The General and Special Senses

Dr. Ali Ebneshahidi
Function of senses

• 1. Detection of sensations allow the human body to be aware of changes (or *stimuli*) that occur in the environment or inside the body.

• 2. These senses permit the central nervous system to produce reactions for the stimuli and maintain body homeostasis.

• 3. **Somatic senses** ("soma" means body) detect touch, pain pressure, temperature, and tension on the skin and in internal organs.

• 4. **Special senses** detect the sensations of taste, smell, hearing, equilibrium, and sight, only in special sense organs in the head region (a phenomenon known as “cephalization”).

• 5. All senses are detected by sensory receptors, and after integration and processing being done in the central nervous system, motor nerves produce a response.
Types of Receptors

1. Chemoreceptors
   a) detect chemical concentrations.
   b) in somatic senses, chemoreceptors can detect ionic, glucose, oxygen, and carbon dioxide concentrations in the blood and tissue fluids.
   c) in special senses chemoreceptors are responsible for the senses of taste (in oral cavity) and smell (in nasal cavity).

2. Nociceptors
   a) detect pain or tissue damage due to excessive mechanical, electrical, thermal, or chemical forces.
   b) in somatic senses, nociceptors can be found in the skin and many visceral organs detecting tissue damages.

3. Thermoreceptors
   a) detect temperature changes.
   b) in somatic senses, certain thermoreceptors detect cold temperatures in the skin and some visceral organs, while other thermoreceptors detect high temperatures only.
• 4. Mechanoreceptors
  a) detect mechanical forces.
  b) in somatic senses, **proprioceptors** detect muscle tension, **pressoreceptors** detect blood pressure, and **stretch receptors** detect lung inflation, stomach distention, and urinary bladder expansion.
  c) in special senses, mechanoreceptors in the inner ear detect the senses of hearing (in cochlea) and equilibrium (in semicircular canals).

• 5. Photoreceptors
  a) detect light intensity.
  b) in special senses, photoreceptors in the eye detect the tones (by **rods** photoreceptors) and colors (by **cones** photoreceptors) of visual images
Somatic Senses

1. Sensory receptors in the skin, muscles, joints, and visceral organs detect external and internal stimuli of the body.

2. Three types of somatic senses:
   a) **Exteroceptive senses** detect changes that occur at body surface, such as touch, pressure and temperature.
   b) **Proprioceptive senses** detect changes that occur in muscles, tendons, ligaments and joint tissues.
   c) **Visceroceptive senses** detect changes that occur in internal organs.
3. Two major types of receptors for somatic senses:
   - **a) free sensory nerve endings**
     - small swelling at the endings of dendrites that is sensitive to somatic sensations.
     - also are abundant in the dermis and subcutaneous layers of skin.

### Table 13.1 General Sensory Receptors Classified by Structure and Function

<table>
<thead>
<tr>
<th>STRUCTURAL CLASS</th>
<th>ILLUSTRATION</th>
<th>FUNCTIONAL CLASSES ACCORDING TO LOCATION (L) AND STIMULUS TYPE (S)</th>
<th>BODY LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonencapsulated</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Free nerve endings of sensory neurons | ![Illustration](image1.png) | L: Exteroceptors, interoceptors, and proprioceptors  
S: Thermoreceptors (warm and cool), chemoreceptors (itch, pH, etc.), mechanoreceptors (pressure), nociceptors (pain) | Most body tissues; most dense in connective tissues (ligaments, tendons, dermis, joint capsules, periosteum) and epithelia (epidermis, cornea, mucosae, and glands) |
| Modified free nerve endings: Tactile (Merkel) discs | ![Illustration](image2.png) | L: Exteroceptors  
S: Mechanoreceptors (light pressure); slowly adapting | Basal layer of epidermis |
| Hair follicle receptors | ![Illustration](image3.png) | L: Exteroceptors  
S: Mechanoreceptors (hair deflection); rapidly adapting | In and surrounding hair follicles |
b) corpuscular receptors
- endings of dendrites are enclosed in a connective tissue capsule.
- also are abundant in the dermis and subcutaneous layers of skin.

<table>
<thead>
<tr>
<th>Structural Class</th>
<th>Illustration</th>
<th>Functional Classes According to Location (L) and Stimulus Type (S)</th>
<th>Body Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encapsulated</td>
<td></td>
<td>L: Exteroceptors S: Mechanoreceptors (light pressure, discriminative touch, vibration of low frequency); rapidly adapting</td>
<td>Dermal papillae of hairless skin, particularly nipples, external genitalia, fingertips, soles of feet, eyelids</td>
</tr>
<tr>
<td>Tactile (Meissner's) corpuscles</td>
<td><img src="image1" alt="Illustration" /></td>
<td>L: Exteroceptors, interoceptors, and some proprioceptors S: Mechanoreceptors (deep pressure, stretch, vibration of high frequency); rapidly adapting</td>
<td>Dermis and hypodermis; periostea, mesentery, tendons, ligaments, joint capsules; most abundant on fingers, soles of feet, external genitalia, nipples</td>
</tr>
<tr>
<td>Lamellar (Pacinian) corpuscles</td>
<td><img src="image2" alt="Illustration" /></td>
<td>L: Exteroceptors, interoceptors, and some proprioceptors S: Mechanoreceptors (deep pressure, stretch, vibration of high frequency); rapidly adapting</td>
<td>Dermis and hypodermis; periostea, mesentery, tendons, ligaments, joint capsules; most abundant on fingers, soles of feet, external genitalia, nipples</td>
</tr>
<tr>
<td>Bulbous corpuscles (Ruffini endings)</td>
<td><img src="image3" alt="Illustration" /></td>
<td>L: Exteroceptors and proprioceptors S: Mechanoreceptors (deep pressure and stretch); slowly or nonadapting</td>
<td>Deep in dermis, hypodermis, and joint capsules</td>
</tr>
<tr>
<td>Muscle spindles</td>
<td><img src="image4" alt="Illustration" /></td>
<td>L: Proprioceptors S: Mechanoreceptors (muscle stretch, length)</td>
<td>Skeletal muscles, particularly in the extremities</td>
</tr>
<tr>
<td>Tendon organs</td>
<td><img src="image5" alt="Illustration" /></td>
<td>L: Proprioceptors S: Mechanoreceptors (tendon stretch, tension)</td>
<td>Tendons</td>
</tr>
<tr>
<td>Joint kinesthetic receptors</td>
<td><img src="image6" alt="Illustration" /></td>
<td>L: Proprioceptors S: Mechanoreceptors and nociceptors</td>
<td>Joint capsules of synovial joints</td>
</tr>
</tbody>
</table>

© 2016 Pearson Education, Inc.
4. Four kinds of corpuscular receptors:
   a) **Meissner’s corpuscles**: detect low-frequency vibrations and light pressure (touch).
      - found in dermal papillae.
   b) **pacinian corpuscles**: detect deep vibration and pressure.
      - found in subcutaneous tissues.
   c) **Krause’s corpuscles**: detect cold temperatures (below 68 °F or 20 °C).
      - found in the dermis, eyes, lips, and mouth.
   d) **Ruffini’s corpuscles**: detect heat (above 77 °F or 25 °C).
      - found in the dermis.
### Table 13.1 General Sensory Receptors Classified by Structure and Function (continued)

<table>
<thead>
<tr>
<th>STRUCTURAL CLASS</th>
<th>ILLUSTRATION</th>
<th>FUNCTIONAL CLASSES ACCORDING TO LOCATION (L) AND STIMULUS TYPE (S)</th>
<th>BODY LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encapsulated</td>
<td></td>
<td>L: Exteroceptors S: Mechanoreceptors (light pressure, discriminative touch, vibration of low frequency); rapidly adapting</td>
<td>Dermal papillae of hairless skin, particularly nipples, external genitalia, fingertips, soles of feet, eyelids.</td>
</tr>
<tr>
<td>Tactile (Meissner’s) corpuscles</td>
<td>![Illustration](66x36 to 660x528)</td>
<td>L: Exteroceptors, interoceptors, and some proprioceptors S: Mechanoreceptors (deep pressure, stretch, vibration of high frequency); rapidly adapting</td>
<td>Dermis and hypodermis; periostea, mesentery, tendons, ligaments, joint capsules; most abundant on fingers, soles of feet, external genitalia, nipples.</td>
</tr>
<tr>
<td>Lamellar (Pacinian) corpuscles</td>
<td>![Illustration](66x36 to 660x528)</td>
<td>L: Exteroceptors and proprioceptors S: Mechanoreceptors (deep pressure and stretch); slowly or nonadapting</td>
<td>Deep in dermis, hypodermis, and joint capsules.</td>
</tr>
<tr>
<td>Bulbous corpuscles (Ruffini endings)</td>
<td>![Illustration](66x36 to 660x528)</td>
<td>L: Proprioceptors S: Mechanoreceptors (muscle stretch, length)</td>
<td>Skeletal muscles, particularly in the extremities.</td>
</tr>
<tr>
<td>Muscle spindles</td>
<td>![Illustration](66x36 to 660x528)</td>
<td>L: Proprioceptors S: Mechanoreceptors (tendon stretch, tension)</td>
<td>Tendons.</td>
</tr>
<tr>
<td>Tendon organs</td>
<td>![Illustration](66x36 to 660x528)</td>
<td>L: Proprioceptors S: Mechanoreceptors and nociceptors</td>
<td>Joint capsules of synovial joints.</td>
</tr>
<tr>
<td>Joint kinesthetic receptors</td>
<td>![Illustration](66x36 to 660x528)</td>
<td>L: Proprioceptors S: Mechanoreceptors and nociceptors</td>
<td>Joint capsules of synovial joints.</td>
</tr>
</tbody>
</table>

© 2018 Pearson Education, Inc.
Special Senses

1. The senses of **taste** and **smell** (detected by **chemoreceptors**), **hearing** and **equilibrium** (detected by **mecanoreceptors**), and **vision** (detected by **photoreceptors**) are the five special senses.

2. Require specialized sensory receptors within large, complex sensory organs in the **head** region.
Sense of Smell

• **olfactory receptors** located in "olfactory organs" are specialized chemoreceptors in the nasal cavity.

• Olfactory receptors are **bipolar neurons** surrounded by ciliated columnar cells. These sensory cells, after being stimulated by olfactory sensations, send nerve impulses along the olfactory (cranial nerve I) to the cerebrum.

• Gases in the air entering the nasal cavity are dissolved by **nasal mucus** (secreted by goblet cells in the columnar epithelium), and the resulting solution stimulates various olfactory receptors.
Sense of Taste

a) about **10,000 taste buds** occur in the oral cavity, mostly on the tongue. Each taste bud contains **40-60 taste receptors**. These sensory cells are stimulated by taste sensations.

b) chemical substances from the food or beverage enter the mouth and are dissolved in the **saliva** (secreted by salivary glands and mucous membrane of oral cavity).

c) dissolved chemical substances stimulate various taste buds in different regions of the tongue, and combinations of taste sensations produce hundreds of different taste senses.
d) These sensory cells, after being stimulated by taste sensations, send nerve impulses through the facial nerve (nerve VII), glossopharyngeal nerve (nerve IX), or vagus nerve (nerve X) to the cerebrum.
e) four primary taste sensations:
- **sweet** - sensation caused by organic substances such as sugars and amino acids; most sensitive at the tip of tongue.
- **sour** – sensation caused by hydrogen ions ($H^+$) from acidic substances; most sensitive at both sides of the tongue.
- **salty** - sensation caused by metal ions (e.g. $Mg^{++}$) or inorganic salts (e.g. Nacl); most sensitive at the sides and the tip of tongue.
- **bitter** – caused by alkaloids (e.g. nicotine, caffeine) and nonalkaloids (e.g. aspirin); most sensitive at the back of tongue.
a) **Accessory structures** of the eye are those that are not directly related the sense of vision, but facilitate the physiology of the eyeballs.

- **Eyebrows** – to shade the eyes from sunlight, and to prevent perspiration from reaching the eyes.
- **Eyelids** - to protect the eyes from foreign objects (e.g. dust particles), and to prevent desiccation (drying) of the eyes by lubricating fluid.
- **Conjunctiva** - a mucous membrane on the inner lining of eyelids, which produces lubricating and cleansing fluid for the surface of eye.
- **Lacrimal gland** - exocrine gland that secretes a dilute saline solution called tears for moistening the eyes. [Tears contain mucus, antibodies, and antibacterial enzymes that protect the eye from infections. Emotional tears also contain enzymes that seem to help reduce stress levels].
(a) Surface anatomy of the right eye

(b) Lateral view; some structures shown in sagittal section
Anatomy of The Eye

- The wall of the eyeball consists of 3 layers of tissue:
  
  1) Fibrous Tunic: outermost layer, made of fibrous connective tissue with minimal blood vessels.
  
  - Contains 2 regions: sclera (a white area that extends from the back of the eye toward the front) and cornea (a transparent tissue in the front for allowing light to enter the eyeball).
II) Vascular Tunic (Uvea): middle layer, made of thin fibrous connective tissue that contains numerous blood vessels (capillaries).

- contains **choroids** (a pigmented membrane in the back to provide nutrition and absorb light) and **iris** (to regulate the amount of light entering the eye by constriction or dilation).

- includes specialized structures such as **ciliary body** (which regulates the shape of lens), **suspensory ligaments** (which attach the ciliary body to the lens), **lens** (another transparent tissue that bends the light entering the eye), and **pupil** (an opening created by the actions of the iris where a large pupil is caused by a dilated iris, while a small pupil is created by a constricted iris).
(a) **Diagrammatic view.** The vitreous humor is illustrated only in the bottom part of the eyeball.

© 2016 Pearson Education, Inc.
III) sensory tunic (also called retina):

- innermost layer, made of specialized nerve tissue. It contains 2 layers of tissue: an outer pigmented layer (which absorbs light and stores vitamin A) and an inner neural layer (that detects light using photoreceptors and sends nerve impulses to the occipital lobe of cerebrum through the optic nerves).

- 2 types of photoreceptors are found on the neural layer: rods (detect tones of visual images) and cones (detect colors). These sensory cells, after being stimulated by visual sensations, send nerve impulses through the optic nerve (Nerve II) to the occipital lobes of cerebrum.
(a) Posterior aspect of the eyeball

- Neural layer of retina
- Pigmented layer of retina
- Choroid
- Sclera
- Optic disc
- Central artery and vein of retina
- Optic nerve

(b) Cells of the neural layer of the retina

- Ganglion cells
- Axons of ganglion cells
- Bipolar cells
- Photoreceptors: Rod, Cone
- Horizontal cell
- Amacrine cell

Pathway of light
Pathway of signal output
Pigmented layer of retina
(c) Photomicrograph of retina

- Nuclei of ganglion cells
- Axons of ganglion cells
- Nuclei of bipolar cells
- Nuclei of rods and cones
- Pigmented layer of retina
- Outer segments of rods and cones
- Choroid
Central artery and vein emerging from the optic disc

Optic disc

Macula lutea

Retina

Lateral

Medial

© 2016 Pearson Education, Inc.
Chambers and fluids in the eyeball:

- **Anterior cavity:** located between the cornea and lens, contains aqueous humor for supplying oxygen and nutrients to the lens and cornea.

- **Posterior cavity:** located between the lens and retina, contains vitreous humor to transmit light from the lens to the photoreceptors on retina.
Aqueous humor forms by filtration from the capillaries in the ciliary processes.

Aqueous humor flows from the posterior chamber through the pupil into the anterior chamber. Some also flows through the vitreous humor (not shown).

Aqueous humor is reabsorbed into the venous blood by the scleral venous sinus.
Extrinsic muscles of the Eye

Lat. Rectus: innervated by abducens nerve & moves eye lat.


Sup. Rectus: innervated by oculomotor nerve & moves eye sup. & med.

Inf. Rectus: innervated by oculomotor nerve & moves eye inf. & med.

Inf. Oblique: innervated by oculomotor nerve & moves eye sup. & lat.

Sup. Oblique: innervated by trochlear nerve & moves eye inf. & lat.
(b) Superior view of the right eye

- Trochlea
- Superior oblique tendon
- Superior oblique muscle
- Superior rectus muscle
- Axis of rotation of eye
- Inferior rectus muscle
- Medial rectus muscle
- Lateral rectus muscle
- Common tendinous ring

© 2016 Pearson Education, Inc.
<table>
<thead>
<tr>
<th>Muscle</th>
<th>Action</th>
<th>Controlling cranial nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral rectus</td>
<td>Moves eye laterally</td>
<td>VI (abducens)</td>
</tr>
<tr>
<td>Medial rectus</td>
<td>Moves eye medially</td>
<td>III (oculomotor)</td>
</tr>
<tr>
<td>Superior rectus</td>
<td>Elevates eye and turns it medially</td>
<td>III (oculomotor)</td>
</tr>
<tr>
<td>Inferior rectus</td>
<td>Depresses eye and turns it medially</td>
<td>III (oculomotor)</td>
</tr>
<tr>
<td>Inferior oblique</td>
<td>Elevates eye and turns it laterally</td>
<td>III (oculomotor)</td>
</tr>
<tr>
<td>Superior oblique</td>
<td>Depresses eye and turns it laterally</td>
<td>IV (trochlear)</td>
</tr>
</tbody>
</table>

(d) Summary of muscle actions and innervating cranial nerves

© 2016 Pearson Education, Inc.
Sense of Hearing

a) The gross anatomy of the human ear includes the outer ear (consists of auricle and external auditory meatus), middle ear (consists of the tympanic membrane and auditory ossicles, and inner ear (consists of cochlea, 3 semicircular canals, and the vestibulocochlear nerves).
b) The outer ear is responsible for transferring sound waves from the environment to the middle ear.

c) The middle ear is responsible for amplifying sound waves into strong signals for the hearing receptors to detect.

d) The inner ear is responsible for using mechanoreceptors to detect stimuli for hearing (in cochlea) and equilibrium (in semicircular canals) and send the nerve impulses through the vestibulocochlear nerve (nerve VIII) to the brain.
e) auditory ossicles include the **malleus**, **incus**, and **stapes**, which are articulated to one another, but not to the skeleton. The malleus is attached to the tympanic membrane, stapes is attached to the cochlea.
f) the middle ear also contains the **eustachian tube** (auditory tube) that connects with the pharynx for equalizing air pressure in the skull.
g) sound waves hitting onto the tympanic membrane cause the auditory ossicles to vibrate, resulting in amplification of the sound.
h) when the ossicles vibrate waves in the **endolymph** fluid inside the cochlea are generated.

i) endolymph waves bend the stereocilia (modified dendrites) of hearing receptors called **hair cells**, which are located in the **organ of corti** on the **basilar membrane**. Bending of hair cells result in generation of nerve impulses which reach the cerebrum via the cochlear nerve.
a) detected by mechanoreceptors in the semi-circular canals to help maintain body posture and body stability.
b) nerve impulses generated by the receptors in semi-circular canals are transmitted by the vestibular nerve to Nerve VIII, and the signals will be processed by the brain.
1. Sound waves vibrate the tympanic membrane.

2. Auditory ossicles vibrate. Pressure is amplified.

3. Pressure waves created by the stapes pushing on the oval window move through fluid in thescala vestibuli.

4a. Sounds with frequencies below hearing travel through the helicotrema and do not excite hair cells.

4b. Sounds in the hearing range go through the cochlear duct, vibrating the basilar membrane and deflecting hairs on inner hair cells.
C) two types of equilibrium:

**Static equilibrium:** senses the position of the head and vertical and horizontal movement of the body; helps to maintain body posture.

**Dynamic equilibrium:** senses the motions of the head and body (mainly rotational); helps to maintain overall body stability.
d) static equilibrium: receptors called macula located in the semicircular canals detect the position of the head. When the head changes position, fluid in the semicircular canals moves and generates waves that bend the stereocilia on these macula cells.
e) dynamic equilibrium: receptors called **crista ampullaris** located the semicircular canals detect the position of the body. When body moves, similar physiology with equilibrium occurs in the semicircular canals, resulting in nerve impulses being sent to the brain for interpretation.
Clinical Terms

- **Blepharitis**: inflammation of the margins of eyelids.
- **Conjunctivitis**: inflammation of the conjunctiva.
- **Papilledema**: protrusion of optic disc into the eyeball, caused by conditions that increase intracranial pressure.
- **Nystagmus**: involuntary oscillation of the eyes.
- **Exopathalmus**: condition which eyes protrude abnormally (thyroid disease).
- **Otitis Externa**: inflammation of external auditory canal caused by infection.
- **Vertigo**: sensation of dizziness.
- **Tinnitus**: ringing or buzzing in the ears.