The Chemical Senses

Introduction

Virtually every cell in every organism is sensitive to chemicals (chemical messengers). In relation to human sensory perception we are especially concerned with:

- Taste (Gustation) detected by gustatory cells.
- Smell (Olfaction) detected by olfactory cells.
- Other chemical sensations detected by chemoreceptors.

Taste

Basic Tastes

Taste encompasses taste preferences, taste aversions, and taste cravings. Basic tastes include:

- Salty –triggered by NaCl.
- Sour – triggered by H^+.
- Sweet – triggered by sugar and some amino acids.
- Bitter – triggered by quinine, K^+, Mg^{2+}.
- Umami – triggered by monosodium glutamate (MSG).

Flavors are a combination of basic tastes and also involve the combination of taste, smell and feel

The Organs of Taste

Organs detecting taste involve the tongue, palate, pharynx, and epiglottis

- Most of the tongue is sensitive to all basic tastes, however:
  - The tip of the tongue is most sensitive to sweetness
  - The sides of the tongue are most sensitive to saltiness and sourness
  - The back of the tongue is most sensitive to bitterness
- The surface of the tongue contains small projections called papillae:
  - Foliate papillae are shaped like ridges.
  - Vallate papillae are shaped like pimples
  - Fungiform papillae are shaped like mushrooms
- Each Papilla has one to several hundred taste buds
  - Each taste bud has 50-150 taste cells

Taste Receptor Cells

- The chemically sensitive part is in the apical end where microvilli project into the pore.
- Form synapses at the basal end with gustatory afferent axons.
- Also form electrical and chemical synapses with some of the basal cell.
  - Some of the basal cells synapse onto the sensory axons.

Taste Transduction

An oral stimulus causes an electrical response.

Saltiness

- Na^+ channels (insensitive to voltage and blocked by amiloride) stay open all the time.
- Na^+ passes through these channels and cause depolarization which:
    - Opens voltage gated Na^+ channels.
    - Opens voltage gated Ca^{2+} channels.
    - Causes release of neurotransmitter.

Sourness

- H^+ passes through amiloride sensitive Na^+ channels.
- H^+ blocks K^+ channels and causes depolarization.

Bitterness

- Involves the T2R family of G-protein coupled receptors (30 or more types).
- PLC is activated which converts PIP2 into IP3.
    - IP3 opens Ca^{2+} channels in the endoplasmic reticulum and Na^+ channels in the plasma membrane and causes depolarization.
    - Depolarization opens voltage gated Ca^{2+} channels
    - Causes release of neurotransmitter.

Sweetness

- Involves the T1R2+T1R3 family of G-protein coupled receptors.
- PLC is activated which converts PIP2 into IP3 as above for bitterness.

Umami

- Involves the T1R1
- +T1R3 family of G-protein coupled receptors.
- PLC is activated which converts PIP2 into IP3 as above for bitterness.

Central Taste Pathways

- The tongue and throat are innervated by three cranial nerves
    - The anterior 2/3 of the tongue is innervated by the Facial nerve (cn 7).
    - The posterior 1/3 of the tongue is innervated by the Gglossophyaryngeal nerve (cn 9).
    - The throat is innervated by the Vagus nerve (cn 10).
- Cranial nerves 7, 9 and 10 synapse within the Gustatory Nucleus (of the Solitary Nucleus).
- For conscious appreciation, neurons of the Gustatory Nucleus synapse in the:
    - Thalamus (Ventral Posterior Medial Nucleus) which then connects to the:

  - Primary Gustatory Cortex (in the Inferior Parietal Lobe and Insular Cortex).
- For control of feeding and digestion, neurons of the Gustatory Nucleus synapse in:
  - Regions of the Medulla involved in swallowing, salivation, gagging, vomiting, digestion, respiration.
  - Regions of
  - Hypothalamus and limbic system involved in palatability and hunger.

Neural Coding of Taste

- At the start of the gustatory system something like labeled lines are used.
  - Individual taste receptor cells are often fairly selectively sensitive.
  - Primary sensory axons are less specific.
  - Most central taste neurons are broadly responsive.
- Sensory axons may combine information from several other receptors and from other papillae.
- Central neurons receive signals from many axons.
  - Responses of a large number of broadly tuned neurons specify the properties of a stimulus (population coding).

Smell

Smells combine with taste to identify foods; smells warn of potentially harmful substances; smells allow for chemical communication via pheromones.

The Organs of Smell

- The nose and olfactory epithelium contains:
  - Olfactory cells which are sensory neurons.
  - Glia-like supporting cells that produce mucus.
  - Basal cell that are stem cell like and are responsible for replacing the olfactory cells and the supporting cells.

Olfactory Receptor Cells (Neurons)

- Olfactory receptor cells are neurons with three major sections:
  - A complex first section with cilia, a bulb, and a dendrite
  - Cell body
  - Axon

Odorant Transduction

- In the cilia odorant binds to a G-protein coupled receptor.
  - Adenylyl cyclase is activated and ATP is converted to cAMP.
  - cAMP binds to cation channels.
- Sufficient depolarization at the cell body will generate an action potential in the axon.

- There are more than 1000 different odorant receptor genes.
- As with taste, olfaction utilizes a population coding scheme.

Central Olfactory Pathways

- Each olfactory bulb contains about 2000 glomeruli
    - About 25,000 primary olfactory axons synapse on the dendrites of about 100 second order olfactory neurons in each of the glomeruli.
    - Receptor cells of the same type (same receptor gene expressed) connect to only 2 glomeruli.
    - There are excitatory and inhibitory interconnections within and among the glomeruli.
- Axons of the second order olfactory neurons travel through the olfactory tract to synapse in the Olfactory Cortex (lateral and ventral to the Hippocampus) and in the Temporal Lobe.
- Axons of the second order olfactory neurons also synapse on neurons in the Olfactory Tubercle that in turn synapse in the Medial Dorsal Nucleus of the Thalamus.
    - Axons of neurons in the Thalamus then synapse in the Orbitofrontal Cortex.

Olfactory Information Processing

Olfactory processing involves population coding, olfactory mapping, and temporal coding

- Responses from different receptor cells combine together - population coding.
- Neurons in specific places in the olfactory bulb respond to particular odors - olfactory mapping.
    - Smell of a particular chemical is converted into a map of “neural space.”
- The time of neuron firing, not just which neurons respond - temporal coding.