Ch. 9 – Sensory Systems

• Sensation = information about environmental conditions (inside or outside of the body) is detected and sent to CNS
  – Vs. perception = consciously aware of sensation (only ~1% of sensations are perceived!)

Sensory receptors

• Sensory receptors = structures that detect stimuli (changes) in conditions both inside and outside of body and send that info to CNS in the form of action potentials (the “language” of the NS)
  – Sensory receptors are specialized to detect different kinds of stimuli: light, sound, pressure, chemicals, temperature, etc. (see next slide for general receptor types)
    • In each case, the trick is for the stimulus to trigger the opening or closing of gated sodium channels
    • Ultimately, though, what you sense (and perceive) depends on where in the brain the info is sent to
  – Sensory adaptation – receptors slow or stop responding when they are constantly stimulated
    • “Getting used to” a stimulus
    • Most sensory receptors respond maximally to changes in stimulus intensity
    • E.g. adapting to temperature of a hot bath

Steps of sensation and perception

General types of sensory receptors

• Mechanoreceptors – respond to physical distortion (stretching, compressing, twisting) of receptor
  – Touch, pressure, vibration, proprioception (body and limb position), hearing, equilibrium
• Thermoreceptors – respond to changes in temperature
• Photoreceptors – respond to light
  – Vision
• Chemoreceptors – respond to presence of chemicals
  – Smell, taste, levels of certain chemicals in body fluids (e.g. O₂, CO₂, glucose, etc.)
• Pain receptors – respond to very strong stimuli usually resulting from tissue damage (stimuli most often are chemical or mechanical in nature)
The senses

- **General senses**: touch, pressure, vibration, temperature, proprioception, pain
  - Receptors widely distributed **throughout body** and tend to be relatively **simple in structure**: free nerve endings (dendrites) or modifications thereof
- **Special senses**: vision (sight), hearing (audition), smell (olfaction), taste (gustation), equilibrium (balance)
  - Receptors found in special **sense organs** only and tend to be more **complex in structure**

### General sense receptors in the skin

**Merkel cell**
- Dendrites
- Capsule
- Afferent fiber

**Merkel disk**
- (d) Merkel disk (light touch)

**Meissner’s corpuscle**
- (e) Meissner’s corpuscle (light touch)

**Free nerve endings**
- (b) Free nerve endings wrapped around hair (touch)
- (f) Free nerve endings (pain, heat, cold)

**Pacinian corpuscle**
- (a) Pacinian corpuscle (strong pressure)

**Ruffini corpuscle**
- (g) Ruffini corpuscle (continuous pressure)

### Table 9.1: A Review of the Structures of the Eye and Their Functions

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>DESCRIPTION</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer layer (fibrous)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sclera</td>
<td>Outer layer of the eye</td>
<td>Protects the eyeball</td>
</tr>
<tr>
<td>Cornea</td>
<td>Transparent dome of tissue forming the outer layer at the front of the eye</td>
<td>Refracts light, focusing it on the retina</td>
</tr>
<tr>
<td>Middle layer (vascular)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choroid</td>
<td>Pigmented layer containing blood vessels</td>
<td>Absorbs stray light; delivers nutrients and oxygen to tissues of eye</td>
</tr>
<tr>
<td>Ciliary body</td>
<td>Encircles lens; contains the ciliary muscles</td>
<td>Controls shape of lens; secretes aqueous humor</td>
</tr>
<tr>
<td>Iris</td>
<td>Colored part of the eye</td>
<td>Regulates the amount of light entering the eye through the pupil</td>
</tr>
<tr>
<td>Pupil</td>
<td>Opening at the center of the iris</td>
<td>Opening for incoming light</td>
</tr>
<tr>
<td>Inner layer (nervous)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retina</td>
<td>Layer of tissue that contains the photoreceptors (rods and cones) also contains bipolar and ganglion cells involved in retinal processing</td>
<td>Receives light and generates neural messages</td>
</tr>
<tr>
<td>Rods</td>
<td>Photoreceptor</td>
<td>Responsible for black and white vision and vision in dim light</td>
</tr>
<tr>
<td>Cones</td>
<td>Photoreceptor</td>
<td>Responsible for color vision and visual acuity</td>
</tr>
<tr>
<td>Fovea</td>
<td>Small pit in the retina that has a high concentration of cones</td>
<td>Provides detailed color vision</td>
</tr>
<tr>
<td>Other structures of the eye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lens</td>
<td>Transparent, semi spherical body of tissue behind the iris and pupil</td>
<td>Fine focusing of light onto retina</td>
</tr>
<tr>
<td>Aqueous humor</td>
<td>Clear fluid found between the cornea and the lens</td>
<td>Refracts light and helps maintain shape of the eyeball</td>
</tr>
<tr>
<td>Vitreous humor</td>
<td>Gelatinous substance found within the chamber behind the lens</td>
<td>Refracts light and helps maintain shape of the eyeball</td>
</tr>
<tr>
<td>Optic nerve</td>
<td>Group of axons from the eye to the brain</td>
<td>Transmits impulses from the retina to the brain</td>
</tr>
</tbody>
</table>

**Vision: anatomy of the eye**

- Optic nerve
- Optic disk (blind spot)
- Fovea
- Choroid
- Retina
- Vitreous humor (fills the posterior chamber)
- Lens
- Ciliary body
- Aqueous humor (fills the anterior chamber)
- Cornea
- Iris
- Pupil
- Sclera

Figure 9.4: Biology of Humans, 6/e © 2007 Pearson Prentice Hall, Inc.
Light refraction and accommodation

- **Refraction** – bending of incoming light rays
  - Accomplished by cornea, lens, humors
- **Accommodation** – changing shape of lens to refract (focus) light precisely onto retina

![Diagram showing refraction and accommodation](image)

Photoreceptors

- ~ 6 million **cones**, ~ 120 million **rods**
- 3 types of cones respond maximally to different wavelengths (colors) of light:
  - Red, blue, and green cones
  - Brain interprets color based on degree of stimulation of various cone types

![Diagram showing photoreceptors](image)

Summary of the visual process

1. Light strikes an object.
2. Some wavelengths of light are absorbed, others are reflected.
3. The reflected light strikes the photoreceptors of the retina.
4. A pigment in the photoreceptor absorbs the light. The pigment is chemically altered.
5. The degree of change difference across the membrane changes.
6. Neural signals are sent to the brain, where the image is interpreted.
Hearing: the nature of sound

The amplitude (height) of the wave determines the loudness of the sound.

The frequency (cycles per second) of the waves determines the pitch of the sound.

### Table 9.3 Review of the Structures of the Ear and Their Functions

<table>
<thead>
<tr>
<th>STRUCTURE</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Outer ear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinna</td>
<td>Flimsy, funnel-shaped part of the ear protruding from the side of the head</td>
<td>Collects and directs sound waves</td>
</tr>
<tr>
<td>External auditory canal</td>
<td>Canal between pinna and tympanic membrane</td>
<td>Directs sound to the middle ear</td>
</tr>
<tr>
<td>Middle ear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eardrum (tympanic membrane)</td>
<td>Membrane spanning the end of the external auditory canal</td>
<td>Vibrates in response to sound waves</td>
</tr>
<tr>
<td>Malleus (hammer), incus (anvil), and stapes (stirrup)</td>
<td>Three tiny bones of the middle ear</td>
<td>Amplify the vibrations of the tympanic membrane and transmit vibrations to inner ear</td>
</tr>
<tr>
<td>Auditory tube</td>
<td>A tube that connects the middle ear with the throat</td>
<td>Allows equalization of pressure in middle ear with external air pressure</td>
</tr>
<tr>
<td>Inner ear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cochlea</td>
<td>Fluid-filled, bony, snail-shaped chamber</td>
<td>Houses spiral organ (of Corti) and has openings called oval window and round window</td>
</tr>
<tr>
<td>Spiral organ (of Corti)</td>
<td>Contains hair cells</td>
<td>The organ of hearing</td>
</tr>
<tr>
<td>Oval window</td>
<td>Membrane between the middle and inner ear that the stapes presses against</td>
<td>Transmit the movements of the stapes to the fluid in the inner ear</td>
</tr>
<tr>
<td>Round window</td>
<td>Membrane at the end of the lower canal in cochlea</td>
<td>Relieves pressure created by the movements of the oval window</td>
</tr>
<tr>
<td>Vestibular apparatus</td>
<td>Fluid-filled chambers and canals</td>
<td>Monitors position and movement of the head</td>
</tr>
<tr>
<td>Vestibule (utriculus and sacculus)</td>
<td>Two fluid-filled chambers</td>
<td>Maintains static equilibrium (body and head stationary information on position of head)</td>
</tr>
<tr>
<td>Semicircular canals</td>
<td>Three fluid-filled chambers oriented at right angles to one another</td>
<td>Maintain dynamic equilibrium (body or head moving)</td>
</tr>
</tbody>
</table>

**The cochlea**

- **Upper compartment (vestibular canal):**
  - Inner ear
  - Basilar membrane
  - Central compartment (cochlear duct)
  - The spiral organ (of Corti) is the actual organ of hearing

- **Lower compartment (tympanic canal):**
  - Auditory nerve
  - Inner hair cell
  - Outer hair cell
  - Tectorial membrane

**Anatomy of the ear**

- Outer ear (receiver)
- Middle ear (amplifier)
- Inner ear (transmitter)
- Eardrum (tympanic membrane)
- Malleus (hammer), incus (anvil), and stapes (stirrup)
- Auditory tube
- Vestibular apparatus
- Vestibule
- Auditory nerve
- Upper compartment (vestibular canal)
- Lower compartment (tympanic canal)
- Inner ear
- Basilar membrane

- The pinna gathers sound and funnels it into the external auditory canal to the tympanic membrane, or eardrum.
- The eardrum transmits sound waves to the middle ear.
- The middle ear amplifies the sound waves and conveys the vibrations of the eardrum to the inner ear.
- The cochlea converts pressure waves to neural messages that are sent to the brain for interpretation as sound.
The process of hearing

Balance (equilibrium)

- **2 kinds:**
  - **Static equilibrium:** provides information on body position relative to gravity
    - Utricle and saccule (within vestibule) contain sensory organs that detect position of head in space
      - E.g. tilted to one side, upside down
  - **Dynamic equilibrium:** provides information on body position in response to movement
    - Utricle and saccule contain sensory organs that also detect linear (straight-line) acceleration (and deceleration) of head
      - E.g. accelerating in car, elevator ride
    - Semicircular canals contain sensory organs that detect angular (rotational) acceleration (and deceleration) of head
      - E.g. spinning until getting dizzy, “head-banging”

Static equilibrium: utricle and saccule

Static equilibrium:  utricle and saccule

Static equilibrium

Step 1: The vestibule consists of the utricle and the saccule, two fluid-filled cavities.

Step 2: The utricle and the saccule contain hair cells with overlying gelatinous material. Embedded in the gelatinous material are granules of calcium carbonate called otoliths.

Step 3: When the head is tilted, otoliths in the gelatinous material slide “downhill” over the hair cells, stimulating them. The hair cells send signals to the brain.

Step 4: The brain interprets the signals to know the position of the head.
Smell (olfaction)

- A chemical sense
- A rarity: olfactory receptors (which are neurons) replaced ~ every 60 days

Taste

- Another chemical sense – closely related to smell
- Taste cells (which are not neurons) replaced ~ every 10 days!