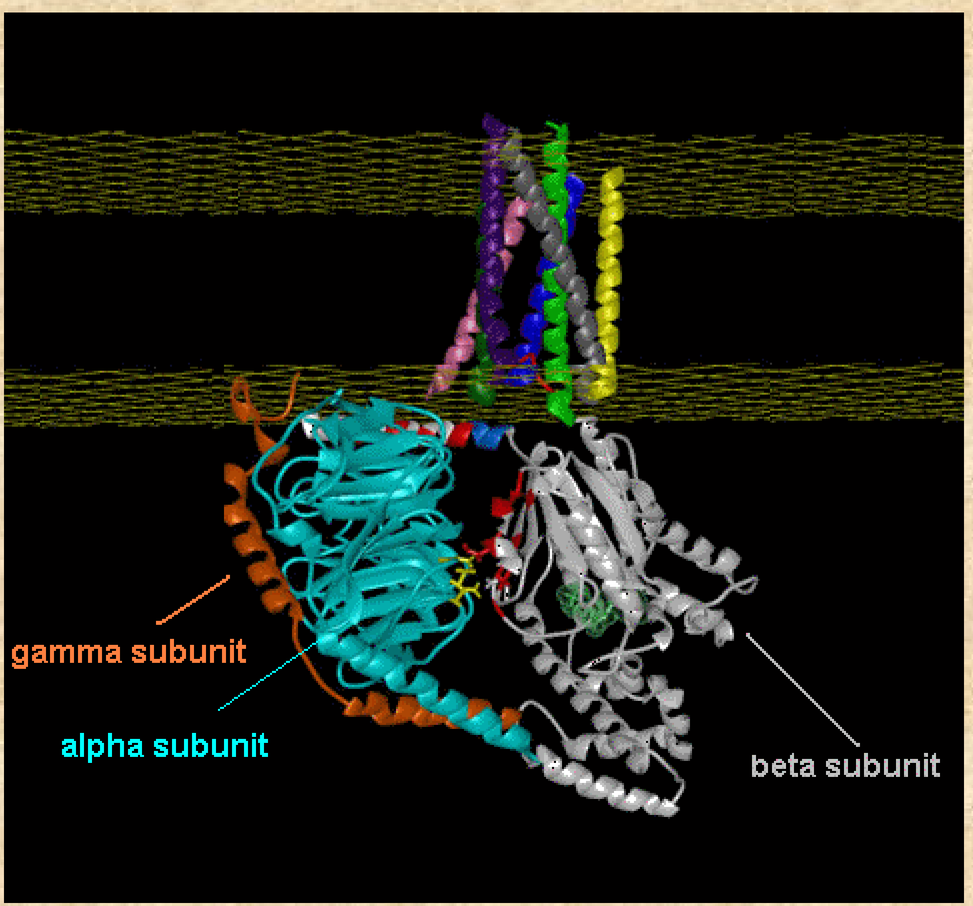
Distribution of human olfactory receptor genes by chromosome location
(Glusman et al)

Transduction

The receptor proteins
are known as
G-coupled receptor proteins

The reason is that the receptor protein molecules are attached to **G-proteins** lying just inside the cell membrane.

These initiate electrochemical activity needed for signaling.



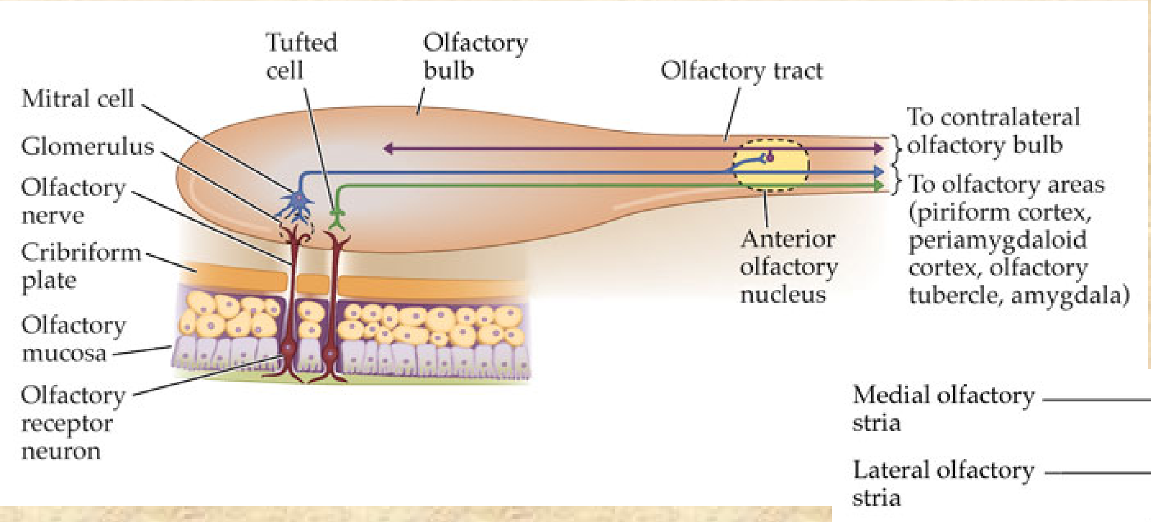
Leffingwell

G-coupled protein receptor in
membrane (top) with
G-protein just inside
the membrane (bottom, shown
in copper, blue and gray)

Olfactory System Pathways

Note that the two olfactory bulbs connect to one another

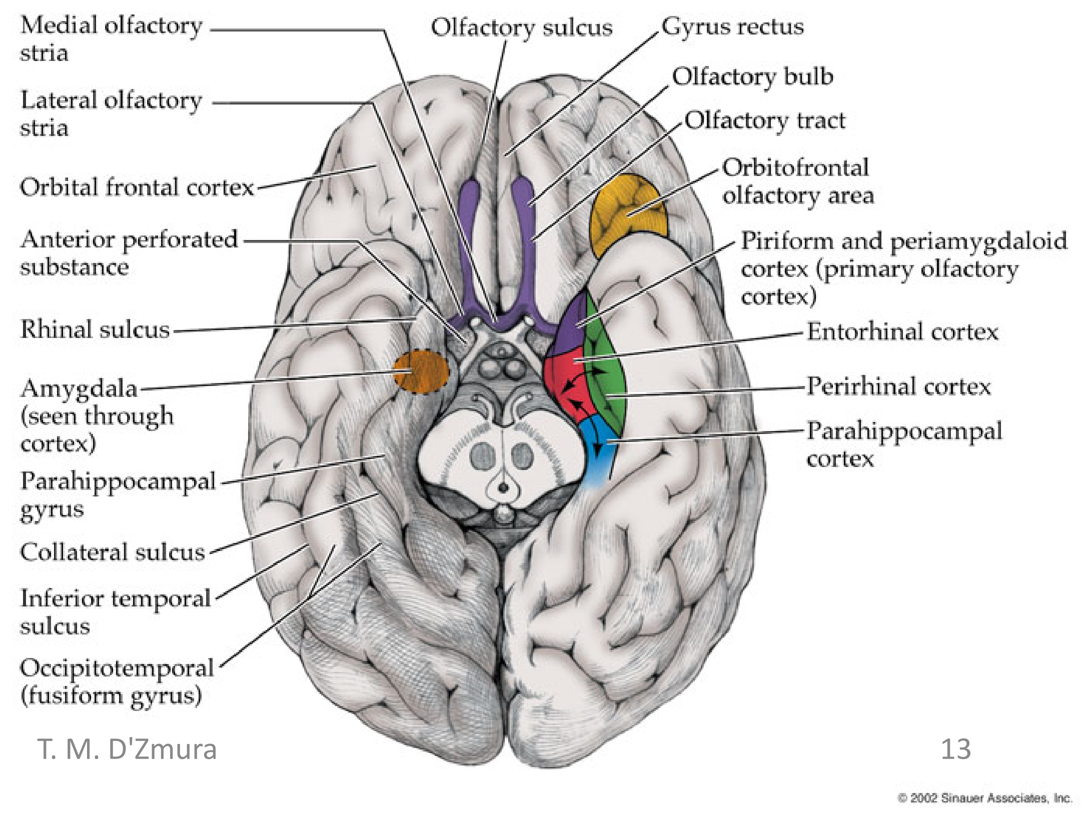
piriform cortex – primary olfactory cortex



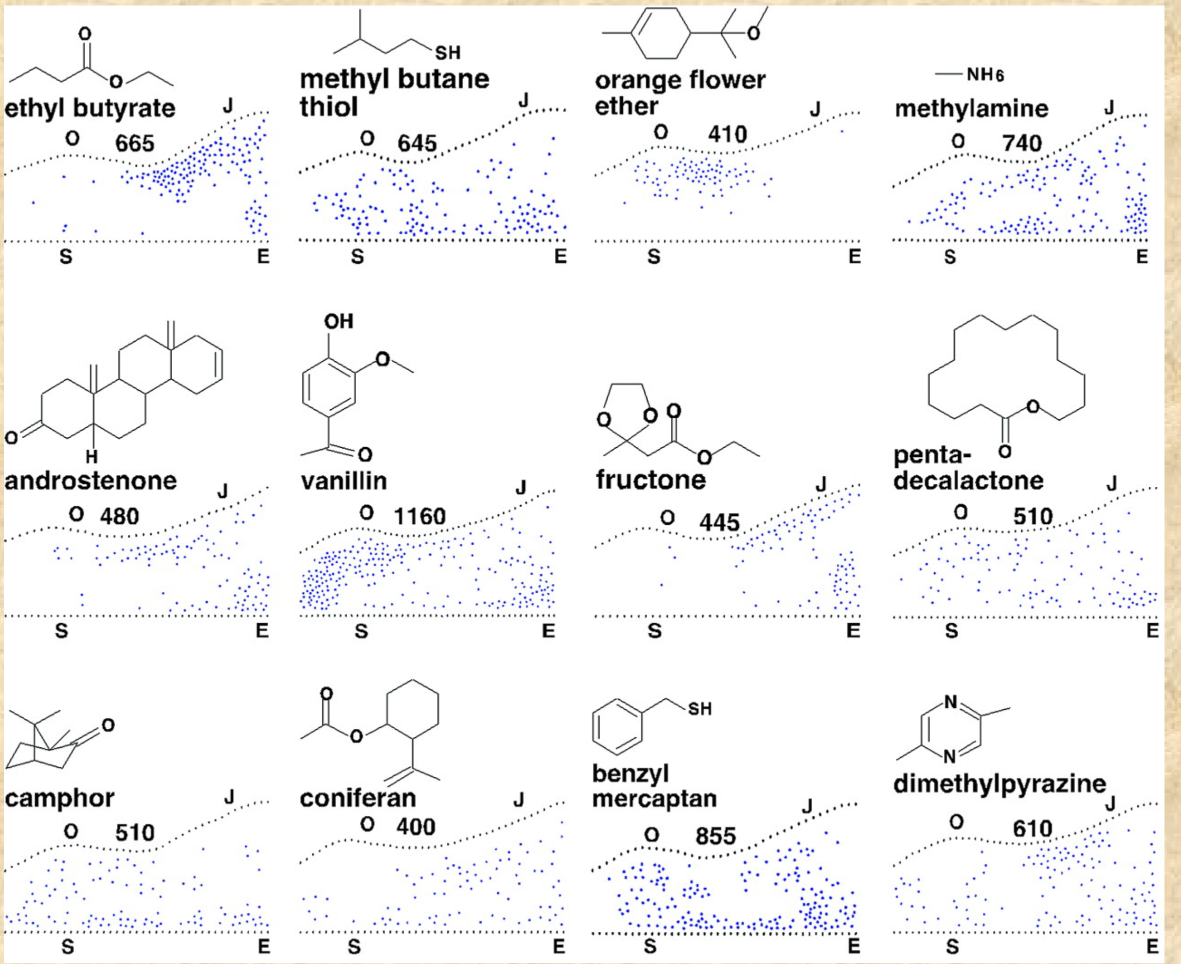
note that projections from the olfactory bulb to the brain remain on the same side!

(left bulb – left side of brain, right bulb – right side of brain)

unlike vision, audition



Primary olfactory cortex



Spatial patterns of neuron activity in mouse anterior piriform cortex depend on odorant molecule (Zou et al.)

Olfactory sensitivity

Fact: smell intensity discrimination is better using the
right nostril than the left nostril

Recall: olfactory pathways stay on the same side of the brain
as where they begin

Right hemisphere of the brain more specialized for certain types
of olfactory processing (smell intensity discrimination)

Yet unpleasant smells tend to activate selectively the
left amygdala and the left smell cortex...

Pheromones

Odorants with a special biological significance, often related to reproduction, released by individuals and sensed by those of the same species

Pheromones have a strong influence on behavior in other species; whether they strongly influence human behavior is less clear.

the case in insects is quite clear:
releasers – automatically trigger a specific behavioral response
(attract a mate)
primers – trigger glandular and other physiological responses
(queen bee controls swarming, new queen production
and proportions of bee types using primers)
insect pheromone: a specific molecule produced by
a specific gland and detected by
a specific receptor

mammals?
female dog in heat attracts male dogs ("releaser" pheromones)

Pheromone Detection by the Accessory Olfactory System

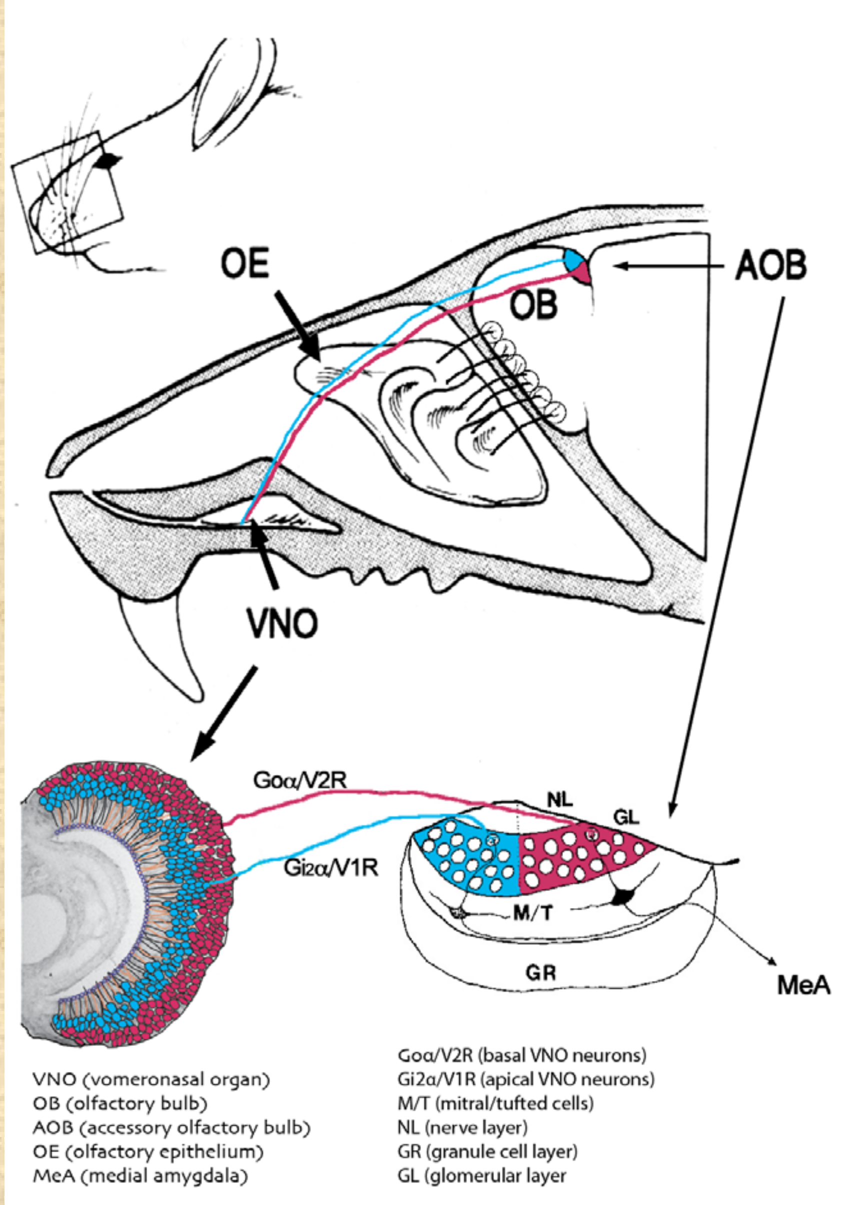
Vomeronasal organ

possesses olfactory receptors sensitive to pheromones

Axons pass to the

Accessory olfactory bulb

Its neurons project to areas of the brain concerned with reproductive behavior



Pheromone Detection

Humans?

Although we possess vomeronasal organs

1) there are few axons leading away from them

2) we have no accessory olfactory bulb

It is thought that a variety of pheromone-like sensitivities in humans are due to activity of the primary olfactory system

Hypothalamus

in men, activated by female-released odorants

in women, activated by male-released odorants

no such activation in anosmics possessing vomeronasal organs

Smell and Human Behavior

On the whole, females identify smells better than males

People readily identify
- their own body odor
- gender of a person with a particular body odor
  (quality and intensity)
- gender based on hand odor
- gender based on breath odor

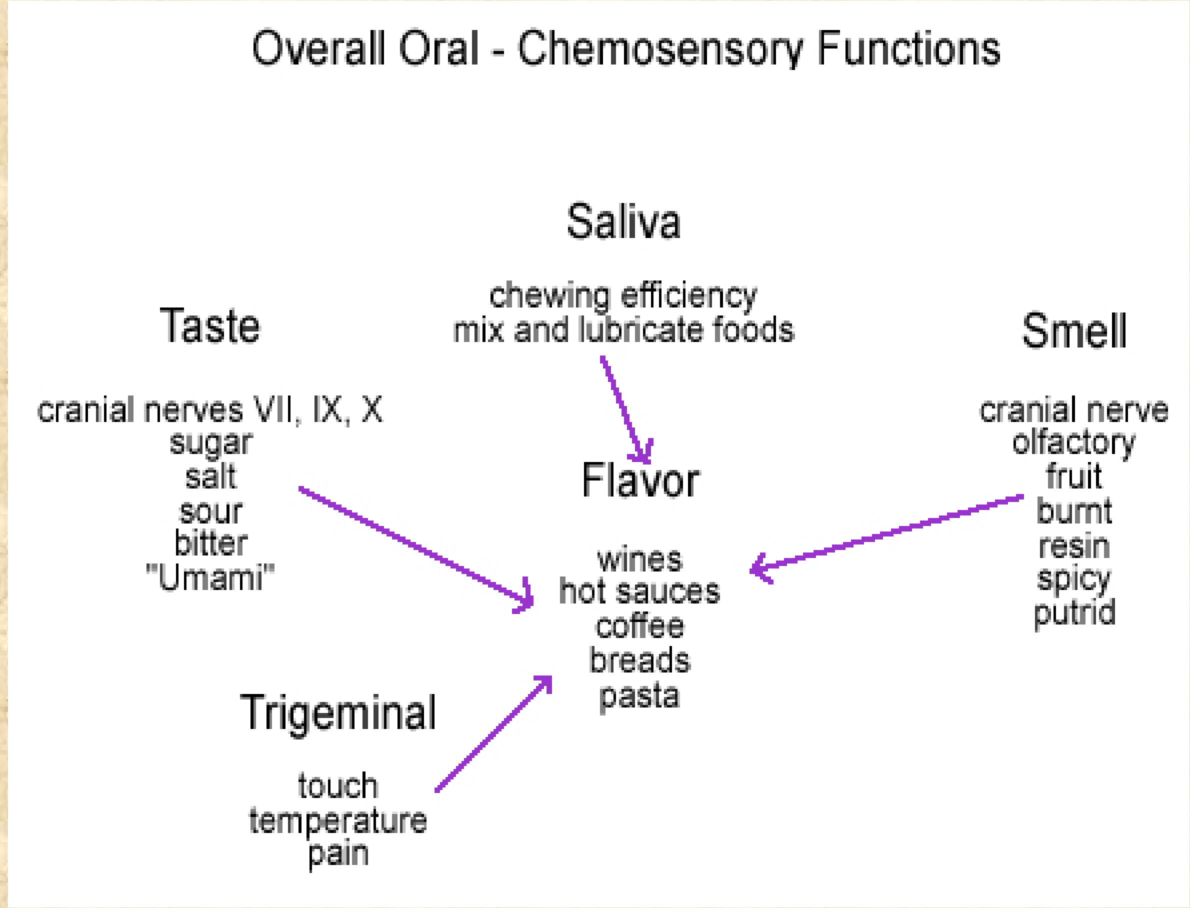
Infants identify their mother's odors

Parents and children recognize each other's odors

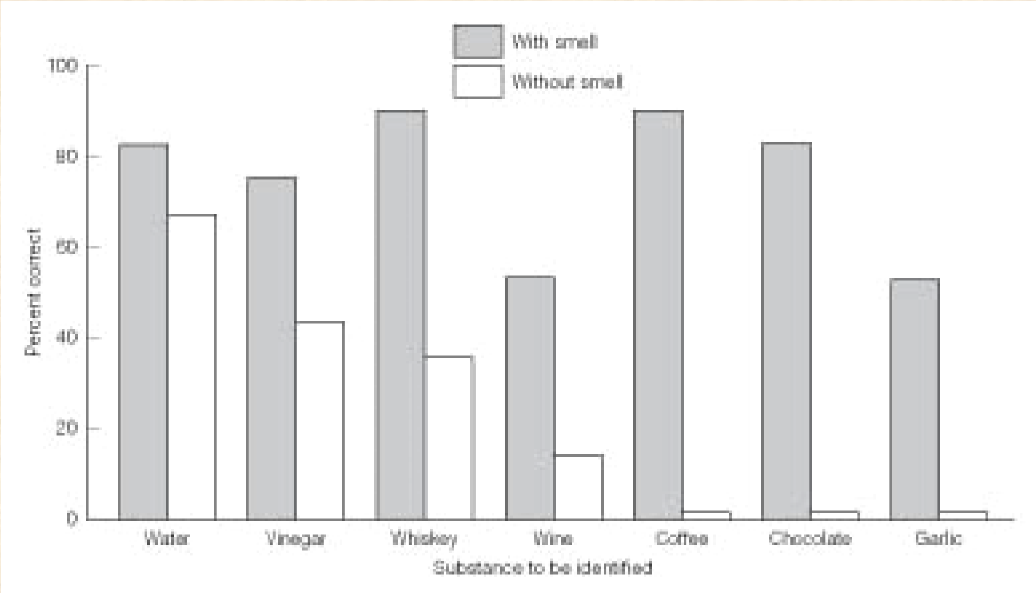
Taste (Gustation)

- Receptors for *taste* are located on the *papillae,* found primarily on the tongue.
- There are five types of receptors.
  - Each type is sensitive to a range of inputs.
  - Qualities of taste (sweet, salty, sour, bitter, umami) are coded by response pattern across five types.

Gustation – the sense of taste



The *flavor* that we attribute to food is **not** due wholly to gustation. The sense of smell (olfaction) is also very important.



Substance identification performance (percent correct)
with (dark bars) and without (light bars)
the sense of smell

Taste Stimuli: Molecules (*tastants*)

Those that taste

Sweet

Salty

Sour

Bitter

Umami (delicious, savory)

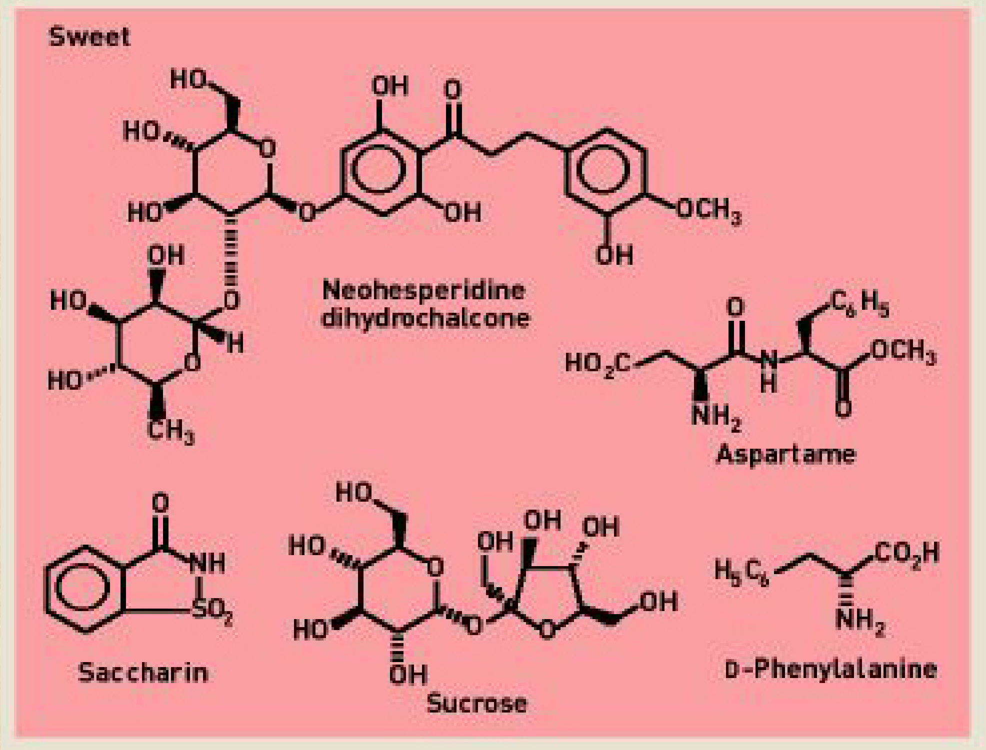
presumably due to the presence of receptors whose activity generates these taste perceptions

Taste Stimuli: Molecules (*tastants*)

Sweet sugars

glucose,
sucrose,
lactose,
fructose,
etc.

...and a variety of other molecules



Taste Stimuli: Molecules (*tastants*)

Salty

salts

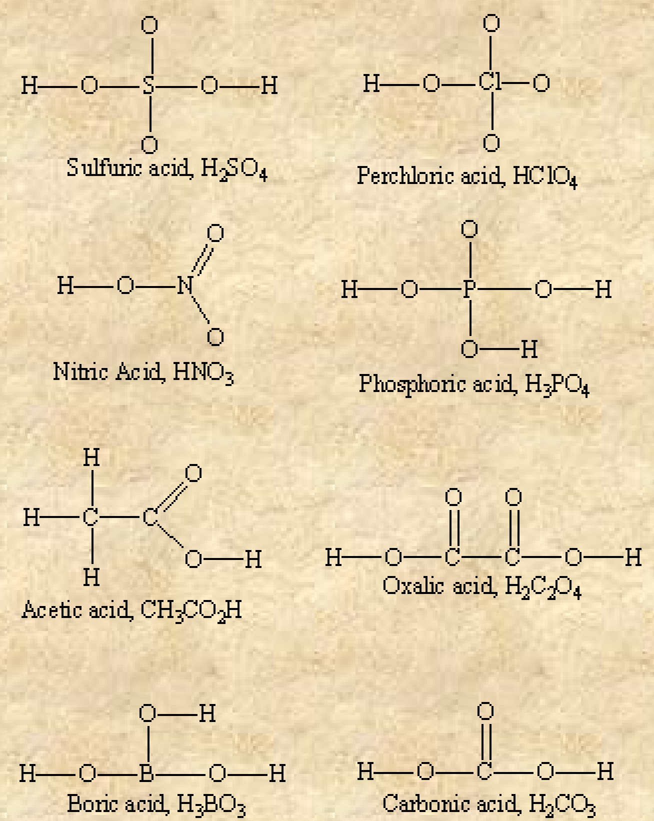
formed by
acid-base
reactions

sodium chloride (NaCl)
potassium chloride
calcium chloride
etc.

when dissolved in saliva, these comprise positively- and negatively-charged ions

watch NaCl (table salt) dissolve in water to produce a solution of Na+ and Cl- ions:
http://www.mpcfaculty.net/mark_bishop/NaCl_dissolves.htm

Taste Stimuli: Molecules (*tastants*)



Sour acids

for example, hydrochloric acid (HCl)

An acid molecule typically has one or more protons, H+, positively charged, that seek to bond with negatively charged species (like those found in bases)

Taste Stimuli: Molecules (*tastants*)

Bitter

bases

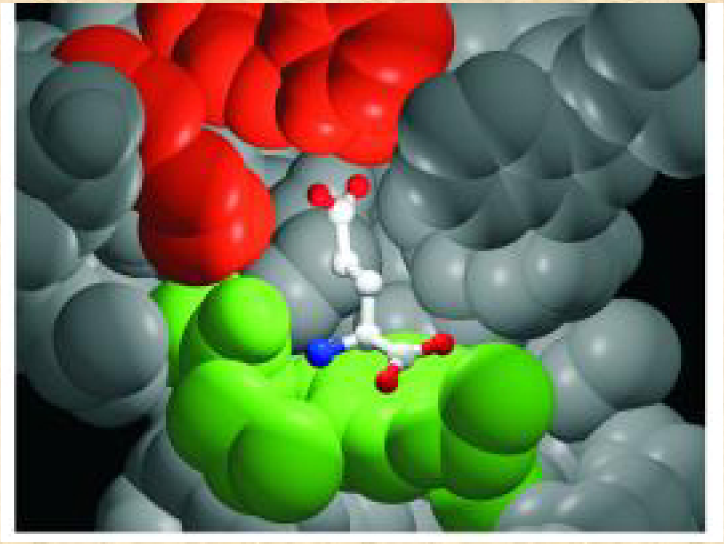
sodium hydroxide (NaOH)

often have components capable of reacting with acid protons to produce water + salt

HCl + NaOH => NaCl + H_2O

alkaloids – highly poisonous

Taste Stimuli: Molecules (*tastants*)



L-glutamate (an amino acid)
contacting umami-receptive
membrane molecules (red/green)

Umami (delicious, savory)

amino acids

like
glutamate
glutamine

present in MSG and, more generally, *proteins* tongue

(peripheral taste organ)

small to medium size molecules

↓

dissolve in saliva

↕

enter taste pore

↕

bind to receptor in cilia

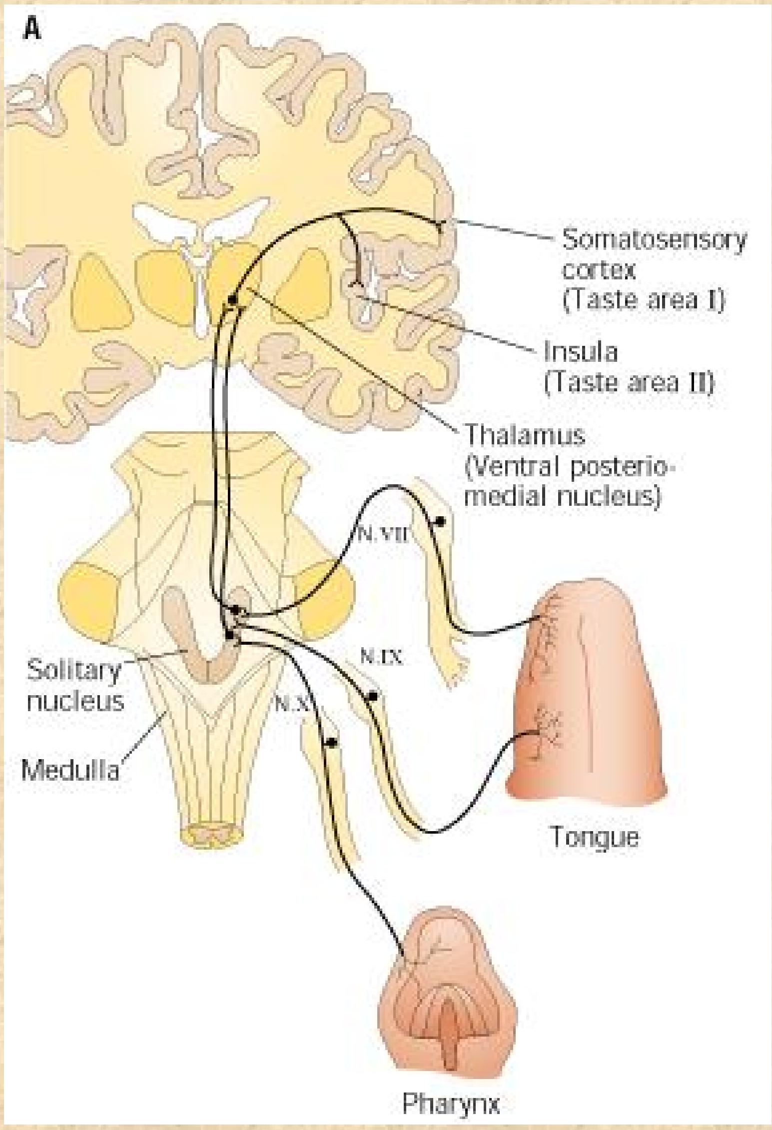
↓

receptor potential (graded)

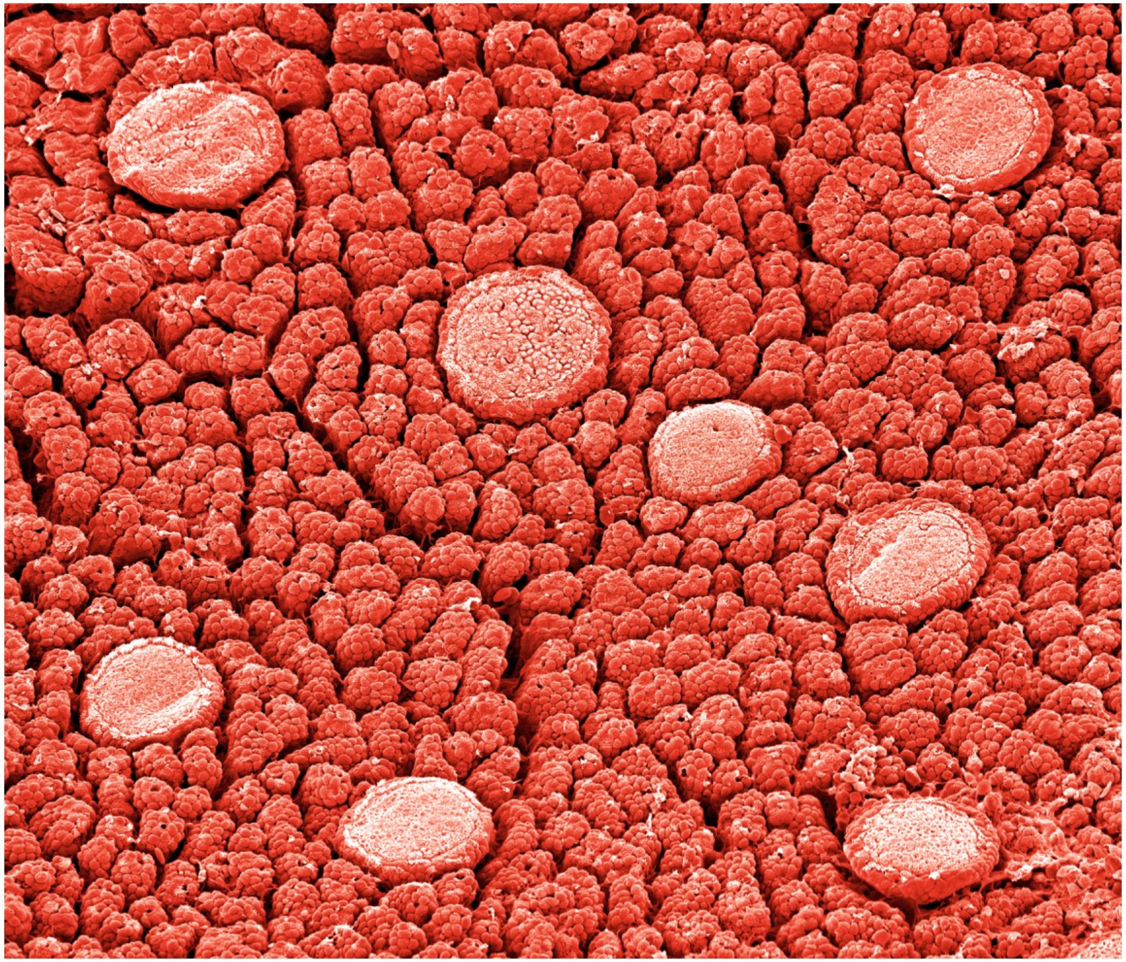
↓

action potentials

central taste pathways

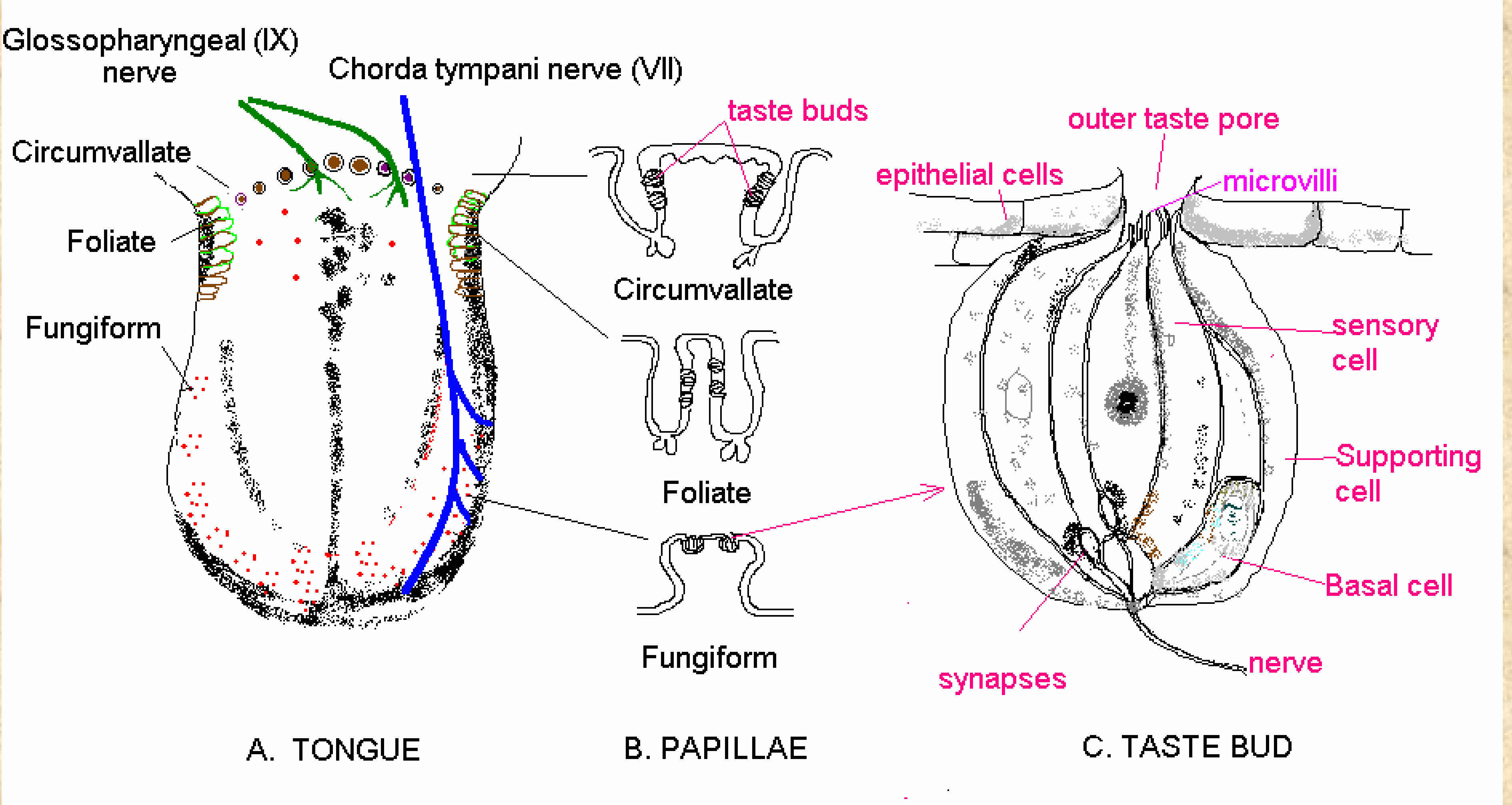


Papillae (pink disks)



Psychology, 8/e Figure 4.14

Tongue, Papillae & Taste Buds



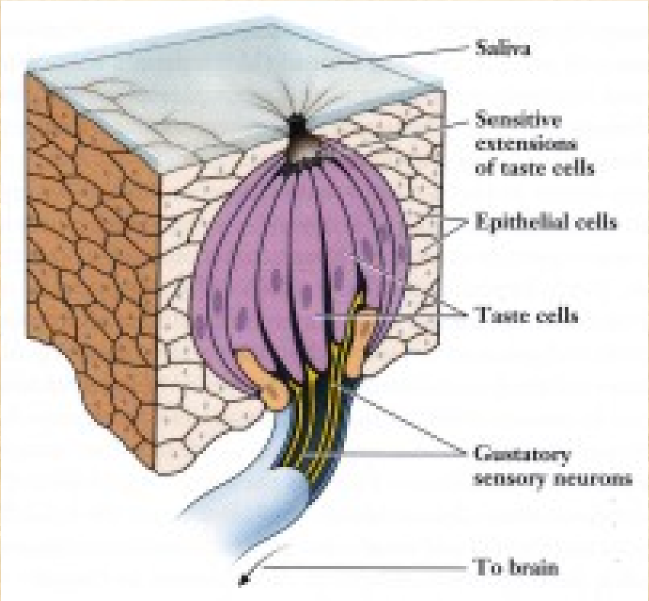
Taste Buds

There are approximately 10,000 taste buds in a young person's mouth

Each taste bud has a variable number (several – 30) of receptor cells

The life span of a single taste receptor cell is only a few days;
they regenerate – like skin

Mature cells (central) &
immature cells (peripheral)

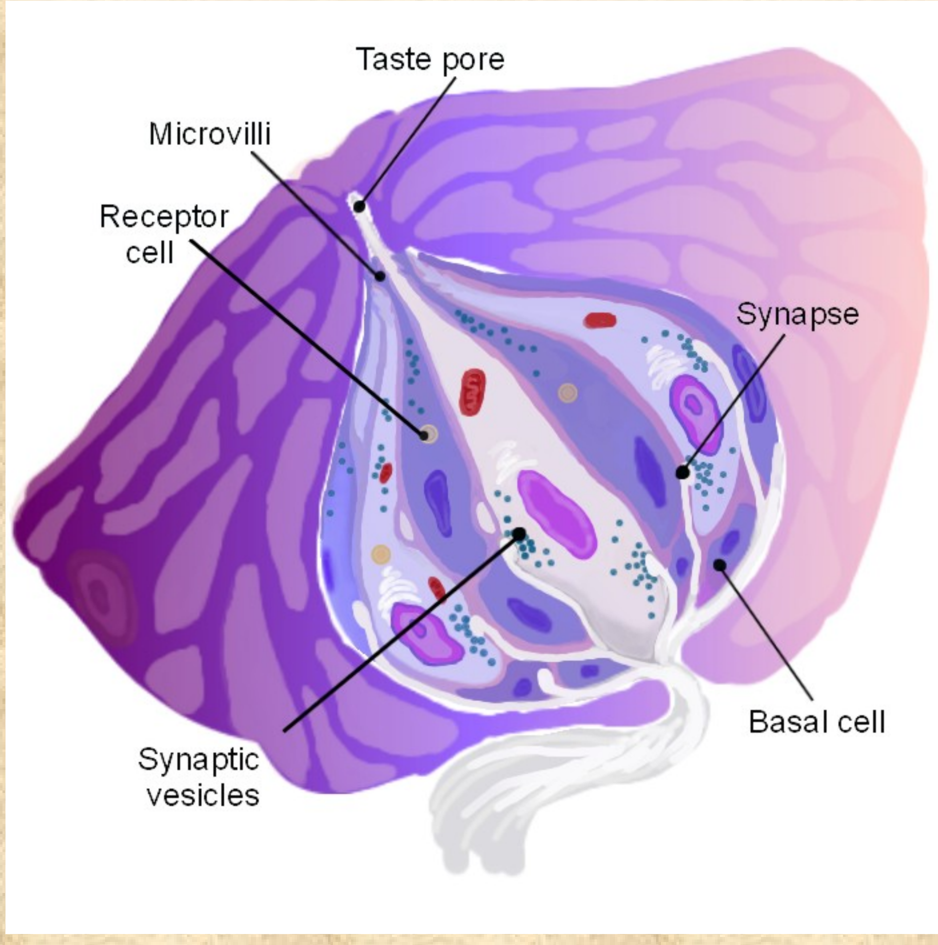


Taste Buds

Microvilli protrude from top end of each taste receptor cell into the **taste pore**

Tastant molecules interact with microvilli membrane molecules

How they interact depends on the kind of taste receptor cell...



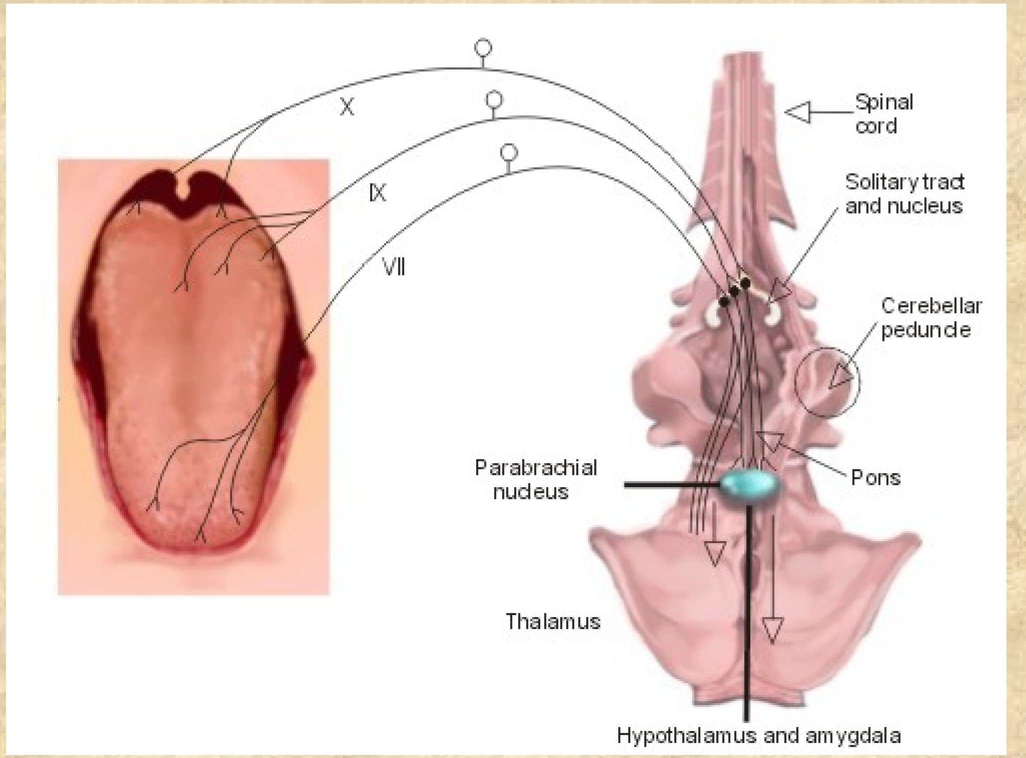
Neural pathways

Three cranial nerves carry taste receptor cell signals to the brain

VII – chorda tympani
IX - glossopharyngeal
X – vagus

Signals are carried to various nuclei in the **solitary tract** in the medulla (brainstem)

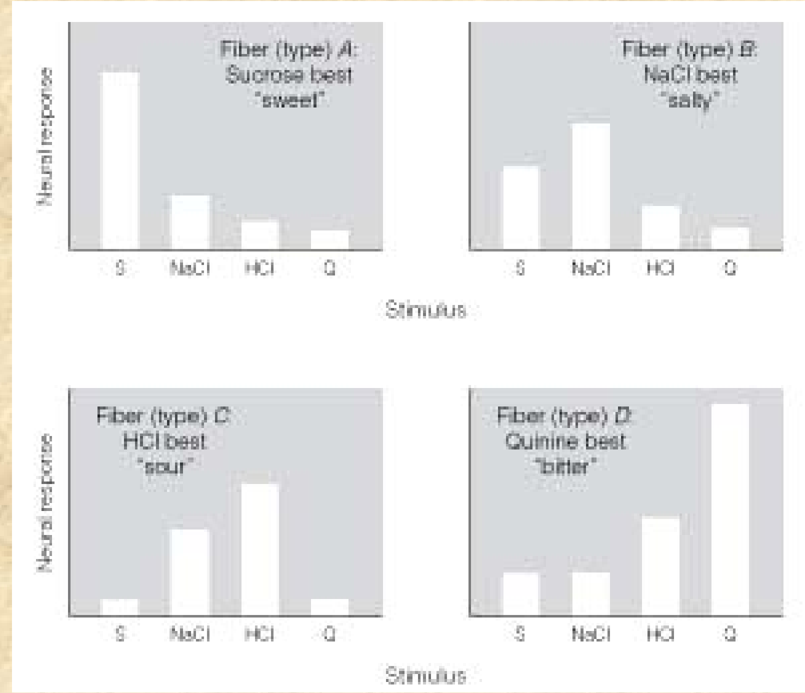
Signals then pass to the **parabrachial nucleus** and directly, via the **medial lemniscus**, to the thalamus



Perception of Taste Quality: Response Pattern

VIIth nerve Fiber A responds best to sucrose,
less well to salt, hydrochloric acid and quinine
("sweet")

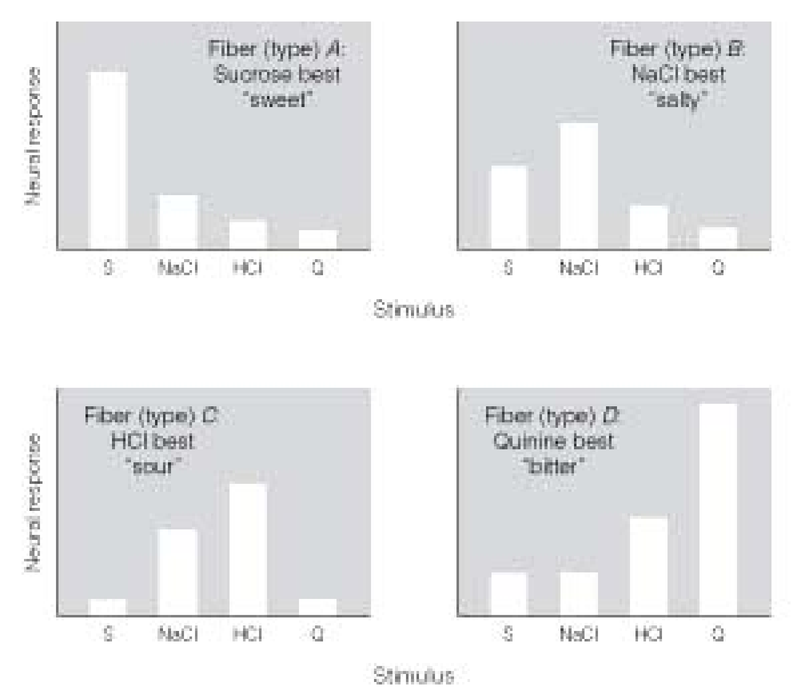
Fiber B responds best to salt
("salty")

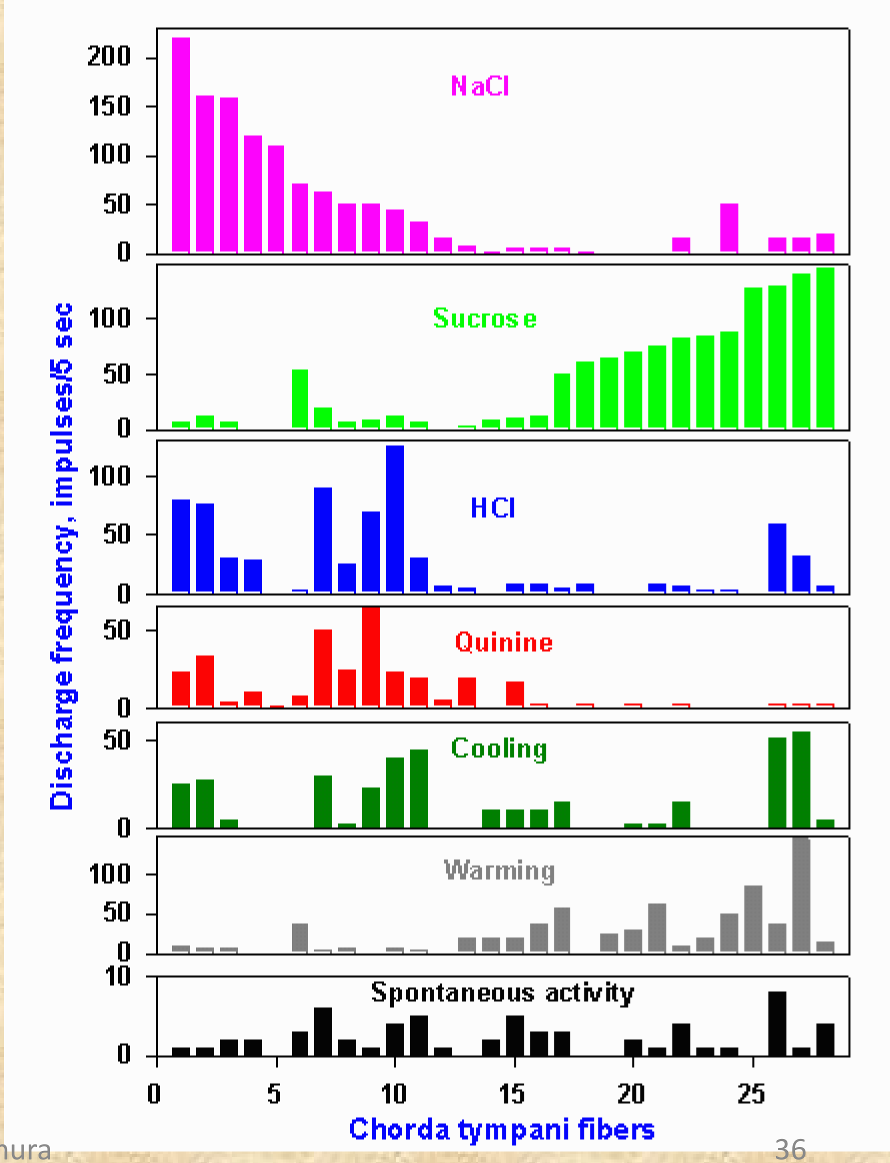


Fiber C responds best to hydrochloric acid
("sour")

Fiber D responds best to quinine
("bitter")

Perception of Taste Quality: Response Pattern



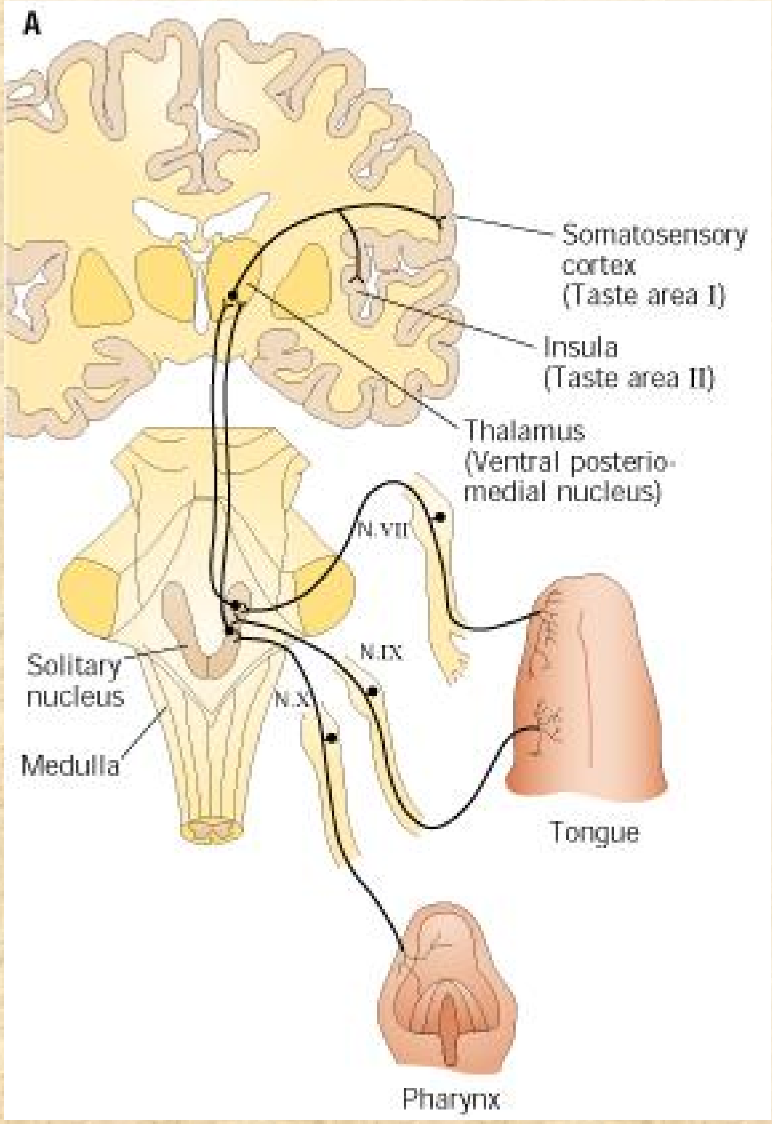


Preferences shown for a variety of fibers in the VIIth nerve

Neural pathways

Taste signals arrive via the
medial lemniscus at the
taste center of the thalamus:
ventral posterio-medial nucleus

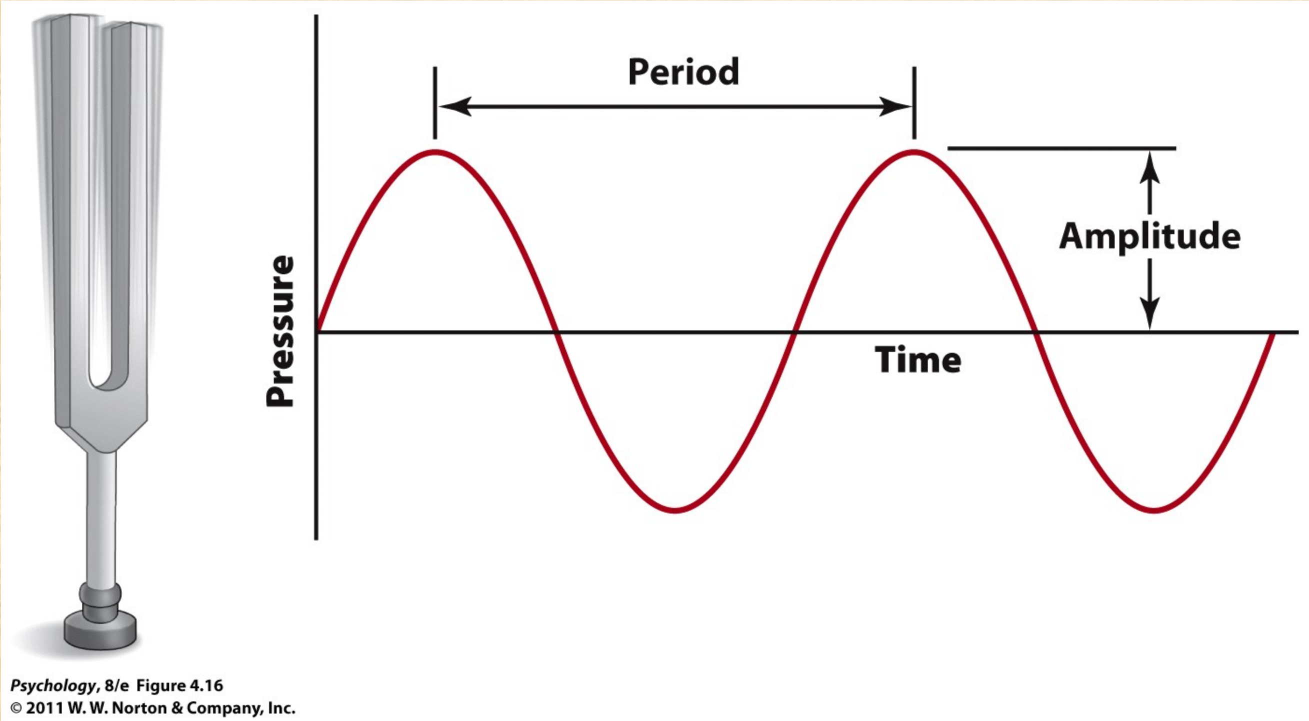
This nucleus projects to
primary somatosensory cortex
(close to facial touch)
and to
anterio-insular cortex



Hearing - *Audition*

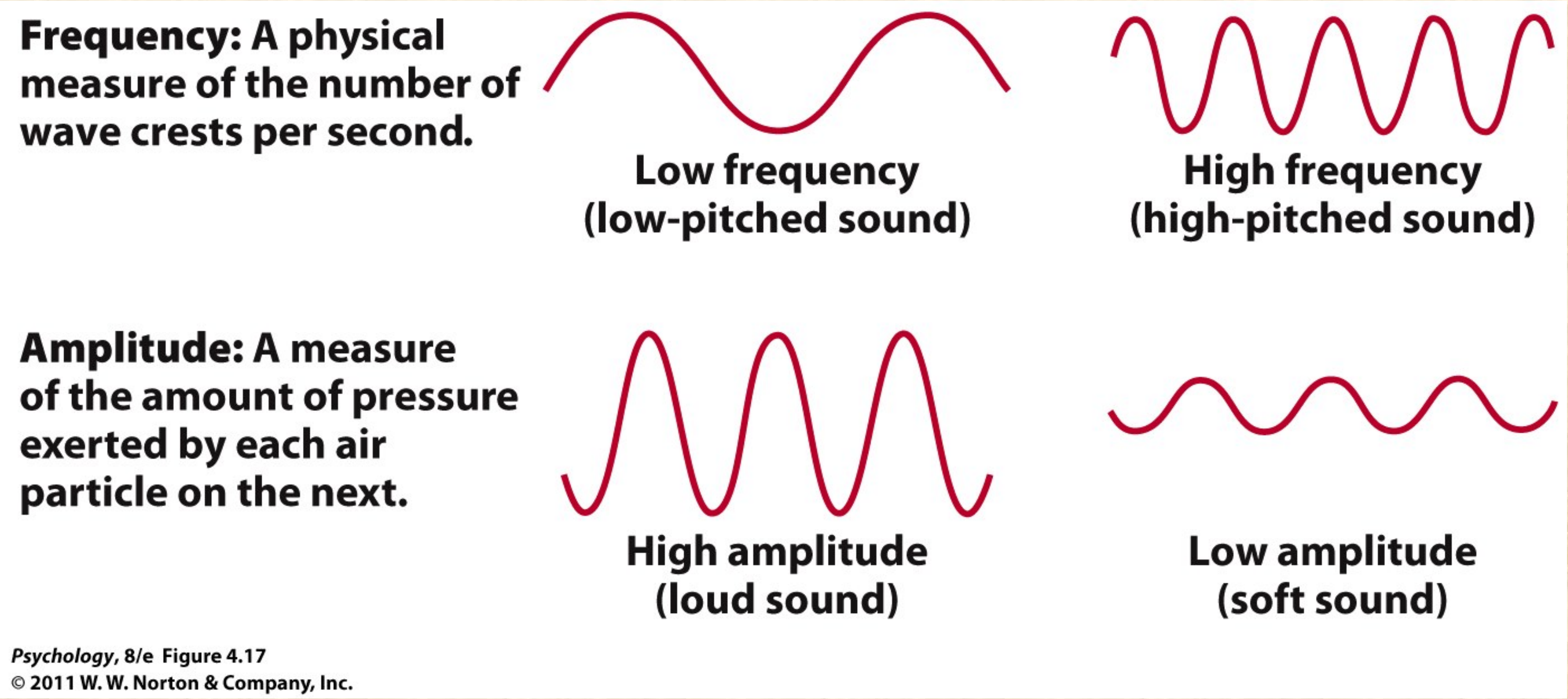
- *Sound waves*
  - can vary in *amplitude* and *frequency*
  - create vibrations in eardrum
  - transmitted by the *auditory ossicles*
  - to the *oval window*—movements create waves in the *cochlea*
  - *hair cell* receptor neurons in the cochlea transduce sound pressure waves into neural signals

A *pure tone* has a sound pressure wave described by a sinusoidal function.



Pure tones vary in their

- *amplitude* (related to the perceptual variable *loudness*)
- *frequency* (related to the perceptual variable *pitch*)



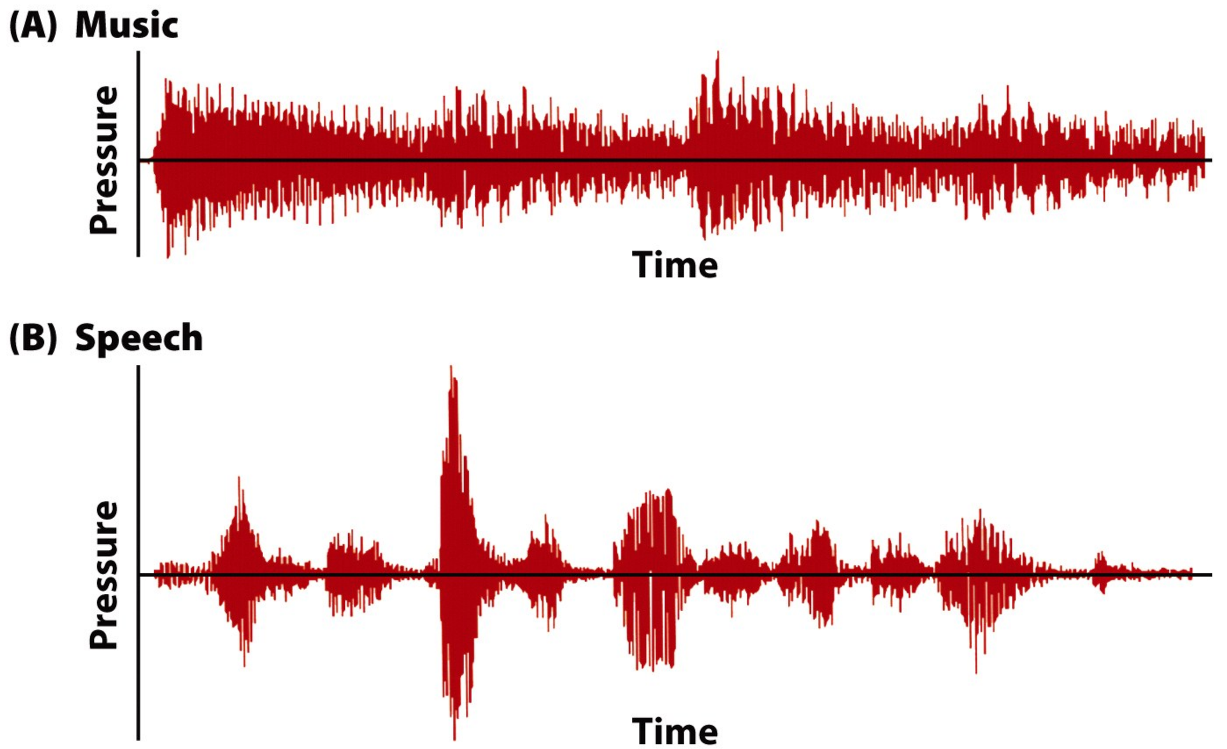
Units of frequency are Hertz (Hz):
number of cycles (full waves) per second

TABLE 4.3	Sound Frequencies of Some Musical Tones	
	Sound	Frequency (hertz)*
	Top note of grand piano	4,244
	Top note of piccolo	3,951
	Top range of soprano voice	1,152
	Top range of alto voice	640
	Middle C	261
	Bottom range of baritone voice	96
	Bottom range of bass voice	80
	Bottom note of organ (can be felt but not heard)	16

*Note that some orchestras, and some musicians, choose to tune their instruments differently. Middle C, for example, is sometimes tuned to a frequency of 256 hertz, or one as high as 264.

Psychology, 8/e Table 4.3

Almost all sounds are described by *complex* waveforms. These can be analyzed in terms of a sum of pure tone waveforms (Fourier analysis)



Psychology, 8/e Figure 4.18

try the sound-generating Java applet at http://www.phys.hawaii.edu/~teb/java/ntnujava/sound/sound.html