University of the Philippines Manila
COLLEGE OF NURSING

N3-Anatomy and Physiology
1st Semester AY 2022-2023

STUDY GUIDE
Week # 5

SOMATIC AND SPECIAL SENSES

Introduction

In this study guide, we shall examine the physiology of somatic sensation and the anatomy and functions of special senses.

Learning outcomes

After going through this topic, you should be able to:

1. Define a sensation and describe the conditions needed for a sensation to occur;
2. Describe the location and function of the receptors for tactile, thermal, and pain sensations;
3. Identify the various structure of the eyes and ears;
4. Describe the receptors for olfaction, gustation, vision, hearing, and equilibrium
5. Discuss the following pathways: gustatory, visual, hearing, and equilibrium.

Resources that you need to read

Please read the main references below to have a better understanding of the topic.

1. Betts JG, Desaix Peter, Johnson E et al (2017). *Anatomy and Physiology.* OpenStax Rice University.

   Specific chapters you need to read:
   Chapter 14.1 Sensory Perception 600-620

   Note: You may access this open education resource in this link: https://openstax.org/details/books/anatomy-and-physiology. You have an option to view the book online or download the PDF file.

2. Tortora GJ & Derrickson B. (2014). *Principles of Anatomy and Physiology.* John Wiley & Sons, Inc. 13th edition.

   Specific chapters you need to read:
   Chapter 16.1. Sensations
   Chapter 16.2. Somatic sensations
   Chapter 17. Special Senses pages

Topic outline

The specific topics that will be covered in this study guide are as follows:

1. Sensations
2. Somatic sensations
3. The special senses: olfaction
4. The special senses: gustation
5. The special senses: vision
6. The special senses: hearing
7. The special senses: equilibrium

1. Sensations

There are two sensory modalities (1) general senses and (2) special senses.

The *general senses* refer to the somatic senses which include tactile, thermal, pain, and proprioceptive sensations; and visceral senses provide information about the conditions of the internal organs such as pressure, hunger, and temperature.

The *special senses* include the sensory modalities of smell, taste, vision, hearing, and equilibrium.

Sensation is basically the conscious or subconscious awareness of changes in the external or internal environment. Four conditions must be satisfied for sensation to occur:

- Stimulus- should activate a sensory receptor. It could be in the form of light, heat, pressure, mechanical energy, or chemical energy.
- Sensory receptor- this is necessary to convert the stimulus into an electrical signal
- Conduction- of nerve impulses along the neural pathway
- Integration- of nerve impulses in the brain.

Sensory receptors can be classified given their (a) microscopic structure; (b) location of the receptors and the origin of stimuli that activate them; and (c) type of stimulus detected.

According to microscopic structure

On the microscopic level, sensory receptors can be classified as:

a. Free nerve endings- this consists of bare dendrites and these are associated with pain, thermal, itch, and some touch sensations.

b. Encapsulated nerve endings – this consists of dendrites enclosed in a connective tissue capsule and these are association with pressure, vibration, and some touch sensations.

c. Separate cells- these are receptor cells that synapses with a first-order neuron. These are located in the retina (photoreceptors), inner ear (hair cells), and taste buds in the tongue.

According to location of the receptors and the origin of stimuli that activate them

Sensory receptors can also be classified based on their location and the origin of stimuli that activate them:

a. Exteroceptors – these are located near the external surface of the body and they are sensitive to stimuli originating outside the body. This includes the sensations of hearing, vision, smell, taste, touch, pressure, vibration, temperature, and pain caused by an external stimuli.

b. Interoceptors- also called the *visceroceptors* are located in blood vessel, visceral organs, muscles, and the nervous system to monitor internal environment.

c. Proprioceptors- are located in muscles, tendons, joints, and inner ear. They provide information about body position, muscle length and tension, and the position and movement of joints.

According to stimulus detected

Sensory receptors can also be classified depending on the stimulus that they detect:

a. Mechanoreceptors- detect mechanical pressure, provide sensations of touch, pressure, vibration, proprioception, hearing, and equilibrium. They also monitor stretching of blood vessels, and internal organs.

b. Thermoreceptors- detect changes in temperature

c. Nociceptors- respond to painful stimuli resulting from physical or chemical damage to tissue

d. Photoreceptors- detect light that strikes the retina of the eye

e. Chemoreceptors- detect chemicals in the mouth (taste), nose (smell), and body fluids

f. Osmoreceptors- sense the osmotic pressure of body fluids

2. Somatic sensations

Somatic sensations arise from the stimulation of sensory receptors in the skin, mucous membranes, tendons, and joints. The somatic sensory receptors are unevenly distributed e.g., the highest distribution are in the tip of the tongue, lips, and fingertips.

There are basically four somatic sensations: (1) tactile sensations; (2) thermal sensations; (3) pain sensations; and (4) proprioceptive sensations.

Tactile sensations

There are several sensory receptors in the skin that produce tactile sensations of touch, pressure, pain, vibration, and stretch as follows:

a. Free nerve endings- for pain, itch, tickle

b. Meissner corpuscle- for light touch and low frequency vibrations
c. Ruffini endings- respond to skin stretch
d. Root hair plexus- respond to touch
e. Pacinian corpuscle- respond to deep pressure and high frequency vibration
f. Krause end bulbs- for touch and pressure
g. Merkel disks- for gentle touch, and tactile discrimination

Thermal sensations

The thermoreceptors are free nerve endings. The *cold receptors* are located in the epidermis and activated by temperatures between 10C to 40C while the *warm receptors* are located in the dermis and activated by temperatures between 32C to 48C. Temperature below 10C and above 48C already stimulate nociceptors and are felt as pain sensations.

Pain sensations

Nociceptors are free nerve endings, and they are found in almost every tissue except the brain. The sensation of pain can be produced by:

- Excessive stimulation of sensory receptors
- Excessive stretching of a structure
- Prolonged muscular contractions
- Inadequate blood flow to an organ
- Presence of certain chemical substances
- Very low or high temperature

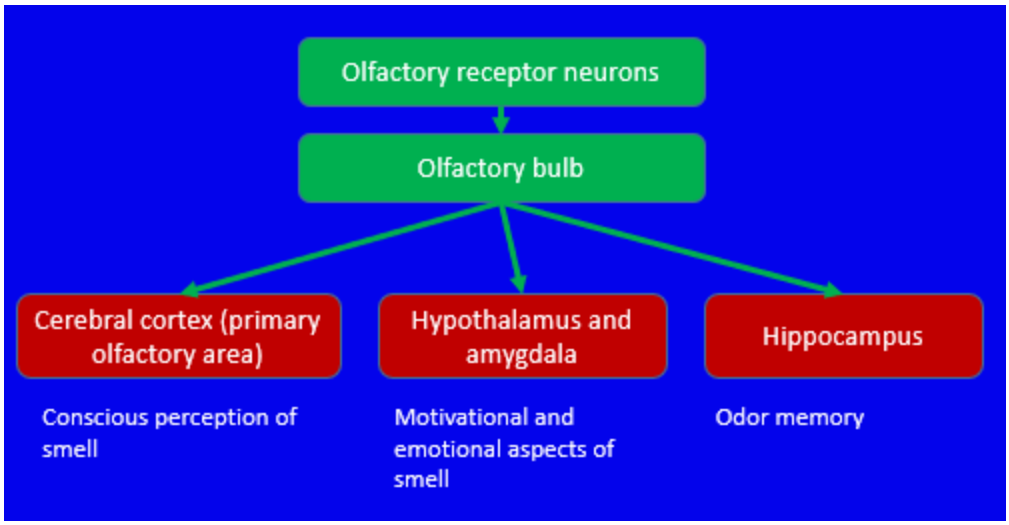
There are two types of pain: (1) *fast pain* and (2) *slow pain.* Fast pain occurs very rapidly and it is also know as acute, sharp, or pricking pain. This is the type of pain that is not felt in deeper tissues of the body. Slow pain, on the other hand, increases in intensity gradually over a period of several seconds or minutes. It is an excruciating pain, often described as chronic, burning, aching, or throbbing. It can occur in skin and deep tissues and it can also be referred. *Referred pain* is a visceral pain that is felt far from the stimulated organ. For example, pain in the liver caused by an obstruction can sometime present as neck or shoulder pain. Pain from heart attack can present as pain in the medial part of the left arm.

Proprioceptive sensations

Kinesthesia is the perception of body movements and this is due to the action of proprioceptors which are in the skeletal muscles, tendons, synovial joints, and inner ear (hair cells). The nerve impulses for conscious proprioception pass along sensory tracts in the spinal cord and brain stem and these are related to the primary somatosensory area. Proprioceptive impulses also pass to the cerebellum.

3. The Special Senses: Olfaction

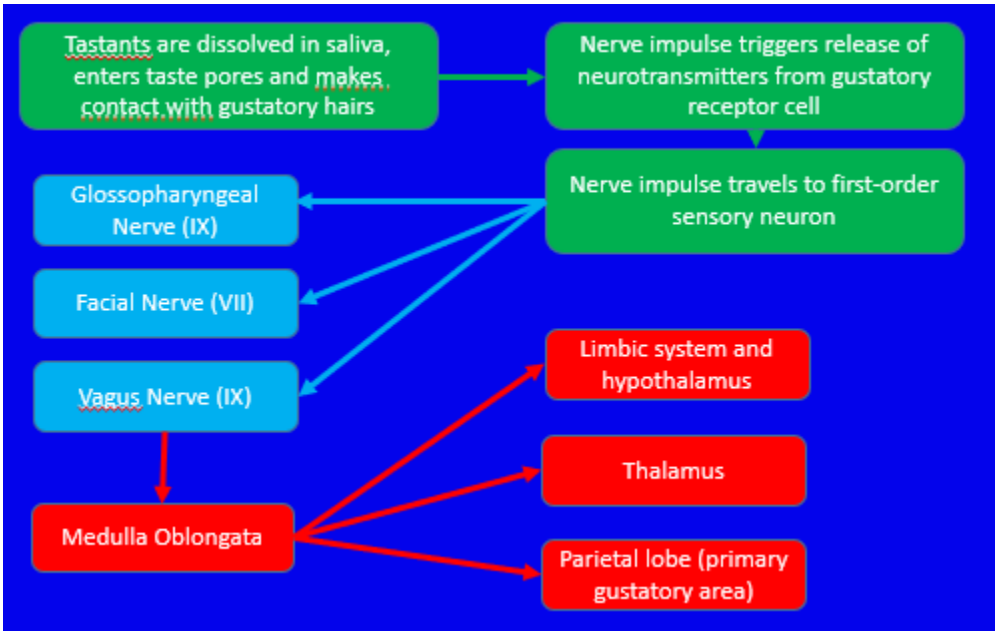
The chemicals from odor are sensed by *olfactory hairs* which are located in the apical surface of the olfactory cavity epithelium. The stimulus is then carried to the olfactory bulb to the brain. The olfactory pathway is depicted in the illustration below:



4. The Special Senses: Gustation

Gustation can only distinguish five primary tastes: sour, sweet, bitter, salty, and umami. Other flavors are combinations of the five, and the accompanying olfactory and tactile sensations. The chemicals from tastes are sensed by the *taste buds* which are the gustatory receptors. The taste buds are located in elevations in the tongue called *papilla.*

The gustatory pathway is depicted in the illustration below:



5. The Special Senses: Vision

Here are some important parts of the eye:

(1) Eyebrows and eyelashes- protect the eyeball from foreign object, sweat, and direct rays of the sun
(2) Lacrimal apparatus- group of glands, ducts, canals that produce and drain lacrimal fluid or tears (which contain lysozyme).
(3) Cornea- fibrous coat the covers the iris and helps focus light onto retina
(4) Sclera- "white" of the eye; it is composed of dense connective tissue that gives share to eyeball and protects the inner parts
(5) Conjunctive- covers the sclera but not the cornea and lines the inner surface of the eyelids
(6) Choroid- thin membrane that lines most of the internal surface of the sclera. It is highly vascular. It contains melanocytes which produce melanin that absorbs stray light rays within the eyeball.
(7) Ciliary body- it contains the *ciliary process* that secretes aqueous humor. It also has the *ciliary muscle* that alters the shape of the lens.
(8) Lens- the transparent structure that focuses light to retina
(9) Iris- this is the colored part of the eyeball. This is composed of smooth muscles which regulated the amount of light that enters the eye.
(10) Pupil- the entry point of light
(11) Retina- beginning of the visual pathway. It has two layers: the *neural layer* and *pigmented layer*.

The Retina

The neural layer of the retina is an outgrowth of the brain that contains three distinct layers of the retinal neuron – photoreceptor layer, bipolar cell layer, and ganglion cell layer. Light passes through the ganglion and bipolar cell layers before entering the photoreceptor layer.

The pigmented layer, on the other hand, has melanin-containing epithelial cells located between the choroid and neural part of the retina. The melanin helps absorb stray light rays.

The retina contains two types of photoreceptor cells – the rods and the cones. The *rods* allow us to see shares of gray in dim light such as moonlight, while the *cones* are stimulated by brighter light giving rise to highly acute color vision. Another difference of rods and cones is the number of cells that synapses with bipolar cells. Several rods synapses with a bipolar cell and this increases light sensitivity but blurs image. A cone, on the other hand, synapses with just a single bipolar cell and this increases the acuity of image.

The *fovea* is the part of the retina that has dense collection of cones and this is where the visual acuity is highest. However, there is also a *blind spot* in which photoreceptor cells are nonexistent.

The Interior of the Eyeball

The *anterior segment* of the eyeball is located anterior to the lens and this is filled with *aqueous humor*. The aqueous humor is a fluid secreted by the ciliary process and drains into the *canal of Schlemm* to reenter the circulation. The aqueous humor helps maintain the shape of the eye and it nourishes the lens and cornea.

The *posterior segment* of the eyeball is posterior to the lens and contains *vitreous humor*. The vitreous humor helps prevent the eyeball from collapsing and holds the retina against the choroid.

Intraocular pressure

This refers to the fluid pressure produced by the aqueous humor. It functions to help maintain the shape of the eyeball and keeps the retina smoothly pressed against the choroid so the retina is well-nourished and forms clear images. The normal intraocular pressure (approximately 16mmHg) is maintained by a balance between production and drainage of aqueous humor.

How are images formed?

Images are formed by a synchronous action of the different parts of the eye specifically: refraction or bending of light by the lens and cornea, change in the shape of the lens, and constriction and narrowing of the pupil.

With the refraction of light rays, the image formed in the retina are inverted and undergo right-to-left reversal. The brain stores inverted and reversed images and interprets visual images as being correctly oriented in space.

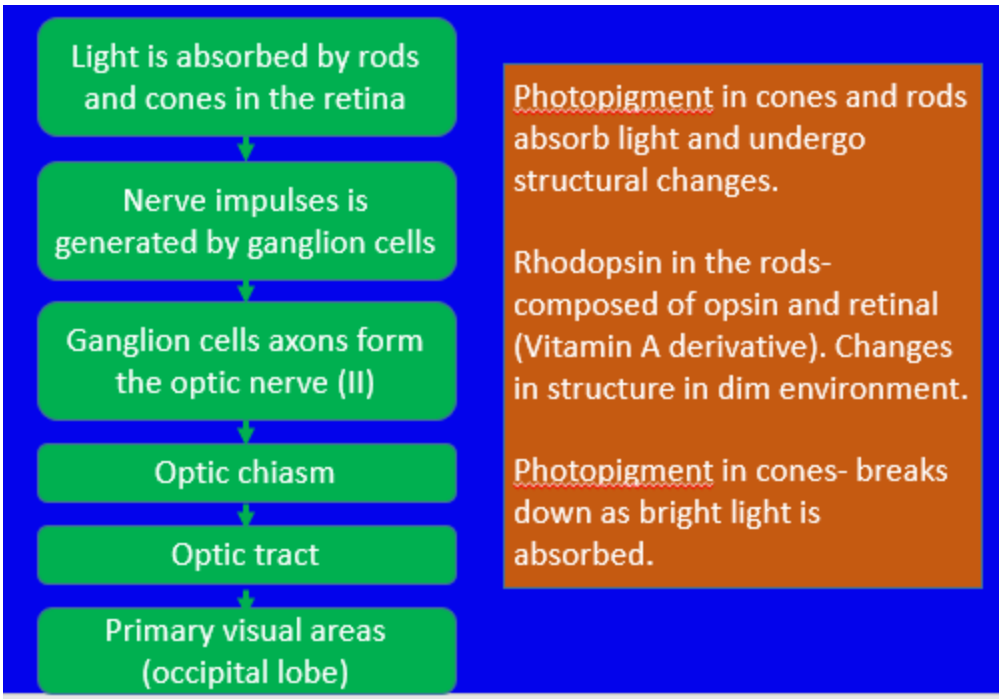
The refraction of light rays is done by the lens. The lens is both convex in its anterior and posterior surface and the more convex it is, the more is its ability to refract light. When a person is focusing on an image that near, the lens tend to be more convex and this process is called *accommodation.*

After the lights are refracted, this needs to enter the eye through the pupils. The dilation and constriction of pupils is necessary to control the amount of light that goes through. Constriction is the narrowing of the diameter of the pupils due to the contraction of the circular muscles of the iris. This occurs simultaneously with accommodation and prevents lights rays from entering the eye through the periphery of the lens. The pupil also constricts to bright light to limit the amount of light entering the retina.

Binocular vision allows for the perception of depth and appreciation of the 3D nature of objects. *Convergence* refers to the autonomic movement of the two eyeballs toward the midline due to the coordinated movement of extrinsic eye muscles. The nearer the object, the greater the convergence needed to maintain binocular vision.

The visual pathway

Below is an illustration of the visual pathway:



6. The Special Senses: Hearing

Here are some important parts of the ears:

External ear

(1) Auricle- made of elastic cartilage and it has a role in collecting sound waves and directing them to the external auditory canal
(2) External auditory canal- it has hairs and ceruminous glands that secrete cerumen. The cerumen prevents foreign objects from entering the ear
(3) Tympanic membrane (eardrum)- this is a semi-transparent partition between the external auditory canal and the middle ear. The soundwaves cause the tympanic membrane to vibrate

Middle ear

(4) Eustachian tube- also known as the auditory tube. It connects the middle ear with the upper part of the throat, and it can equalize the pressure on both sides of the eardrum.
(5) Stapes, incus, and malleus- collectively known as the auditory ossicles. They transmit vibration or sound waves to inner ear. There are tiny skeletal muscles that control the amount of movement of these bones to prevent damage.

Inner ear

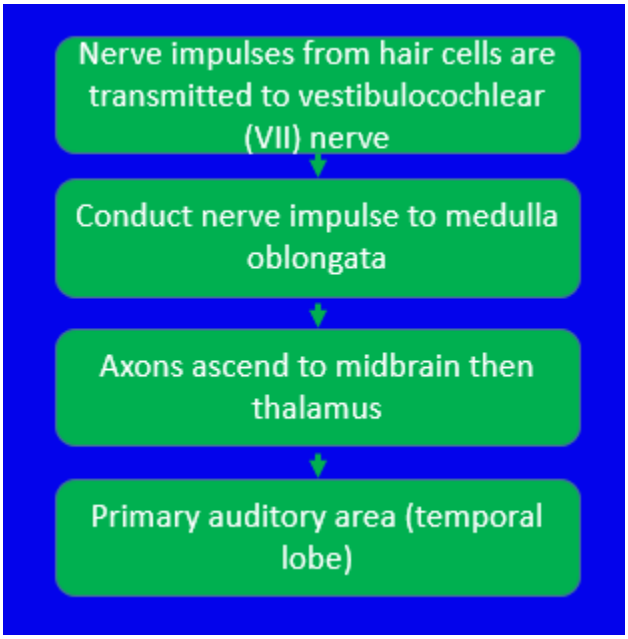
(6) Cochlea- part of the bony labyrinth. This is the sense organ for hearing. It contain the *perilymph.*
(7) Semicircular canals- part of the bony labyrinth. These are the sense organ for equilibrium and balance. They also contain *perilymph.*
(8) Organ of Corti- is located between the cochlear duct and tympanic duct in the cochlea. It contains supporting cells and hair cells (which detect sound waves).

How are we able to hear?

The sense of hearing is produced through the following steps:

1. The auricle direct sound waves into the external auditory canal
2. The sound waves vibrate the eardrum. More intense sounds produce larger vibrations.
3. The sound waves are then transmitted to the auditory ossicles as they start to vibrate
4. The back and forth movement of the stapes pushes the *oval window* in and out. This movement sets up fluid pressure waves in perilymph in the cochlea.
5. The fluid pressure waves are then transmitted from *scala vestibule* to *scala tympani* and eventually to the membrane covering the round window in the cochlea
6. The pressure waves deform he walls of the scala vestibule and scala tympani. This then creates pressure in the *endolymph* inside the cochlear duct.
7. Pressure waves in the endolymph cause the *basilar membrane* to vibrate which moves the hair cells in the organ of Corti. The hair cells, then, release neurotransmitter to conduct the nerve impulse to the vestibulocochlear (VII) nerve.

The auditory pathway is illustrated below:



7. The Special Senses: Equilibrium

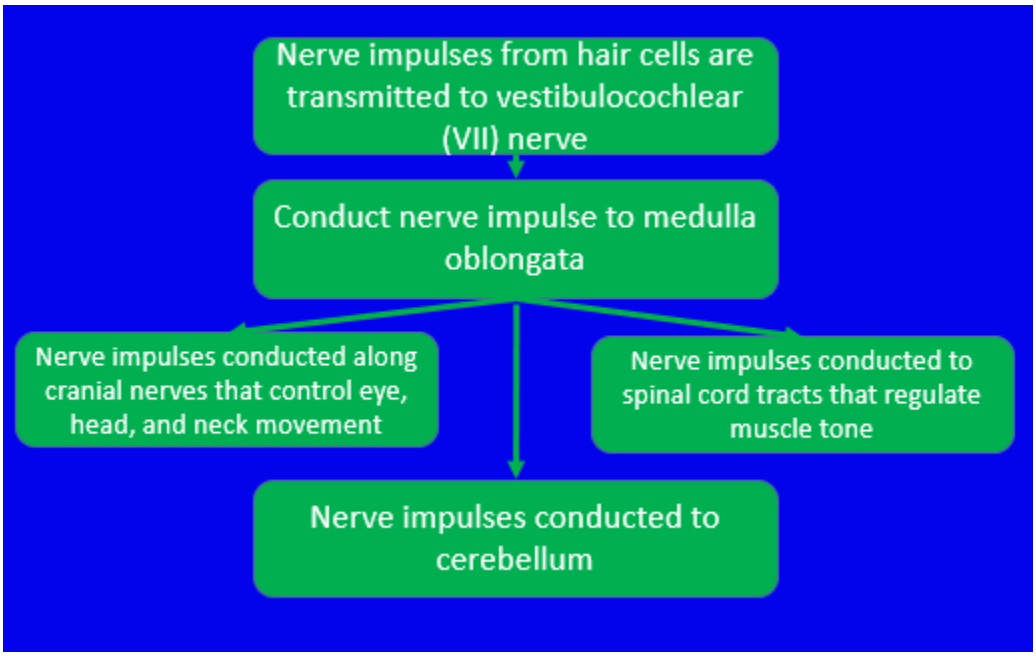
There are two types of equilibrium: (1) *Static equilibrium* and (2) *dynamic equilibrium*. Static equilibrium refers to the maintenance of the body position (mainly the head) relative to the force of gravity. Examples of movements that utilize static equilibrium include tilting of the head, and linear acceleration or deceleration. Dynamic equilibrium, on the other hand, refers to the maintenance of body position in response to rotational acceleration or deceleration.

The *vestibular apparatus* refers to the organs for equilibrium (also found in the ear) which include the saccule, utricle, and the membranous semicircular canals. The utricle and saccule contains the *macula* which contain the receptors for static equilibrium. The macula contains two kinds of cells: hair cells

which are the sensory receptors, and the supporting cells. If you tilt your head forward, gravity pulls the membrane sliding over the hair cells in the direction of the tilt. This stimulate the hair cells which then triggers nerve impulses to the vestibulocochlear (VII) nerve.

The *semicircular canals*, also found within the vestibular apparatus in the ear, contain the hair cells that detect dynamic equilibrium. The *cristae* in the semicircular canals contain both the hair cells and the supporting cells. Head movement moves the hair cells in the semicircular canals. This then stimulates the hair cells which triggers nerve impulses to the vestibulocochlear (VII) nerve.

Below is an illustration of the equilibrium pathway:



References:

1. Betts JG, Desaix Peter, Johnson E et al (2017). Chapter 1 An Introduction to the Human Body. *Anatomy and Physiology.* OpenStax Rice University. Pp 7-40.

2. Tortora GJ & Derrickson B. (2014). Chapter 1 An Introduction to the Human Body. *Principles of Anatomy and Physiology.* John Wiley & Sons, Inc. 14 edition. Pp 1-26.