The senses are connected to the nervous system. The sensory receptors and specialized receptors function to detect any fluctuations, stimuli, or changes that surround an individual. The senses enable an individual to be more aware of the environment and be able to process the information from the senses to perceive and to make decisions to maintain homeostasis. The senses can be general such as with the bodily or somatic senses. Somatic senses detect general or nonspecific changes while the specialized senses detect unique stimuli. The specialized senses are more complex in the physiology and how they detect the changes that may occur in the environment.

**Somatic senses**

- Classification of receptors
  - Sensory receptors are the dendrites and the branching of the dendrites of the sensory neurons. Their function is to collect information about a stimulus and send an impulse through the fibers to the CNS.
  - Sensory receptors are classified based on the type of stimulus they are sensitive.
    - Chemoreceptors detect concentrations of chemicals
    - Photoreceptors detect light energy
    - Thermoreceptors detect fluctuations in temperature
    - Mechanoreceptors detect mechanical forces such as movement and pressure
    - Pain receptors respond to tissue damage

- Sensory Impulses follow a general pathway:
  1. Stimulus is detected by the receptor
  2. Trigger zone is activated on the neuron and action potentials or a sensory nerve impulse is fired
  3. The nerve impulse travels down the peripheral nerve to reach the CNS
  4. CNS analyzes and interprets the impulses for perception, making a decision, or producing sensations.

- Sensation is the feeling produced when the brain interprets the sensory impulse, and then the brain projects the impulse back to the point of origin so that the individual can be aware of the location of the stimulus.

- Sensory Adaptation occurs when there is a continuous exposure to the same stimulus which will cause the sensory receptors to send sensory impulses at a decreasing rate to the CNS. The sensory receptors have become less irritated or less responsive to the stimulus.

- Touch and pressure receptors

  **REFER TO FIGURE 10.1**

  - Free nerve ending of sensory nerve fibers are in close proximity to the epithelial tissues and detect all types of stimuli.
  - Meissner’s corpuscle is a modified nerve ending made up of connective tissue and nerve fibers that detect light touch. It has a widespread distribution but is most abundant in the hairless portion of the skin. It is locate in the dermal papillae of the dermis.
  - Pacinian corpuscle is a modified nerve ending made up of connective tissue and nerves fibers that detect heavy pressure. It has a widespread distribution and is located in the reticular region of the dermis, hypodermis, tendon, ligament, and joints.

- Temperature receptors are free nerve ending of sensory nerve fibers.
  - Heat or warm receptors detect temperatures in the range of 77°F -113°F or 25°C-45°C
  - Cold receptors detect temperatures in the range of 50°F- 68°F or 10°C-20°C
  - Extreme temperature beyond the range of cold and warm receptors detection will stimulate pain receptors (freezing or burning)

- Pain receptors are free nerve endings that have a wide distribution that detect tissue damage.
- Sense of pain is detected everywhere but the brain. The brain lacks pain receptors. The only receptors located in the viscera are pain receptors.
- Visceral pain can sometimes be interpreted and projected by the CNS incorrectly. This mistake can cause referred pain. Referred pain is an error in projection by the CNS to the wrong region of stimulus due to the fact that sensory impulses from different regions of the body share common pathways to the CNS. Therefore, the point of origin may not be clearly interpreted.

**REFER TO FIGURES 10.2-10.3**
- Example: Pain receptors from the heart may send sensory impulses to the CNS but because these receptors share the same pathway as the sensory receptors of the upper left limb, the CNS may project pain sensations to the left arm instead to the actual point of origin in the heart.—One of the primary symptoms of a heart attack.

- **Pain fibers**
  - Acute pain fibers are thin, myelinated fibers that send sensory impulses quickly. The conduction of the impulses can travel as fast as the stimulus detected. Once the stimulus ceases, the pain impulses end. Hence, acute pain is described as being sharp or pricking pain. Acute pain is well-localized and has a clear pinpoint on the location of the source of pain.
  - Chronic pain fibers are thin, unmyelinated fibers that send sensory impulses slowly. There is usually a lag time between the end of a stimulus and the end of a chronic pain impulse. The impulse is slow to conduct and slow to stop. The point of origin of the stimulus is more difficult to recognize. Therefore, chronic pain is considered to be dull and aching.

- **Regulation/Suppression**
  - Thalamus regulates and makes awareness of pain
  - Cerebral cortex judges the intensity of the pain and the location of the pain. It also aids in forming emotions associated with the pain.
  - Brain stem release chemicals called peptides to suppress the pain. Enkephalins and serotonin hinders or reduces the pain impulses traveling to the CNS.
  - Hypothalamus and pituitary gland releases endorphins to control pain.

**Special senses**
- Sense of smell—highly adaptive and accentuate sense of taste
  - Location: nasal cavity
  - Type of receptor: chemoreceptors
  - Olfactory organ: Ciliated bipolar neuron surrounded by supporting epithelial cells. Dendrites extended into the nasal cavity while the axon extends through the olfactory foramina of the ethmoid bone to connect to the olfactory lobes or bulbs (Cranial nerve I).

**REFER TO FIGURE 10.4**
- Olfactory nerve pathway
  1. Odor made up of chemicals dissolve in the warm moisture of the nasal cavity. Specific receptors are stimulated by a specific “odor code or combination”.
  2. The cilia create a gentle current and mix the chemicals with the moisture within the nasal cavity.
  3. Dendrites are stimulated and conduct an impulse through the neuron and axon.
  4. The impulse synapses to the olfactory bulbs
  5. Olfactory bulbs transmit the impulse to the limbic system to associate memory with the chemicals of smell and to the olfactory cortex of the temporal lobe for processing

- Sense of taste – highly adaptive and accentuate sense of smell
Location: Papillae of the tongue (ridge-like surfaces of the tongue) and throughout the oral cavity
Type of receptor: chemoreceptors
Taste organ: Taste buds—consist of taste cells with taste hairs surrounded by supporting epithelial cells. The taste hairs of the taste cells extend out of a region called taste pores. The taste hairs are sensitive to the chemicals of taste. The taste pores open into the oral cavity.

**REFER TO FIGURE 10.5**
- **Taste nerve pathway**
  1. Chemicals in the food and liquids are dissolved in saliva.
  2. Specific taste cells are stimulated because the taste hairs protrude into the taste pores.
  3. An impulse is fired by the taste cells.
  4. Taste impulses synapse to the facial, glossopharynx, and vagus nerves
  5. From the cranial nerves, the taste impulses travel up the medulla oblongata to arrive at the thalamus for sorting.
  6. The thalamus routes the taste impulses to the parietal lobe for processing.

- Sense of hearing
  - **Anatomy of the ear**
    **REFER TO FIGURE 10.6**
    - **External Ear**
      - Auricle—“the ear lobe” collects the sound waves and channels them into the ear
      - External Auditory (Acoustic) Meatus—the ear canal. It carries the sound waves to the tympanic membrane. It contains ceruminous glands that help to keep and trap debris from entering further into the ear
      - Tympanic membrane—“the eardrum”. As the sound waves arrive at the tympanic membrane, the tympanic membrane converts the sounds waves into vibrations
    - **Middle Ear**
      - Tympanic cavity—air-filled space in the temporal bone
      - Auditory ossicles—occupy the space of the tympanic membrane. The auditory ossicles are malleus, incus, and stapes (the smallest bones of the human body). The functions of these ossicles are amply and transmit the vibrations into the inner ear. Vibration from the tympanic membrane vibration the malleus. The malleus vibrates the incus. The incus vibrates the stapes. The stapes connects to the inner ear so the vibrations from the stapes enter the inner ear.
    **REFER TO FIGURE 10.7**
    - Auditory or Eustachian tube—tube that connects the middle ear to the throat. Its function to aid in equalizing the pressure on either side of the tympanic membrane. When the pressure is not equal, then the sound becomes less distinct or muzzled. Swallowing or chewing gum will help to equalize the pressure. Once the pressure is equal, then the ear will “pop.” Example: Travelling from lower elevation region to a higher altitude.
    - **Inner Ear**
      **REFER TO FIGURE 10.8**
      - Osseous labyrinth—bony outer wall of the inner ear. It contains a fluid called perilymph.
Membranous labyrinth—membranous wall of the inner ear. It contains a fluid called endolymph.

Cochlea—coiled structure of the inner ear that function in hearing

REFER TO FIGURE 10.9

Compartments of the cochlea
- Scala vestibule—superior compartment of the cochlea. The borders of the scala vestibule consist of osseous labyrinth so perilymph fills the space within this compartment
- Cochlear duct—middle compartment of the cochlea. The borders of the cochlear duct consist of membranous labyrinth. Superior border is called the vestibular membrane while the inferior border is called the basilar membrane. The fluid in this compartment is endolymph.
  - Organ of Corti—the organ for hearing. It consists of hair cells and supporting epithelium.
  - Tectorial membrane—attached to the shelf of the cochlea and lies above the hair cells of the organ of corti
- Scala tympani—inferior compartment of the cochlea. The borders of the scala tympani consist of osseous labyrinth so perilymph is contained in this compartment.

Semicircular canals with ampullae—three semicircular structures of the inner ear that consists of the same walls and fluid of the inner ear. The function of the semicircular canals is to maintain the sense of equilibrium. The ampulla or ampullae (plural) are the bases of the semicircular canals.

Vestibule—bony chamber between the semicircular canals and the cochlea. It consists of two expanded chambers called the utricle and saccule. Its function also serves to maintain sense of equilibrium.

Oval window—the entry into the inner ear. Vibrations from the stapes enter the inner ear through the oval window. Once the vibrations enter the inner ear, the fluids in the labyrinth will vibration to stimulate for hearing.

Round window—the exit for the vibrations to leave the inner ear. Once the vibrations run through the inner ear, the stimulus (vibrations) need to terminate so that the organ of corti will not be stimulated continuously.

Physiological process of hearing

1. Sound waves captured by auricles and enter external auditory meatus.
2. Sound waves causes tympanic membrane to transform the sound waves into vibrations.
3. Tympanic membrane vibrates malleus, which vibrates the incus. Incus vibrates the stapes.
4. The vibrations coming from the stapes enter the oval window of the inner ear and causes movements of fluid within the inner ear (scala vestibuli and cochlear duct).
5. Different frequencies of vibrations stimulate receptor cells.
6. Action potential causes release of neurotransmitters.
8. Nerve impulse travels to CNS to be interpreted

Sense of equilibrium

Static equilibrium—maintaining balance and being aware of head position while the body is still
REFER TO FIGURE 10.11

• Location: within the vestibule—utricle and saccule
• Organ for static equilibrium is the macula. The macula consists of hair cells that serve as the sensory receptors. The hair of the hair cells project into a mass of gelatinous material containing crystals of calcium carbonate called otoliths
• Static equilibrium pathway: The head moves in a direction. Gravity pulls on the gelatinous material and shifting the otoliths in the same direction of the head. The hair on the hair cells bends in the same direction and stimulate the sensory receptors. Impulse is generated and travels to the CNS for interpretation.

Dynamic equilibrium—maintaining balance and being aware of head position while the head and body are moving

REFER TO FIGURE 10.12

• Location: within the ampullae of the semicircular canals
• Organ of dynamic equilibrium is the crista ampullaris. The crista ampullaris is made up of hair cells surround by supporting epithelial cells. The hairs extend upward into a gelatinous material called the cupola.
• Dynamic equilibrium pathway: As the head and body move, the hair cells bend into the cupola and generate an impulse and travels to the CNS for interpretation. The cupola will bend in the opposite direction of the motion of the head. Visual input is used to aid in the balance.

Sense of sight

Anatomy of the eye

REFER TO FIGURES 10.14, 10.17, 10.22

Accessory organs

• Eyelids and eyelashes function to protect the eye and block debris from reaching into the eye
• Lacrimal apparatus function to protect and disinfect the eye. The structure is located on the superior to the eyelid and the lateral side of the eye. The lacrimal apparatus includes the lacrimal gland which produces a solution called tears. The tears travel through canals that will transport the tear across the eye from the lateral side to the medial side of the eye in order to lubricate and cleanse the eye. Tears have an enzyme called lysozyme that is a disinfectant. The tears and debris will drain into the lacrimal duct and be stored for future “flushing” of eye if needed.

REFER TO FIGURE 10.15

• The extrinsic muscles are the muscles that attach to the eye and permit movement of the eye in different directions.

REFER TO FIGURE 10.16

• Tunics of layers of the eye
  • Outer tunic
    ▪ Cornea – the most anterior portion of the eye. Transparent structure that serves as a surface for refraction or bending of light.
    ▪ Sclera – the white of the eye. It contains blood vessels and is vascular.
  • Middle tunic
    ▪ Choroid coat – pigmented and vascular structure that keeps the interior of the eye dark and nourishes the eye
    ▪ Ciliary body – consists of ligaments and muscles that hold the lens in place

REFER TO FIGURE 10.18
- Lens – transparent structure that allows refraction to occur as the light enters the eye
  - Light refraction: The ability to bend light. Two surfaces of the eye that allow for refraction are the cornea and lens.
  - Accommodation: The ability to change the shape of the lens to facilitate focusing

**REFER TO FIGURE 10.19**
- Sight for far distance: muscles of the ciliary body relax causing the ligaments attached to the lens to be taunt. As a result, the lens will be stretched and thin.
  - Sight for near distance: muscles of the ciliary body contract causing the ligaments attached to the lens to be relaxed. As a result, the lens will be thick.
- Iris – set of muscles that adjust the amount of light to enter the eye. The center of the iris is called the pupil. The pupil is the hole that light enters the eye. The iris acts like a diaphragm that will change the diameter of the pupil.

**REFER TO FIGURE 10.20**
- Anterior cavity – region from the cornea to the lens. This cavity contains a fluid called aqueous humor. The aqueous humor serves to nourish the eye and maintain the shape of the front of the eye.
  - Inner tunic
    - Retina – vascular structure that contains the photoreceptors: rods and cones.

**REFER TO FIGURES 10.21, 10.25**
- Rods: elongated photoreceptors that allow for colorless or black and white vision. Enables us to see in dim light and provides general outlines. Enzyme called rhodopsin will decompose in the presence of light and stimulate a change in the photoreceptors.
- Cones: blunt photoreceptors that allow for color vision. Enables us to see sharp detail. Fovea centralis is a region that contains the most cones and provides for the sharpest vision. The cones are organized in sets. Different wavelengths of color light will stimulate different sets of cones. If all sets are stimulated, the color perceived is white. If none of the sets are stimulated, the color perceived is black. Intermediate hues results in an overlap of stimulated cones. Color blindness is a condition that results in a lack a particular cone pigments.
- Posterior cavity – region from the lens to the back of the eye. This cavity contains a fluid called vitreous humor. The vitreous humor helps to maintain the shape of the back of the eye.
- Optic disk – region in the eye where the blood vessels and nerves converge before leaving the eye. There are no photoreceptors in this region.

**REFER TO FIGURE 10.23**
- Optic nerve – two optic nerves with one nerve innervating to each eye. Provides a two-way path to and from the eye and CNS. The
medial nerve fibers of the nerves will cross at the optic chiasma to provide information from each of the eye to both hemispheres of the cerebrum.

**REFER TO FIGURE 10.26**

- Physiological process of sight
  1. Light waves enter the eye.
  2. Cornea and lens present convex surfaces to refract the image, shrinking it down, and reversing the image.
  3. Light waves strikes the visual receptor cells, either rods or cones. Pigments within each receptor cell decompose when they absorb light energy.
  4. Rods are much more sensitive to light and enable vision in black and white and in lower light.
  5. The pigment, rhodopsin, are located in rods and decompose in the presence of light. The decomposition of the pigment causes a change in the rods.
  6. Sensory neurons detect the change and send an impulse away from the retina.
  7. Cones enable color vision, and the different wavelengths of light stimulate different set of cones. Sensory neurons detect the change, but the brain determines which cones are stimulated.
  8. Fovea centralis is an area of the retina that contains only cones and produces the sharpest vision.
  9. The impulse leaves the retina through the optic disk and then leaves the eye through the optic nerve to the brain.
  10. A portion of the nerves cross at the optic chiasma. Nerve impulse continue on the optic tract until they reach the thalamus and then to the visual cortex of the occipital lobes so that the images are perceived and right side up.