Chemosensory Systems
Flavor Perception

Olfaction
Taste
Texture
Temperature
Consistency
Common chemical sense
  “heat” of red pepper
  “coolness” of menthol
Taste
# 4+1 Taste Primaries

<table>
<thead>
<tr>
<th>Taste</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salty</td>
<td>Safe (approach)</td>
</tr>
<tr>
<td>Sour</td>
<td>Acidic; unripe/poor nutritional value (avoid)</td>
</tr>
<tr>
<td>Sweet</td>
<td>Nutritious (approach)</td>
</tr>
<tr>
<td>Bitter</td>
<td>Poisonous (avoid)</td>
</tr>
<tr>
<td>Umami</td>
<td>Amino acids; rich protein source (hearty; savory)</td>
</tr>
</tbody>
</table>
Anatomy of the Tongue

Papillae; Taste buds; Taste receptor cells; Microvilli

50 TRC's per bud
Types of Papillae

Mean number of taste buds = 4000 (1 log unit of variation within human population)
Any region of the tongue with taste buds contains taste cells that will respond to the major taste categories.

Nonetheless, **regional variations in sensitivity** exist:
- **sweet** + **salty** preference on anterior-third of tongue;
- **bitter** at the back of the tongue;
- **sour** along back/sides of the tongue
Transduction

**Salty**

Na\(^+\) ions cross microvillus wall at specialized sites; depolarizing cell; action potentials generated

**Sour**

H\(^+\) ions bind to receptor sites; inhibit K\(^+\) pumps; cell depolarizes and generates neural “spikes”

\([H^+]\) corresponds to acidic strength (i.e., pH)
Transduction

**Sweet; Bitter; Umami**

**G-protein** receptor site woven through microvillus wall

Taste molecule interacts with G-protein:
- inhibits ionic flow across membrane;
- cell depolarizes and starts firing (action potential)
Sensory Coding

• **Intensity**
  Taste cell neurons increase their firing rate with increases in stimulus concentration (mmol)

• **Quality**
  Some sort of global cross-fiber “patterning” whose nature remains elusive
  Individual taste receptor cells have transduction sites for multiple taste categories
Innervation of the Tongue

Facial Nerve (VII)

Glossopharyngeal nerve (IX)

X = Vagus nerve
Ascending Taste Pathways

Posterior frontal lobe; buried in roof of the Sylvian fissure
Primary Taste Cortex Cell Tuning

Cortical taste cells show greater category specificity than taste cells on the tongue.

Note the over-representation of cells specifically tuned to the sweet and salty categories.
Motivational states (e.g., hunger) do not affect the sensitivity of cells in the primary gustatory cortex. However, motivational, emotional and learning experiences heavily influence the sensitivities of cells in the secondary gustatory cortex.
## Sample Taste Detection Thresholds

*(mmol concentrations in water)*

<table>
<thead>
<tr>
<th>Category</th>
<th>Example</th>
<th>Threshold (mmol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>Saccharin</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>Aspartame (artificial sweetener)</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Sucrose (table sugar)</td>
<td>0.65</td>
</tr>
<tr>
<td>Salty</td>
<td>Calcium chloride</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>Sodium chloride</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Potassium chloride</td>
<td>6.3</td>
</tr>
<tr>
<td>Sour</td>
<td>Citric acid</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Acetic acid (vinegar)</td>
<td>0.1</td>
</tr>
<tr>
<td>Bitter</td>
<td>Quinine</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Caffeine</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Urea</td>
<td>15.0</td>
</tr>
<tr>
<td>Umami</td>
<td>Monosodium glutamate</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Great variation in detection thresholds both within and between categories

**General Sensitivity Rule-of-thumb:**
Bitter > Sour, Salty, Sweet > Umami
Temperature vs. Sensitivity

Note: This figure is somewhat inconsistent with our textbook (viz., Fig 4.9)
Difference Thresholds

• JNDs range from 15-25%
  Difficult to predict based upon molecular properties

• Direct scaling procedures tend to yield power law exponents in the 0.8-0.93 range (sucrose = 0.93) (slight compressive nonlinearity)
  \[ I = kC^{0.93} \]

• Taste is the least sensitive of the human senses
Individual Differences in Taste Bud Count (Fungiform Papillae)

[Taste Lab] (PTC/PROP Tasters)
Super-Taster  Normal Taster
Although the search for a general-purpose model for representing the qualitative dimensions of taste has yet to be successful....

Task-specific scales based upon well-defined sensory descriptors have proved to yield reliable results for quality control of foods and beverages.

Much training is required before reliability is achieved.
Taste Stimulus Identification
(with and without olfaction)

Identification of stimulus solutions with vs. without wearing a nose plug to attenuate smell cues (taste+smell = RED bars)

Taste, when isolated from olfaction, is a relatively impoverished sensory input
Olfactory System
Stimulus Requirements

Airborne molecules (vaporous)

Fat soluble (diffusion across mucosa)

No established geometric relationship between molecular geometry and scent category (but L- vs. D- isomer findings)

(“Shape Theory” dominates but yet to be proven)
(Luca Turin’s controversial “quantum tunneling theory”)

Adaptive Advantages of Olfaction

• Locate & track food/prey at a distance
• Long-distance warning beyond line-of-sight and in the dark
• Sexual attraction
  (Are there human pheromones?)
• Hedonic reward system
  Gastronomic delights; Fine wine; etc.
Olfactory Epithelium

ORC = olfactory receptor cell

ORCs replaced every 30-60 days in rodent models
...but what about humans?
Olfactory Transduction
G-Protein Receptor/Cascade

Olfactory Receptor Cell

Odourant Receptor

G

cAMP

Na^+

Mucus layer

ORC Membrane

Cilium
Olfactory Bulb

12 Million ORCs in olfactory epithelium (200 Million in Bloodhound)
1000 olfactory proteins/receptor types (5% of genome in rat; Axel & Buck)
300+ and counting olfactory proteins in humans (1% of genome)
2000 Glomeruli in olfactory bulb
“Odor Maps”

Pattern of glomeruli activation in oestrous female ferrets after exposure to control, female and male scent markings

Woodley & Baun (2004)
*European J. Neuroscience*

Glomeruli Activation Movie
Ascending Pathways

- Olfactory bulb
- Orbitofrontal cortex
- Piriform cortex
- Entorhinal cortex
- Olfactory tract
- Olfactory tubercle
- Amygdala
- Piriform cortex
- Entorhinal cortex
- Anterior olfactory nucleus
Ascending Pathway Schematic

- **Olfactory receptor**
- **Olfactory nerve**
- **Olfactory bulb**
- **AON* (anterior olfactory nucleus)**
- **Olfactory tract**
- **Entorhinal cortex**
- **Piriform cortex**
- **Olfactory tubercle**
- **Primary olfactory cortex**
- **Thalamus**
- **Hippocampus**
- **Orbitofrontal cortex**

*Secondary Gustatory Cortex*
Olfactory Models and Psychophysics
Henning’s Smell Prism
(6 primaries odors + geometry)
One Face of the Henning Smell Prism
MultiDimensional Scaling Approach

Similarity

Pleasantness

Clove
Camphor
Menthol
Cinnamon
Eucalyptus
Vanilla
Lemon
Turpentine
Feces
Sweaty socks
Vinegar
Rotten eggs
## Highly Diverse Smell Thresholds

(micrograms/Liter)

<table>
<thead>
<tr>
<th>Smell</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musk</td>
<td>0.00007</td>
</tr>
<tr>
<td>Lemon</td>
<td>0.003</td>
</tr>
<tr>
<td>Vanilla</td>
<td>0.002</td>
</tr>
<tr>
<td>Rotten eggs</td>
<td>0.2</td>
</tr>
<tr>
<td>Bitter almond</td>
<td>3.0</td>
</tr>
<tr>
<td>Perspiration</td>
<td>9.0</td>
</tr>
<tr>
<td>Banana</td>
<td>39.0</td>
</tr>
<tr>
<td>Wintergreen</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Million-fold difference between most and least sensitive thresholds.
Olfactory Sensitivity

- Absolute thresholds vary by 6 log units across known stimulus set
- JND = 7%
  More sensitive than taste
  Implications for odor localization
- Females generally demonstrate superior detection and discrimination
% Identification of Common Odors

(Females > Males except dark bars)
% Identification of Common Odors
Some Intriguing Findings

- Wallace (1977) 80-90% accurate gender identification upon “blind” sniff of the hand
- Russell (1977) 22-of-29 college students could discriminate their own sweaty T-shirt from 2 distractors
- Human “pheromones”? (vestigial VNO)
- McClintock Effect (slippery phenomenon...i.e., unreliable effect)