Auditory & Chemo-sensory Organs in Fishes

FRM-221 "Physiology of Finfish & Shellfish"

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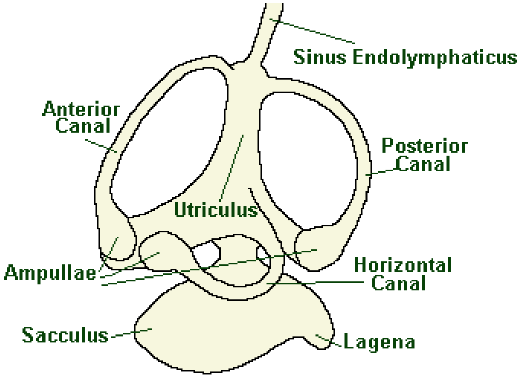
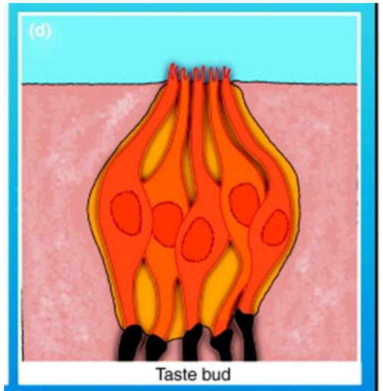
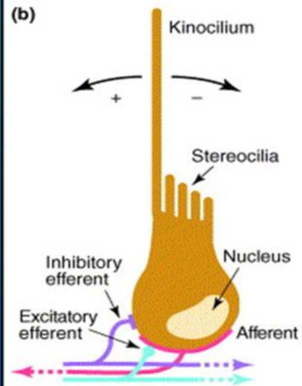
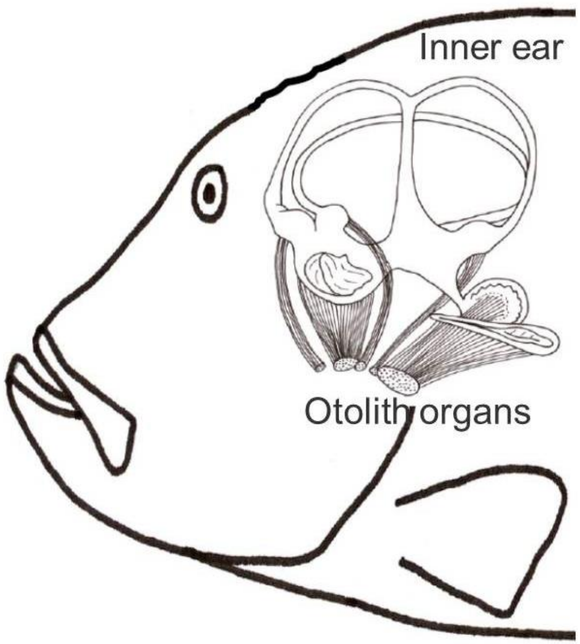
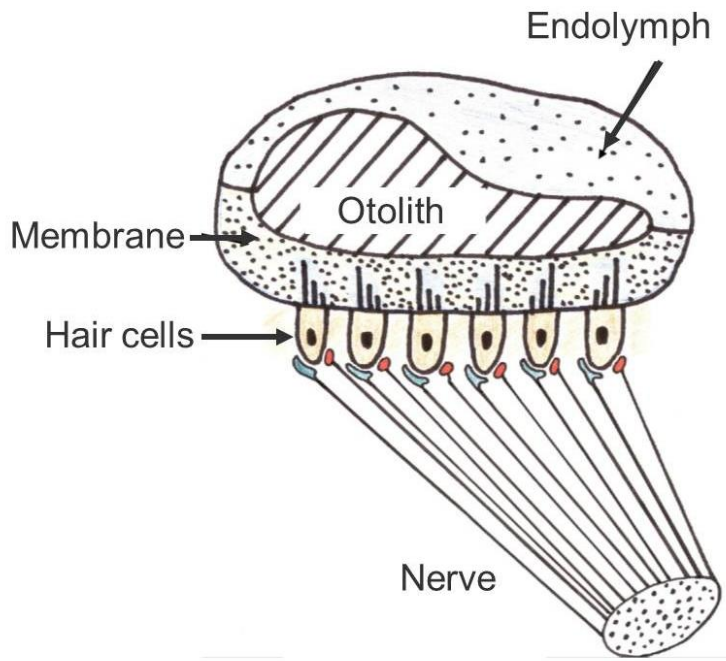


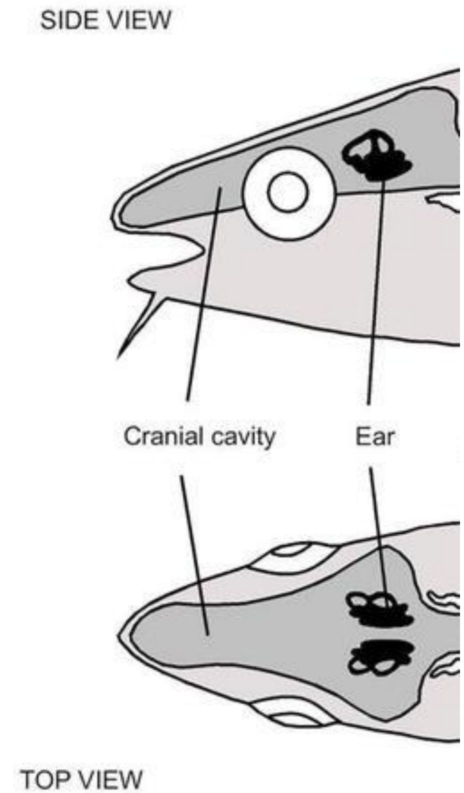




Internal Ear or Membranous Labyrinth







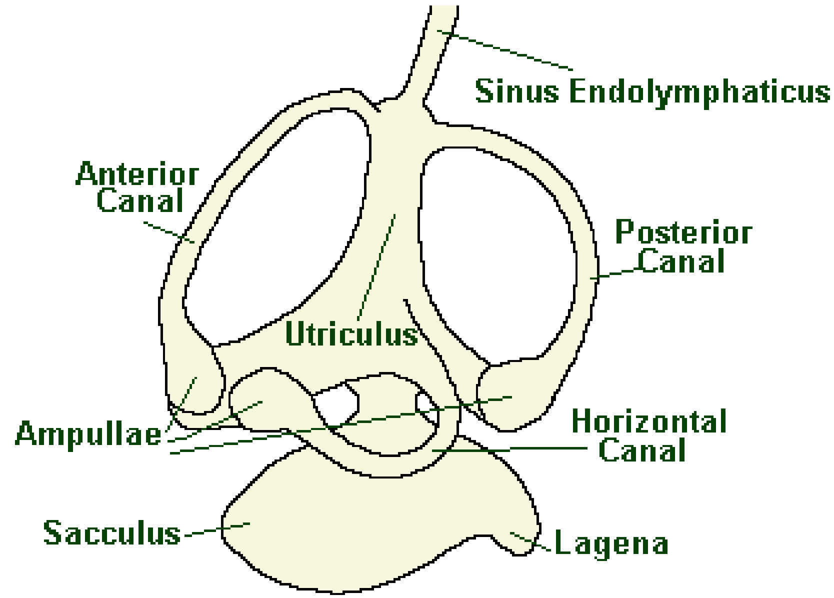
- The membranous labyrinth or the internal ear is the chief **organ of hearing and equilibrium.**

Internal Ear or Membranous Labyrinth

- Internal ear is a membranous sac partially divided into an upper chamber **utriculus** and a lower one called **sacculus**, having a small outgrowth, the **lagena**.

- **Three semi circular canals** open into the utriculus.

- Each canal has a small swelling at the end called **ampulla.**



Structure of Membranous Labyrinth

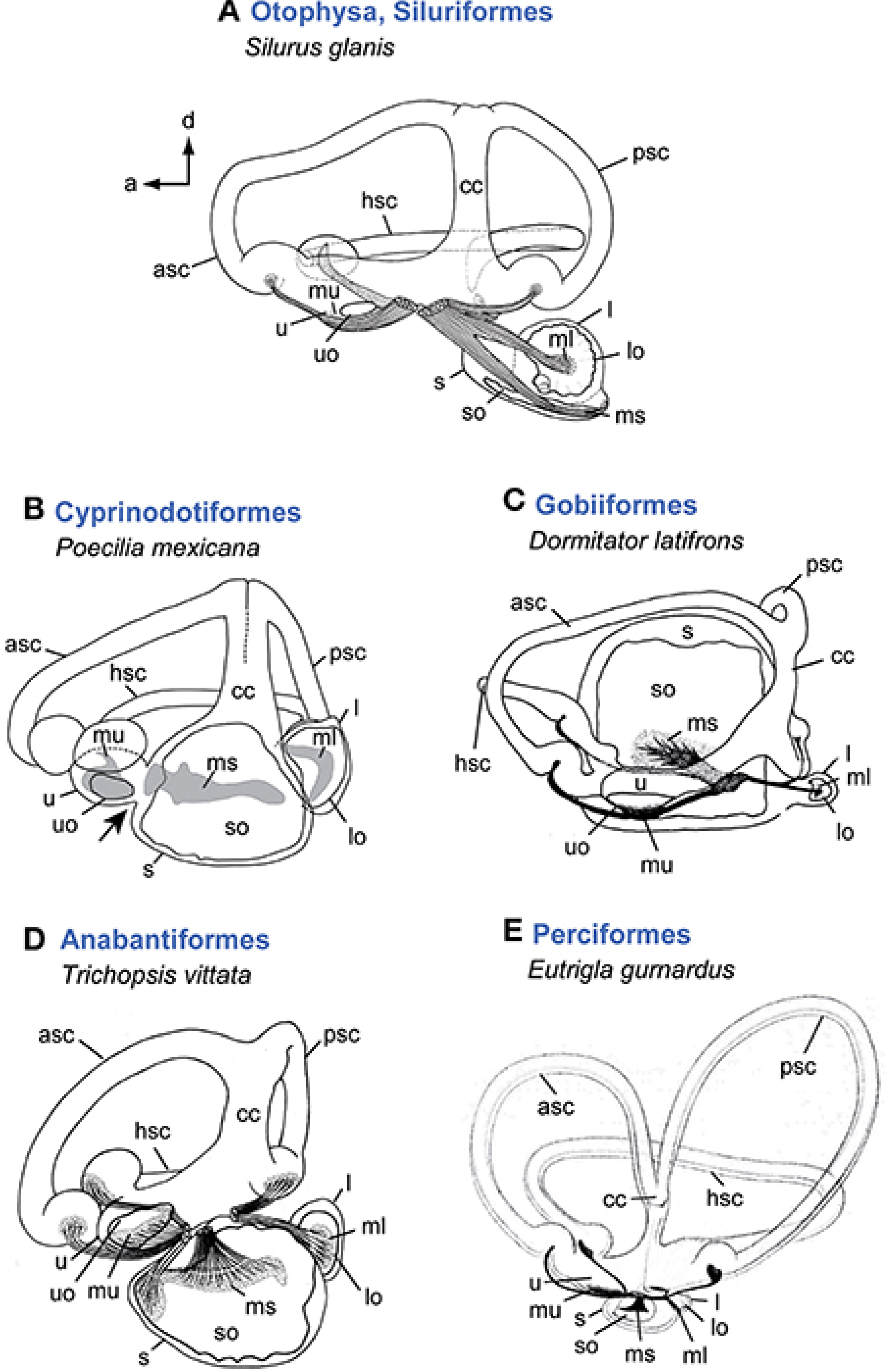
Internal Ear or Membranous Labyrinth

The cavity of utriculus, sacculus and lagena contain a fluid called endolymph and group of highly sensitive cells (Sensory Hair Cells) are present in their wall.

In the cavity of ear, solid concretions called otolith are present. Otoliths are made of calcium carbonate and their size and shape is highly variable among species.

Three otholiths are present in three sac and called lapillus, sagitta and asteriscus.

Semi circular canals and utriculus are mainly responsible for the maintenance of equilibrium while the sacculus and lagena are site for the sense of hearing.



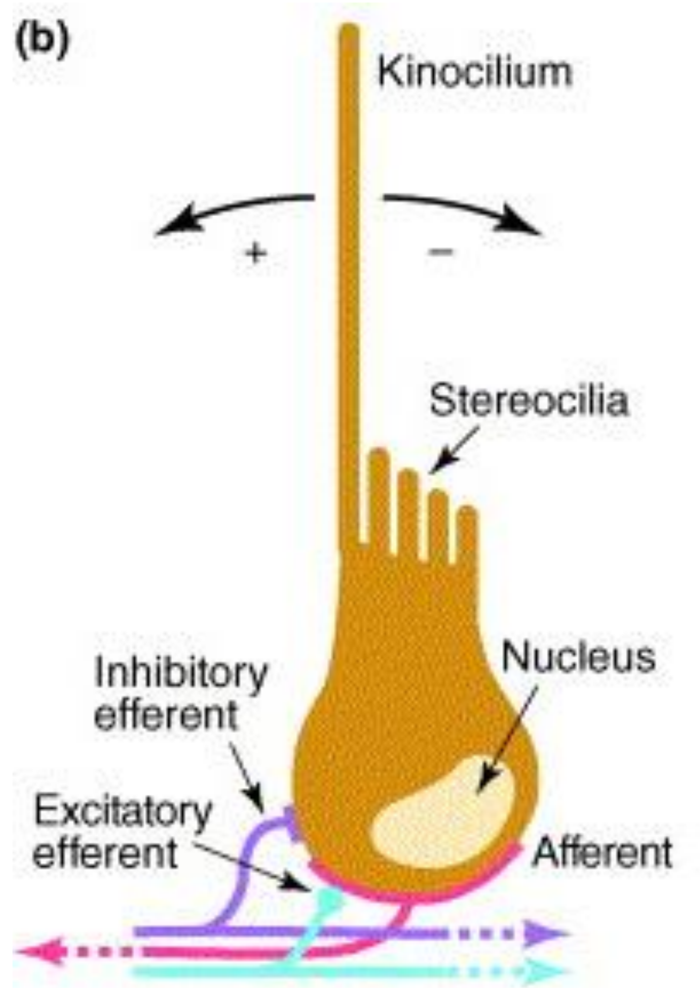
Structure diversity in inner ear of Teleost

Sensory Hair Cell

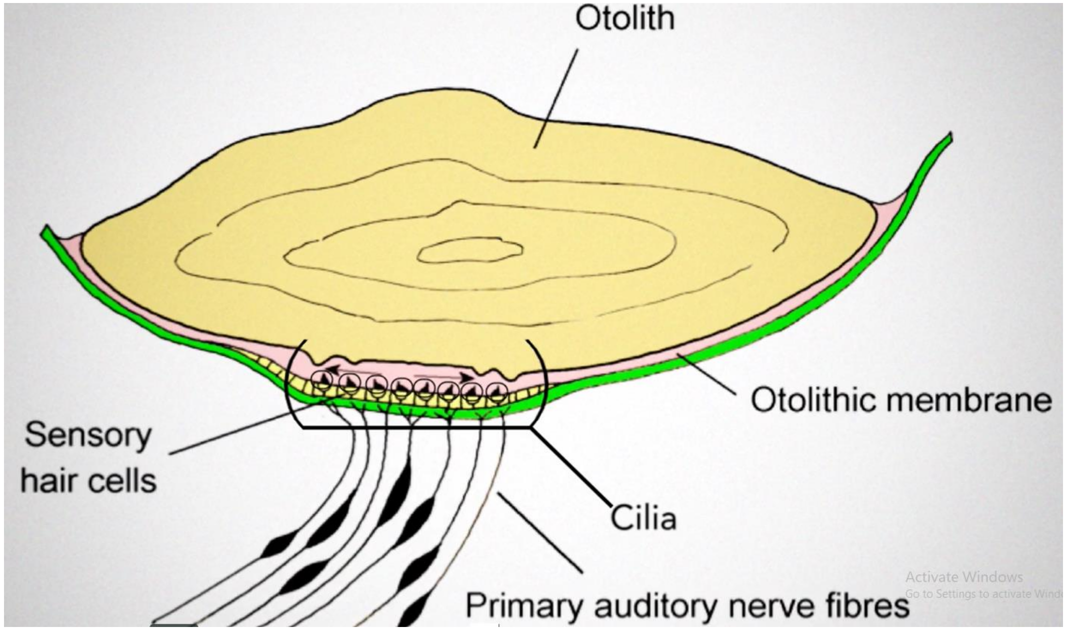
- ➢The hair cells are sensitive to mechanical deflection of hairy processes. Electrical potential exist at the apical and baso-lateral ends of the cells, due to difference in ionic contents of extra and intracellular fluids.

- ➢Deflection of cilia cause flow of ions across the membrane

- ➢Afferent fibers excited when stereocilia bend towards kinocilium, while deflection in opposite direction inhibit the afferent fibers.



Auditory mechanism in inner ear

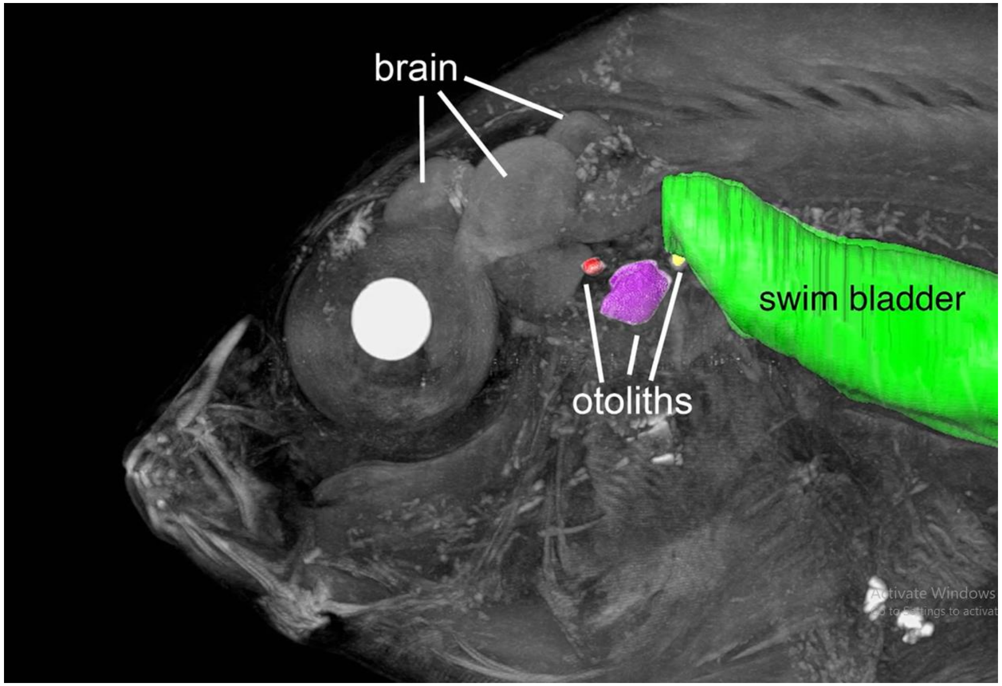


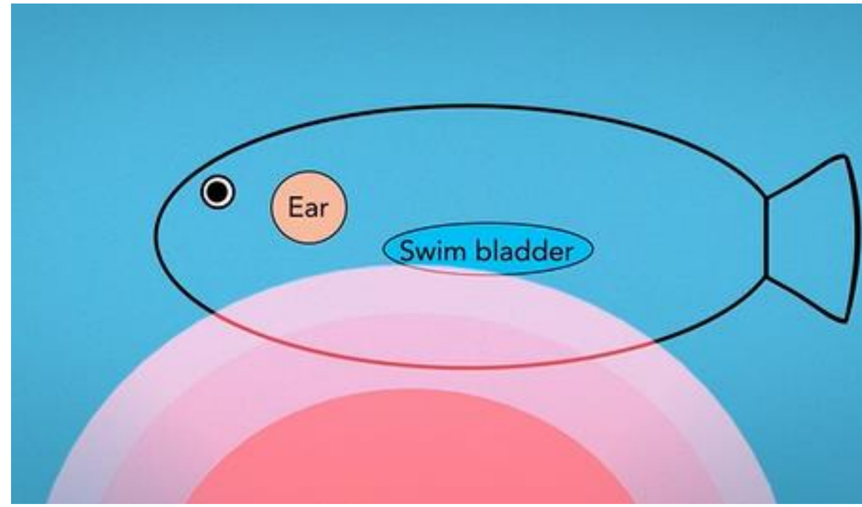
Fishes are approximately the same density as water, so sound passes right through their bodies, which move in concert with the traveling sound wave. Otoliths, which are present in inner ear are much denser than water and a fish's body.

Because of the density difference between the fish's body and the otoliths, the otoliths move at a different amplitude and phase in response to sound waves than the rest of the fish.

The difference between the motion of the fish's body and the otoliths results in bending of the cilia on the hair cells that are located in the inner ear. This differential movement between the cilia and the otolith is interpreted by the brain as sound.

Hearing & Swim Bladder





Factor affecting the levels and range of frequencies that a fish can hear is the proximity of the swim bladder to the inner ear. The gas within the swim bladder has a density that is much lower than that of water and of the fish's body. As a result, the gas in the swim bladder can be easily compressed by sound pressure waves. The swim bladder changes in volume in reaction to passing sound waves, essentially re-transmitting the sound stimulus. If the re-transmitted sound from the swim bladder reaches the ear, this may result in the stimulation of the hair cells of the inner ear.

https://dosits.org/animals/sound-reception/how-do-fish-hear/

Hearing & Swim Bladder

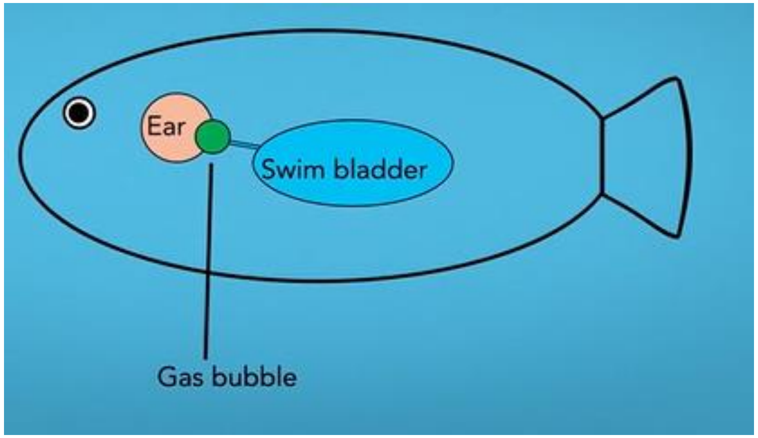
Whether the re-transmitted stimulus from the swim bladder enhances hearing depends on the physical relationship between the swim bladder and inner ear. It appears that species lacking a swim bladder (e.g., elasmobranchs and flatfishes) are not particular sensitive to sounds and have a narrow hearing bandwidth.

In contrast, the swim bladder enhances hearing in those species that have structural modifications that help conduct the sound from the swim bladder to the ear. For example in carps, minnows, catfishes the swim bladder is mechanically linked to the inner ears via the Weberian ossicles, a series of modified bones of the vertebral column (the first few vertebrae of the backbone).

The Weberian ossicles are thought to move in response to sound stimuli that cause movements of the wall of the swim bladder and generally improve hearing sensitivity.

Hearing & Swim Bladder

In other species, the swim bladder may extend forward so that it comes near to, or actually contacts, the inner ear. This is found in species as diverse as some squirrelfishes, some butterflyfishes, and in the Atlantic cod. In these cases, when the re-transmitted sound from the swim bladder has to go only a very short distance, and so it is more likely to stimulate the inner ear.



One of the most interesting examples of a structural modification that enhances hearing is found in the clupeiform fishes (e.g., herrings, shads, sardines, anchovies). These fishes have a pair of elongated gas-filled ducts that extend from the swim bladder and enter the skull. Each duct ends in a small bubble of compressible gas that comes in contact with a region of the inner ear, the utricle. The presence of a gas bubble in close proximity to the utricle enhances the ability of the swim bladder to stimulate the ear and thus increases hearing sensitivity to a wide range of frequencies.

Chemosensory Organs

Fish have two well defined chemical-sensing system

1. **Gustatory System (Taste)**

2. **Olfactory System (Smell)**

Chemo-sensory Behavior

Feeding → **Gustation**

Detecting Danger

Non sexual Social interaction

Orientation

Reproductive synchrony

} **Olfactory**

Gustatory System

The sense of taste is generally defined as the portion of nervous system associated with sensory cells of taste buds.

Although, fishes have dense concentration of taste buds in their mouth, the distribution of these structure may also frequently include the gills and exterior surface of the animal.

The gustatory sense of fishes is associated with distinct cranial nerves (VII, IX, X), all of which are projected to different areas of brain.

Taste Buds

✓Sensory cells of taste buds present on the external body, lips and rostral palate form synapse with facial (cranial nerve VII) neurons

✓Sensory cells of taste buds present along the floor of the oral cavity and gill rakers of first gill arch form synapse with glossopharyngeal (cranial nerve IX) neurons

✓Sensory cells of taste buds present more posterior in pharynx synapse with vagal (cranial nerve X) neurons

❖Taste buds that synapse with cranial nerve VII are important in appetitive (food search) feeding activity

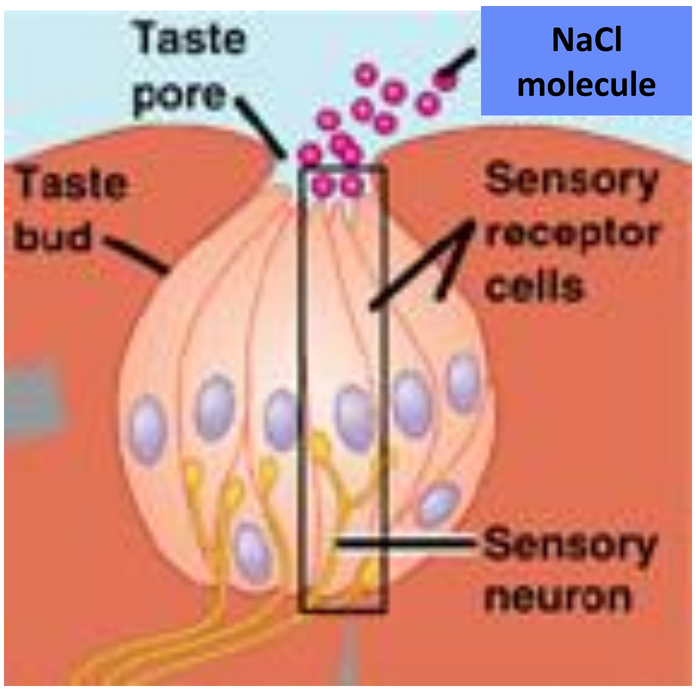
❖Taste buds that synapse with IX and X cranial nerves are important in consummatory (ingestive and swallowing) feeding behavior.

Taste bud

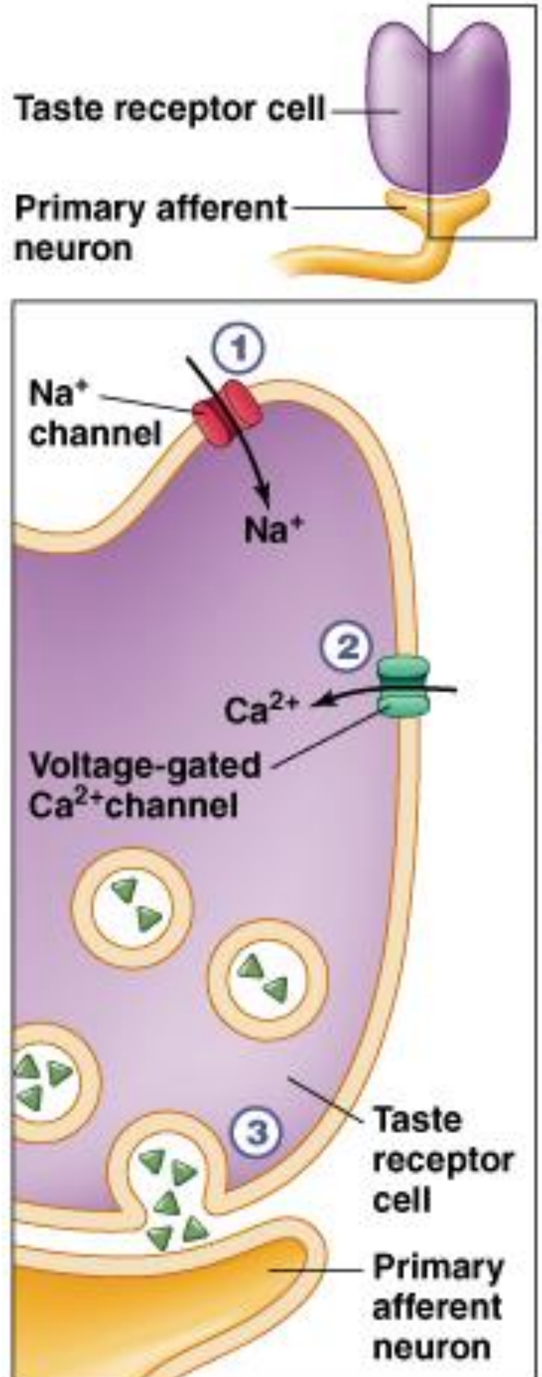
Taste Physiology

Chemical stimuli dissolved in the water enter the mucous layer at the apical portion of the taste bud and bind to taste receptor molecules located within the membrane of the apical microvilli of sensory cells.

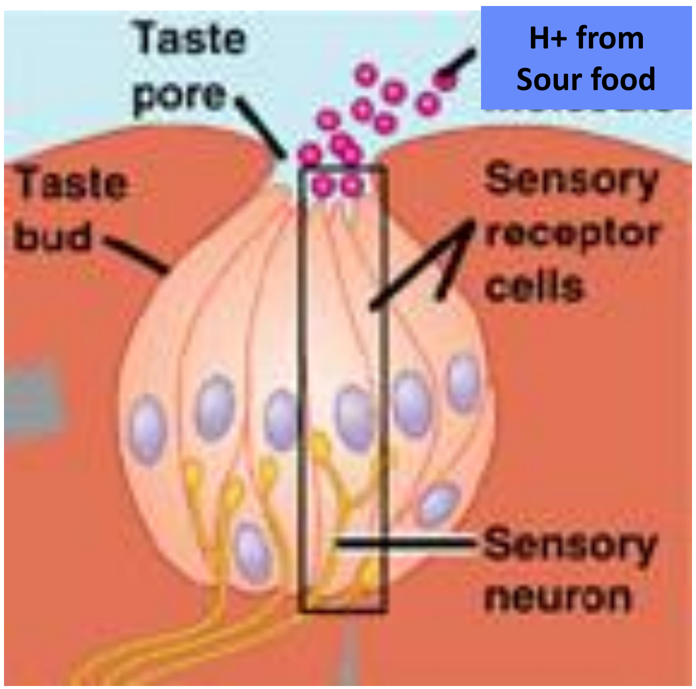
These interaction leads to a membrane conductance change, depolarization of the cell and release of a neuro-transmitter that results in either the production or modulation of action potential activity in the taste fibers. This series of events, termed as "taste transduction".

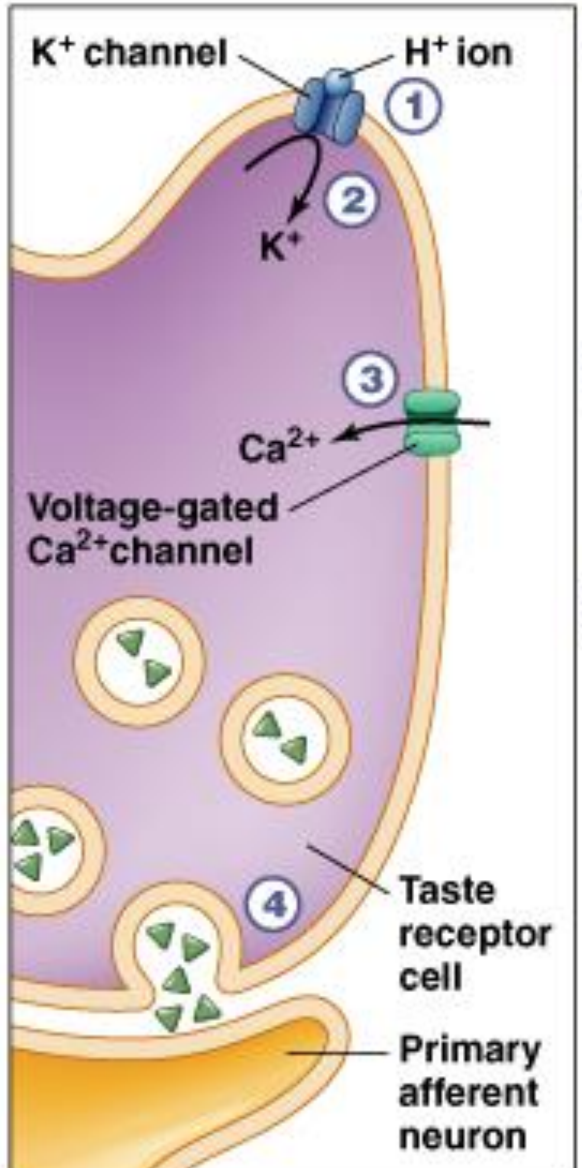


Salty Taste Transduction



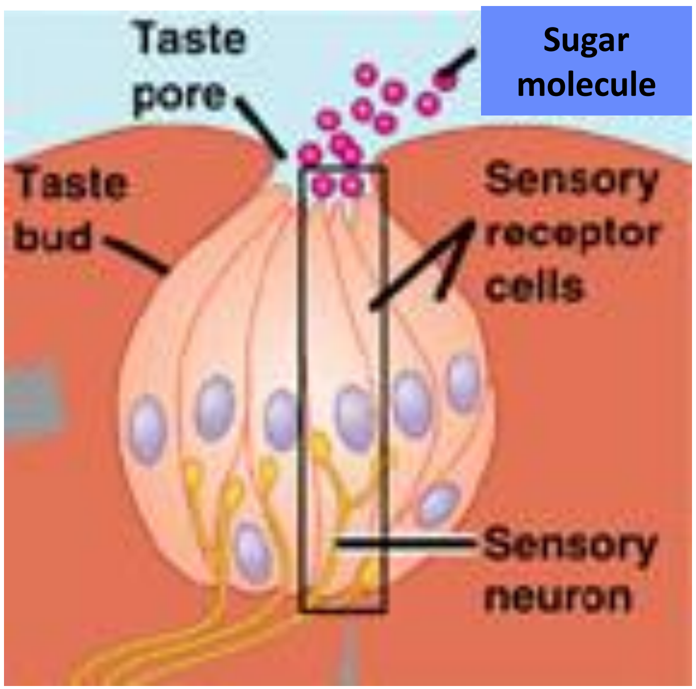
1. Na^+ from salty food enters through a Na^+ channel.
2. The resulting depolarization opens voltage-gated Ca^{2+} channels.
3. The influx of Ca^{2+} causes neurotransmitter release.



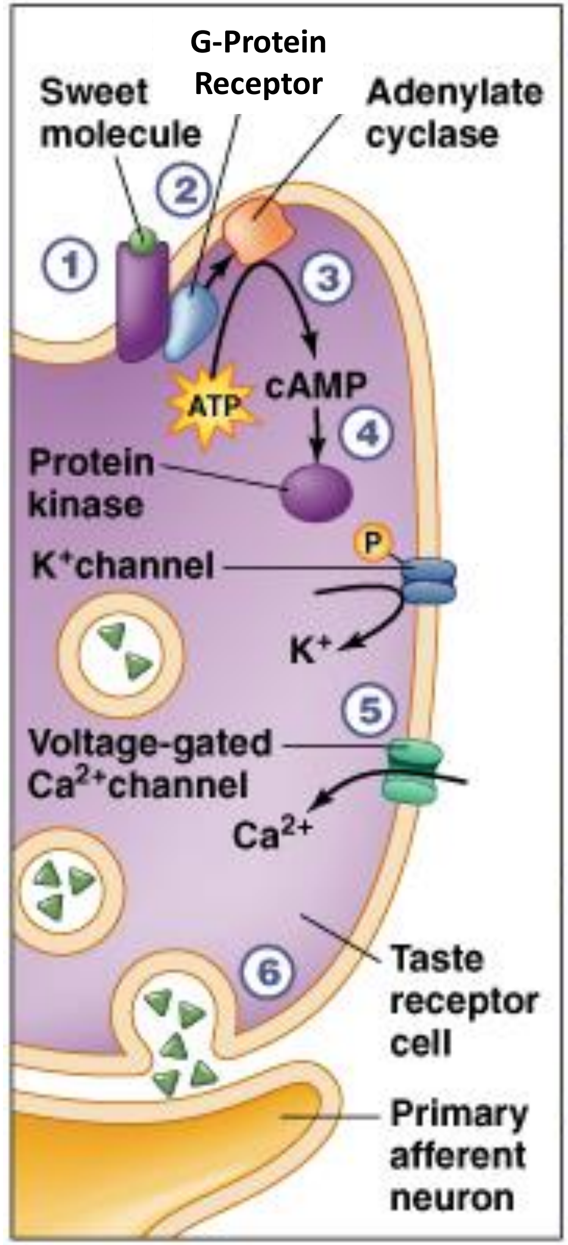


1. H^+ ions from sour foods block the K^+ channel.
2. This blockage prevents K^+ from leaving the cell.
3. The resulting depolarization opens voltage-gated Ca^{2+} channels.
4. The influx of Ca^{2+} causes neurotransmitter release.

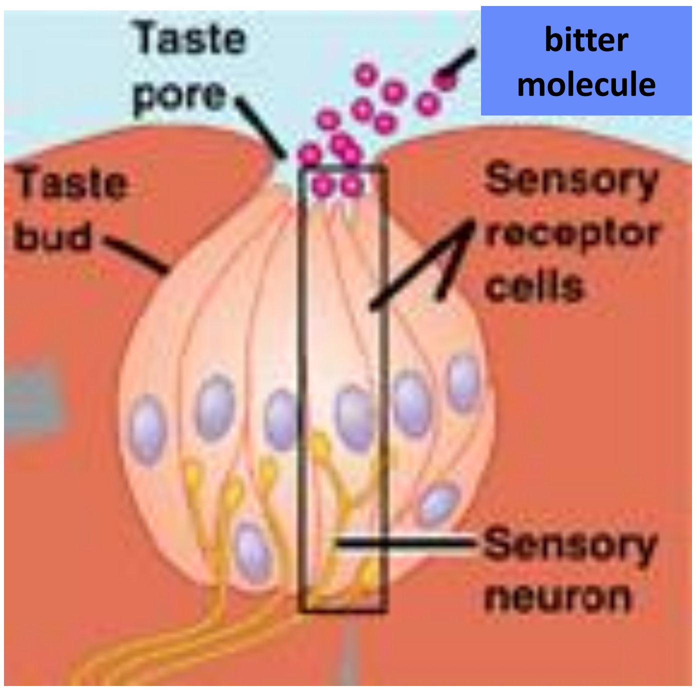
Sour Taste Transduction



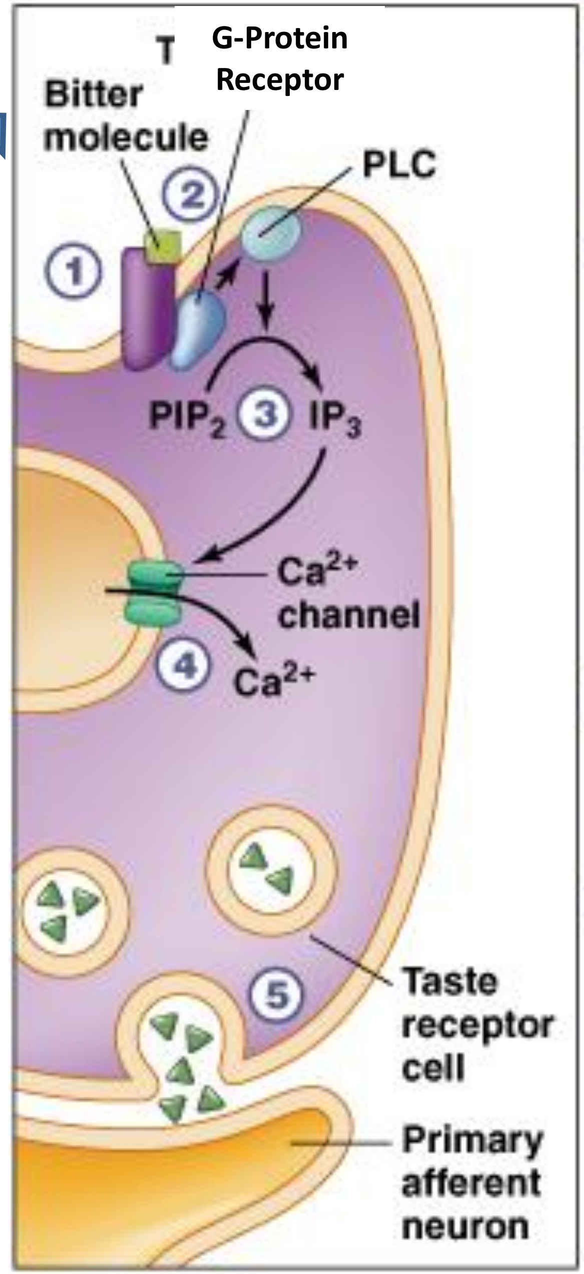
Sweet Taste Transduction



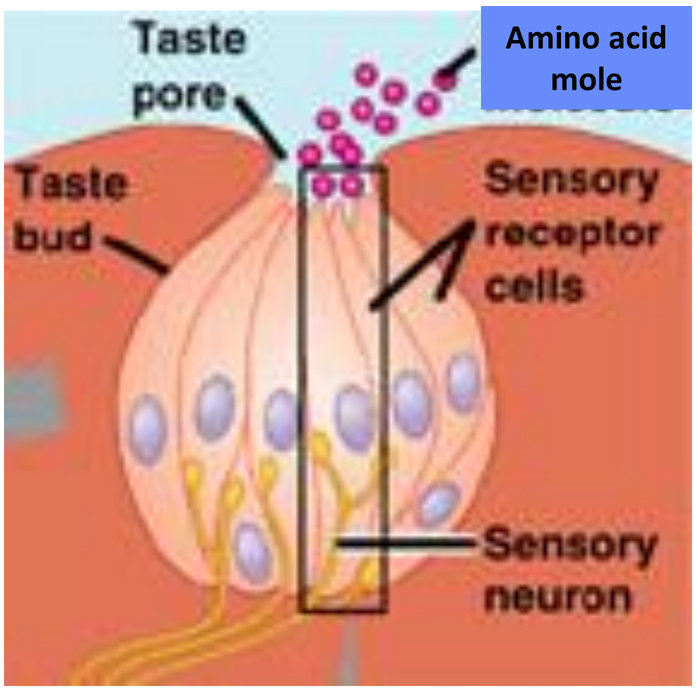
1. A sweet substance binds to its receptor, causing a conformational change.
2. The activated G protein, gustducin, activates adenylate cyclase.
3. Adenylate cyclase catalyzes the conversion of ATP to cAMP.
4. The cAMP activates a protein kinase that phosphorylates and closes a K^+ channel.
5. The resulting depolarization opens voltage-gated Ca^{2+} channels.
6. The influx of Ca^{2+} causes neurotransmitter release.



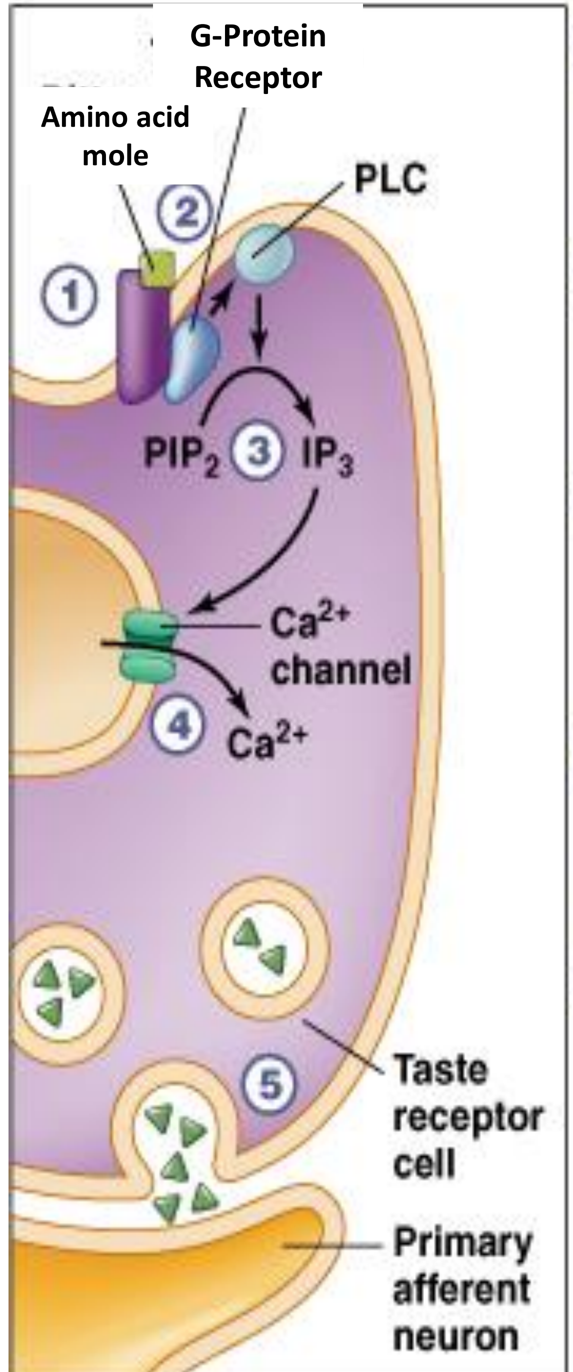
Bitter Taste Transduction



1. A bitter substance binds to its receptor, causing a conformational change.
2. The activated G protein, transducin, activates phospholipase C (PLC).
3. PLC catalyzes the conversion of PIP_2 into the second messenger IP_3.
4. IP_3 causes the release of Ca^{2+} from intracellular stores.
5. The influx of Ca^{2+} causes neurotransmitter release.



Amino acid taste Transduction



1. Amino acid molecule binds to its receptor, causing a conformational change.
2. The activated G protein, transducin, activates phospholipase C (PLC).
3. PLC catalyzes the conversion of PIP_2 into the second messenger IP_3.
4. IP_3 causes the release of Ca^{2+} from intracellular stores.
5. The influx of Ca^{2+} causes neurotransmitter release.

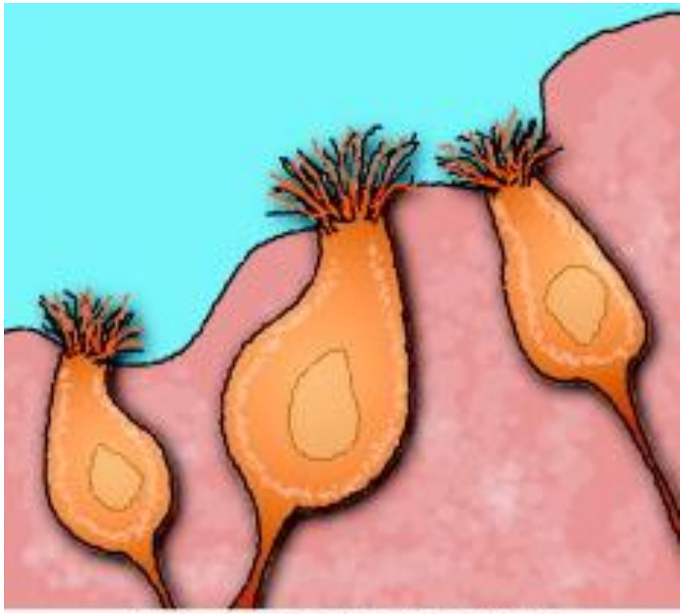
Olfactory System

Olfactory system mediates responsiveness to a much broader range of stimuli, including learned food odors, geographic locations and pheromones.

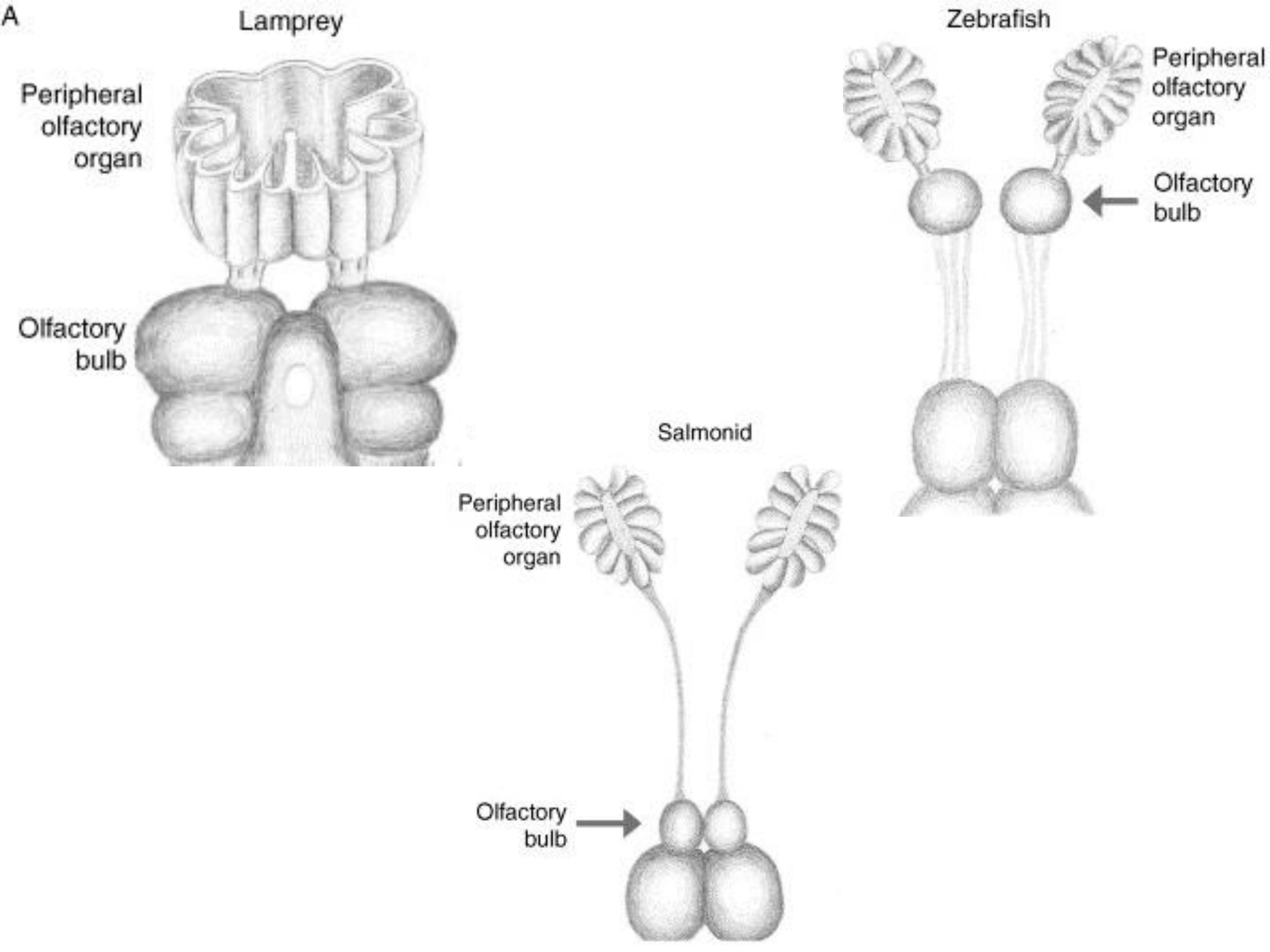
The variety of stimuli detected by the olfactory sense are much greater than gustatory system.

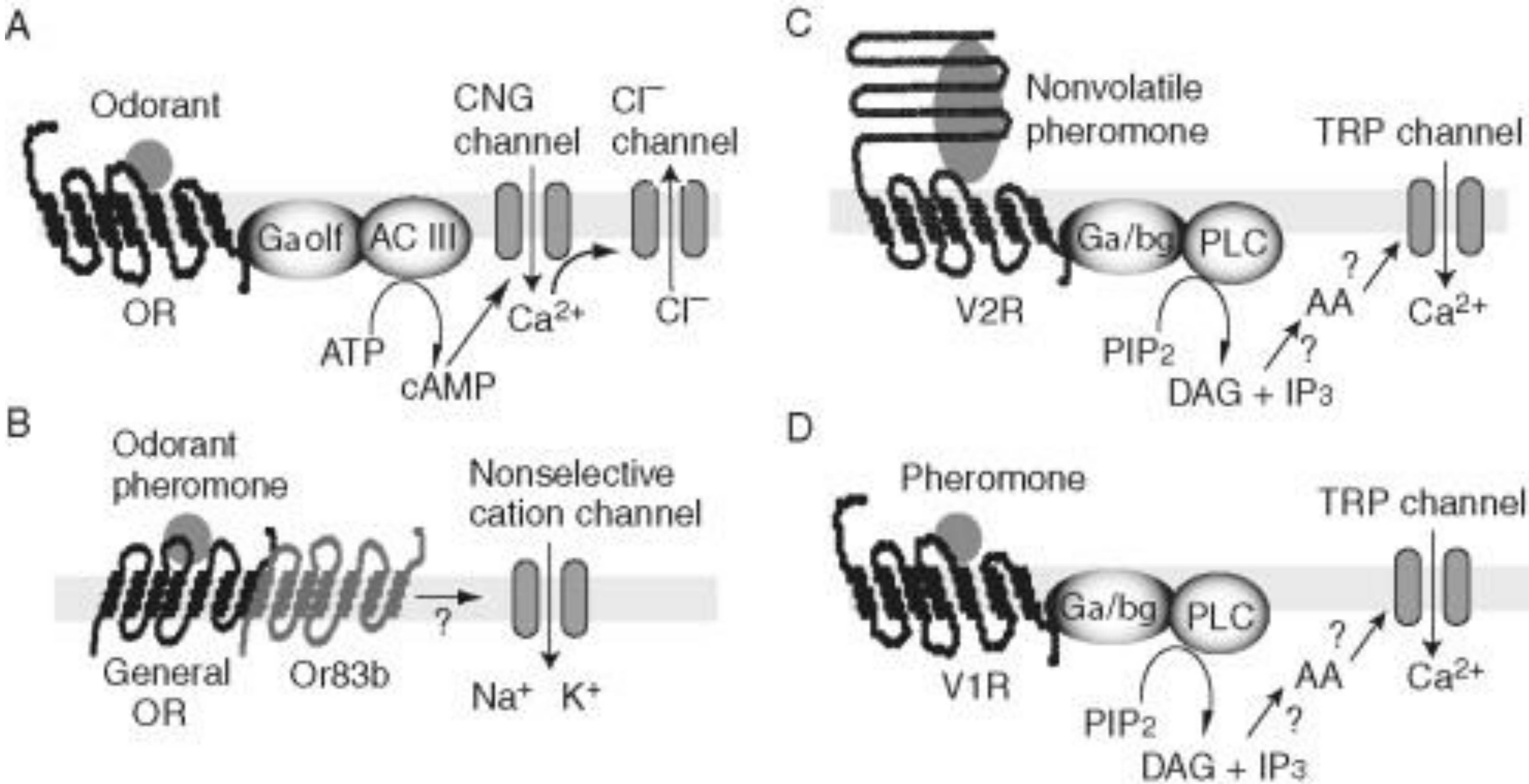
Olfactory sensitivity is mediated by a single cranial nerve (**the olfactory nerve**) projected directly to the brain and regenerate throughout the life of animal.

In fishes, olfactory receptor cells are located in olfactory epithelium which covers much of the surface of olfactory rossette, a structure found within the olfactory chamber of fish rostrum



Olfactory sensory neurons


A
Lamprey
Peripheral olfactory organ
Olfactory bulb
Zebrafish
Peripheral olfactory organ
Olfactory bulb
Salmonid
Peripheral olfactory organ
Olfactory bulb


A
Odorant
CNG
channel
Cl⁻
channel
Ga olf
AC III
OR
ATP
cAMP
Ca2+
Cl⁻
B
Odorant
pheromone
Nonselective
cation channel
?
General
OR
Or83b
Na+
K+
C
Nonvolatile
pheromone
TRP channel
Ga/bg
PLC
V2R
?
AA
Ca2+
PIP2
?
DAG + IP3
D
Pheromone
TRP channel
Ga/bg
PLC
V1R
?
AA
Ca2+
PIP2
?
DAG + IP3

Olfactory Stimuli

- **Amino acids**
- **Bile acids**
- **Gonadal steroids and derivatives**
- **Prostaglandins**
- **Various alcohol, amines, carboxylic acids, nucleotides, aromatic hydrocarbons**