Senses II

taste  smell  touch
Chemical senses

Chemical senses – sense of taste and smell

Chemoreceptors respond to chemical compounds dissolved in water

- Taste – substances dissolved in saliva
- Smell – substances dissolved in nasal mucosa
Sense of taste

- There is about 10,000 taste buds located on the tongue.
- Taste buds are located in tongue papillae.
- Three main types of papillae:
  - philiform, fungiform, a circumvallate.
  - fungiform and circumvallate contains taste buds.
Anatomy of taste buddies

- Each taste buds consists of 3 main types of cells:
  - support cells – surrounding receptor cell
  - basal cells – „stem“ cells
  - chemoreceptor itself – taste cells
Sense of taste

Figure 15.1
Taste feelings

- Five (Six) main taste perceptions
  - sweet – sugar, saccharine, alcohol, some aminoacids
  - salty – iron ions
  - sour – $H^+$ ions
  - bitter – alcaloids as e.g. chinidin, nicotin
  - umami – glutamic acid
  - fat – fatty acids
Sense of taste

- To percept and feel, the chemical compound must:
  - dissolve in salive
  - to get into contact with cilia on taste cells

- Substance binding to cilia will:
  - depolarize membrane of taste receptor, and neurotransmitter is released
  - generator action potential is formed, that will trigger action potential
### Examples of some human thresholds

<table>
<thead>
<tr>
<th>Taste</th>
<th>Substance</th>
<th>Threshold for tasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salty</td>
<td>NaCl</td>
<td>0.01 M</td>
</tr>
<tr>
<td>Sour</td>
<td>HCl</td>
<td>0.0009 M</td>
</tr>
<tr>
<td>Sweet</td>
<td>Sucrose</td>
<td>0.01 M</td>
</tr>
<tr>
<td>Bitter</td>
<td>Quinine</td>
<td>0.000008 M</td>
</tr>
<tr>
<td>Umami</td>
<td>Glutamate</td>
<td>0.0007 M</td>
</tr>
<tr>
<td>Sweet</td>
<td>1-propyl-2 amino-4-nitrobenzene</td>
<td>0.00002 M</td>
</tr>
<tr>
<td>Sweet</td>
<td>Lactose</td>
<td>0.03 M</td>
</tr>
</tbody>
</table>
**(a) Salty**

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

**(b) Sour**

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

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.

(d) Bitter

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.
CNS pathway

- Head nerved VII, IX and X carry the action potential from taste buddies into solitary nuclei in medulla oblongata

- These impulses are led through thalamus into:
  - cortex (insula frontal cortex)
  - hypothalamus and limbic system
CNS pathaway

Figure 15.2
Other senses and taste

- Taste is smell and other sensory functions for 80%
- Thermoreceptors, mechanoreceptors, nociceptors will affect taste
- Food temperature and surface will affect taste
Sense of smell

- Smell organ lies in olfactory epithelium, which is in upper nasal conchae
- Receptor cells of smell are bipolar neurons with olfactory branched cilia
- Olfactory receptors are surrounded by supporting cells
- Basal cells are on basal membrane
Smell physiology

- Olfactory receptors will respond to several different smell causing chemicals
- When bound to ligand on cilia, protein complex will trigger G-protein mechanism, and formed cAMP as a second messenger:
- Opens Na\(^+\) and Ca\(^{2+}\) channels, causing the cell to depolarize, and action potential is created
Olfactory Transduction Process

Odorant binding protein

Active Na\(^+\)/Ca\(^{2+}\) channel
Ca\(^{2+}\)-gated Cl\(^-\) channel
Na\(^+\)/Ca\(^{2+}\) exchanger

Inactive
Active

Adenylate cyclase
ATP
CAMP

Na\(^+\) influx causes depolarization
Depolarization of olfactory receptor cell membrane triggers action potentials in axon of receptor

Figure 15.4
- Olfactory receptor cells are connected to mitral cells.
- Glomerular and mitral cells in the bulbus olfactorius act as primary olfactory centers and process olfactory signals.
- Mitral cells send impulses into:
  - Cortex
  - Hypothalamus, amygdala, and limbic system.
Levels of smell and taste

- Normosmia = normal smell
- Anosmia = without smell
- Ageusia = without taste
- Hyposmia = decreased perception of smell
- Hypogeusia = decreased perception of taste
- Hyperosmia = increased perception of smell
- Phantosmia = perception of smells that do not exist
Somatic senses/perception can be found in whole body, they are connected to visceral organs, skin, muscles and joints.

- touch
- pressure
- proprioception
- temperature
- pain
How do corpuscles work?

- Mechanical stimulation will deform individual corpuscles
  - this leads to mechanical distension/deformation

- Deformation/distension will open ion channels in receptor membrane
  - $\text{Na}^+ \text{ influx} \rightarrow \text{action potential formation}$
Summary of corpuscles

- Meissner
  - Light touch
- Merkel
  - Pressure, deep touch
- Pacinian
  - Vibration and pressure
- Ruffini
  - Skin stretch and finger movement
- Free nerve ending
  - pain
- Golgi tendon
- Muscle spindle
General (Somatic) Senses
(continued)

- Merkel corpuscle
- Meissner's corpuscle
- Pacinian corpuscle
- Free nerve ending
- Golgi tendon organ
- Muscle spindle
### Table 12.1  Response characteristics of the four mechanoreceptor populations

<table>
<thead>
<tr>
<th>Adaptation Rate</th>
<th>Size of Receptive Field</th>
<th>Small</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>FA I (Meissner)</td>
<td>FA II (Pacinian)</td>
<td></td>
</tr>
<tr>
<td>Slow</td>
<td>SA I (Merkel)</td>
<td>SA II (Ruffini)</td>
<td></td>
</tr>
</tbody>
</table>

FA I = fast-adapting type I, FA II = fast-adapting type II, SA I = slow-adapting type I, and SA II = slow-adapting type II. The receptor ending associated with each type is shown in parentheses.
Several nerve fibres come from different parts of the body.
Primary somatosensory areas in brain

- Central sulcus
- S1
- Areas 5, 7
- Lateral sulcus
- S2
- S1
- S2
Senzoric homunculus

(b) Somatosensory map

Primary somatosensory cortex (S1)
Secondary somatosensory cortex (S2)
“Pain is an unpleasant senzoric and/or emotional experience which is created during real or possible tissue damage”
The multipunctate receptive field of an Aδ nociceptor.
<table>
<thead>
<tr>
<th>Fibre Group</th>
<th>Innervation</th>
<th>Mean Diameter</th>
<th>Mean Conduction Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A α</td>
<td>Primary motor to skeletal muscles.</td>
<td>15 µm</td>
<td>100 m/sec</td>
</tr>
<tr>
<td>β</td>
<td>Cutaneous touch and pressure afferents</td>
<td>8 µm</td>
<td>50 m/sec</td>
</tr>
<tr>
<td>γ</td>
<td>Motor to muscle.</td>
<td>6 µm</td>
<td>20 m/sec</td>
</tr>
<tr>
<td>δ</td>
<td>Mechanoreceptors, nociceptors, thermoreceptors.</td>
<td>&lt;3 µm</td>
<td>15 m/sec</td>
</tr>
<tr>
<td>B</td>
<td>Sympathetic preganglionic.</td>
<td>3 µm</td>
<td>7 m/sec</td>
</tr>
<tr>
<td>C</td>
<td>Mechanoreceptors, nociceptors, thermoreceptors, sympathetic postganglionic.</td>
<td>1 µm</td>
<td>1 m/sec</td>
</tr>
</tbody>
</table>
Pain mediators

- $K^+$, $H^+$
- proteolytic enzymes
- bradykinin, histamin, prostaglandins
- serotonin
- leukokinin
- substance P
- acetylcholin
Practicals

- Detection of olfactory sensation
- Detection of taste sensation
- Examination of skin sensation
- Adaptation in skin receptors