Chapter 7: Audition, the Body Senses, and the Chemical Senses
### Sound Waves

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<td>Loudness</td>
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<td>Frequency</td>
<td>Pitch</td>
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<tr>
<td>Complexity</td>
<td>Timbre</td>
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- **Loudness**
  - **Loud**
  - **Soft**

- **Pitch**
  - **Low**
  - **High**

- **Timbre**
  - **Simple**
  - **Complex**

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Divisions of the Ear

- **Outer ear:**
  - Channel to tympanic membrane

- **Middle ear:**
  - Ossicles

- **Inner ear:**
  - Cochlea
The Cochlea

- The **cochlea** is formed from three chambers:
  - Scala vestibuli and scala media are separated by a membrane
  - Scala tympani and scala media are separated by the basilar membrane

- Hair cells within the organ of Corti transduce sound waves into nerve impulses

- The organ of Corti consists of
  - Basilar membrane (forms the base)
  - Tectorial membrane (forms the roof)
  - Hair cells in between
Auditory Hair Cells

- Two types of hair cells are located within the human organ of Corti
  - *Inner hair cells* (approximately 3500) form a single line of cells along the basilar membrane
    - Destruction of inner hair cells eliminates hearing
  - *Outer hair cells* (approximately 12,000) are arranged in three rows along the basilar membrane
    - Outer hair cells serve a structural function
  - Cilia project from the top of each hair cell
    - The tectorial membrane is attached to the outer hair cell cilia
    - When sound waves move the basilar and tectorial membranes, the cilia bend in one direction or the other
    - Shear of the cilia generates a receptor potential that releases a neurotransmitter

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Auditory Transduction

- Cilia tips are joined by a fiber link
- Cilia movement produces tension of the link which opens an ion channel in the adjacent tip
- Calcium and potassium ions flow into the cilia and produce a depolarization
Auditory Pathways

- **Afferent pathways:**
  - Through cochlear nuclei
    - To superior olivary nuclei
    - To inferior colliculus
    - To medial geniculate
    - To auditory cortex

- **Efferent pathway:**
  - Olivocochlear bundle
Place Coding of Pitch

- Different frequencies produce maximal distortion of basilar membrane
  - Sound vibration produces a traveling wave
    - High frequency: near base of basilar membrane
    - Moderate frequency: near apex of basilar membrane
  - Different regions of the basilar membrane project to different areas of auditory cortex
  - Throughout the auditory system there is a tonotopic representation in which adjacent neurons receive signals from adjacent areas of the basilar membrane

- Place coding can account for medium to high sound frequencies, low frequency sounds are coded by rate of firing
Support for Place Theory

- Observations of traveling waves by von Bekesy
  - Different frequencies produce maximal displacement at different points along the basilar membrane

- Antibiotics
  - Induce hair cell loss first at base of basilar membrane, which produces a loss of hearing for high frequency sounds

- Cochlear implants restore speech perception by stimulating different regions of the basilar membrane

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Analysis of the Auditory System

- The various components of the auditory system detect sounds, determine sound location, and recognize sound identity.

- Lesions placed at different levels of the auditory system:
  - Bilateral auditory cortex: animal can detect pitch, intensity diff, but not “tunes”
  - Brachium of inf. colliculus: animal cannot detect frequency or intensity differences
  - Lateral lemniscus: animal is deaf
Somatosenses

- The **somatosenses** provide information relating to events on the skin and to events occurring within the body
  - The **cutaneous** senses receive various signals from the skin that form the sense of touch
    - Pressure
    - Vibration
    - Heating/cooling
    - Stimuli that damage tissue (and produce pain)
  - **Kinesthesia** provides information about the body position and movement
    - Kinesthetic signals arise from receptors located within the joints, tendons, and muscles
Morphology of Skin

Epidermis

Dermis
Cutaneous Senses

- Three different sensations are reported to the brain by receptors localized within skin
  - **Touch** involves perception of pressure and vibration of an object on the skin
    - Pacinian corpuscles detect deformation of the skin
  - **Temperature** is detected by warmth and cold receptors
    - Receptor activation is relative to the baseline temperature
    - The receptors lie at different levels of the skin (cold are close to the surface of the skin)
  - **Pain** is associated with skin tissue damage
Somatosensory Pathways

- The dorsal columns carry information related to touch (precisely localized)
- The spinothalamic tract carries pain and temperature signals (poorly localized)
- Somatosensory cortex is organized into columns
  - There may be 5-10 cortical maps of the body surface
Pain

- Pain serves a functional role for survival
  - Persons lacking pain receptors are at great risk
- Pain stimuli induce species-typical escape and withdrawal responses
  - Pain is a motivational force that can activate behavior
- Pain involves tissue destruction induced by
  - Thermal stimuli
  - Mechanical force
- Pain reception is poorly localized (as is temperature)
- Pain involves an emotional component (that can be used to modify the magnitude of pain perception)
Pain Receptors

- Receptors for pain (nociceptors)
  - Free nerve endings networks within the skin that respond to intense pressure
  - Free nerve endings that respond to heat, acids, and capsaicin (the active ingredient in chili peppers)
  - Receptors that are sensitive to ATP

- Pain receptors are found in:
  - Skin
  - Sheath around muscles, internal organs
  - Cornea of the eye
  - Pulp of the teeth

- Pain receptors are activated by mechanical, chemical stimulation
Analgesia

- Analgesia refers to the reduction of the perception of pain.
- Analgesia can be induced by external and internal stimuli:
  - Hypnosis
  - Massage
  - Acupuncture
  - Opiates
  - Placebo
  - Attention shifts

- Pain stimuli activate primary somatosensory cortex and the anterior cingulate cortex:
  - The anterior cingulate cortex is involved in the aversiveness of pain (hypnosis and PET scanner study)
Opiates and Pain

- Exogenous opiates reduce pain reactivity
- Brain produces several endorphins
- Naloxone reverses opiate activity
  - Naloxone reversibility is taken as an indication of opiate involvement
- Focal brain stimulation can reduce pain
  - PAG in particular is effective
  - Brain stimulation activates a descending pathway that modulates pain (Basbaum and Fields model)
Opiate-Induced Analgesia Circuit

Opiates inhibit activity of inhibitory neuron, thus removing inhibition on neuron that communicates with nucleus raphe magnus.

Periaqueductal gray matter in midbrain

Nucleus raphe magnus in medulla

Dorsal horn of spinal cord gray matter

To brain

Axon contains opiate receptors

Pain pathway

Interneurons inhibit neurons that transmit pain messages to brain

Cell body in dorsal root ganglion

Pain receptor
Gustation

- Gustation is related to eating foods and drinking liquids
  - Molecules within the food dissolve in saliva and activate one of four receptor types
  - Each receptor type provides information about a food
    - Sweet: safe foods
    - Salty: source of sodium ions
    - Bitter: poisonous foods
    - Sour: spoiled foods
- Flavor involves a mixture of taste and olfaction
Transduction of Taste

- Taste molecules bind with a receptor, alter membrane potential, and induce receptor potentials
  - **Saltiness**: best stimulus is sodium chloride
    - Receptor for saltiness may be a simple sodium channel
  - **Sourness** receptors respond to hydrogen ions present in acid solutions
  - **Bitterness**: typical stimulus is an alkaloid (e.g. quinine)
    - Receptors involve a hydrophobic residue
  - **Sweetness**: typical stimulus is a sugar
    - Receptors have a hydrogen ion site
Gustatory Processing

- Gustatory information is transmitted through cranial nerves 7 (anterior tongue), 9 (posterior tongue), and 10 ( palate and epiglottis)
  - First relay station for taste information is the nucleus of the solitary tract (medulla)
  - Taste information is then transmitted to primary gustatory cortex, to the amygdala, and to the hypothalamus
- Recordings from chorda tympani (7th cranial nerve) indicate that taste fibers respond to more than one taste quality and to temperature
  - In cortex, the major groups of taste-sensitive neurons were salty and sweet