

Medical Specialties and Procedures Related to the Digestive System

Gastroenterology

This specialty is focused on the diagnosis and treatment of conditions afflicting the digestive system. Gastroenterology is a branch of internal medicine. A physician who specializes in this area is known as a gastroenterologist. (American College of Gastroenterology, 2021b). To learn more about gastroenterology visit the [American College of Gastroenterology's profile page](#).

Procedures

Upper and Lower Gastrointestinal Series

This is a diagnostic procedure involving the introduction of a contrast medium known as barium. Barium can be introduced by ingesting or by enema. After induction of the barium, x-rays can be taken of the upper and lower gastrointestinal system structures (Johns Hopkins Medicine, 2020). To learn more, visit [Johns Hopkins Medicine's web page on barium x-rays](#).

Fecal Occult Blood Test

This is a test for hidden blood in a fecal sample. A patient is provided with a card to place a small segment of fecal output on. The sample is viewed under a microscope to look for blood. Blood detection can be an indicator of an abnormal growth occurring in the intestines (Johns Hopkins Medicine, 2020a).

Stool Culture

This procedure involves the collection of a small sample of feces which is analyzed for abnormal bacterial growth through a culture check (Johns Hopkins Medicine, 2020a).

Esophagogastroduodenoscopy

An EGD (upper endoscopy) is a procedure by which a physician examines the upper gastrointestinal tract (esophagus, stomach, duodenum) using a special instrument called an endoscope. The physician examines the tissues and is able to take a biopsy, if needed. (Johns Hopkins Medicine, 2020a.)

Test Yourself



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=142#h5p-85>

References

American Cancer Society medial and editorial content team. (2020a). *What is Cancer of the Esophagus?* American Cancer Society, Inc. <https://www.cancer.org/cancer/esophagus-cancer/about/what-is-cancer-of-the-esophagus.html>

American Cancer Society medial and editorial content team. (2020b). *What is Colorectal Cancer?* American Cancer Society, Inc. <https://www.cancer.org/cancer/colon-rectal-cancer/about/what-is-colorectal-cancer.html>

American College of Gastroenterology. (2021a). *Irritable bowel syndrome*. <https://gi.org/topics/irritable-bowel-syndrome/#tabs1>

American College of Gastroenterology. (2021b). *What is Gastroenterology?* <https://gi.org/patients/gi-health-and-disease/what-is-a-gastroenterologist/>

Booth, S. (2018, August 13). *Everything you need to know about hepatitis A, B, C, D, E*. Healthline. <https://www.healthline.com/health-news/everything-you-need-to-know-about-hepatitis#1>

Celiac Disease Foundation. (n.d.) *What is celiac disease?*. Available from: <https://celiac.org>

“Cholecystitis”. (2019, January 15). Radiologyinfo.org. <https://www.radiologyinfo.org/en/info.cfm?pg=cholecystitis>

Johns Hopkins Medicine. (2020). *Barium x-rays (upper and lower GI)*. <https://www.hopkinsmedicine.org/health/conditions-and-diseases/barium-xrays-upper-and-lower-gi>

Johns Hopkins Medicine. (2020a). *Digestive diagnostic procedures*. <https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/digestive-diagnostic-procedures>

Mayo Clinic Staff. (2020, May 22). *Gastroesophageal reflux disease*. Mayo Clinic. <https://www.mayoclinic.org/diseases-conditions/gerd/symptoms-causes/syc-20361940>

Mayo Clinic Staff. (2018, December 7). *Cirrhosis*. Mayo Clinic. Available from: <https://www.mayoclinic.org/diseases-conditions/cirrhosis/symptoms-causes/syc-20351487>

Mayo Clinic Staff. (2019, October 19). *Colon polyps*. Mayo Clinic. <https://www.mayoclinic.org/diseases-conditions/colon-polyps/symptoms-causes/syc-20352875>

UCLA Health. (n.d.) *What is IBD?* <https://www.uclahealth.org/gastro/ibd/about-ibd>

Unless otherwise indicated, this chapter contains material adapted from *Anatomy and Physiology* (on OpenStax), by Betts, et al. and is used under a [CC BY 4.0 international license](https://creativecommons.org/licenses/by/4.0/). Download and access this book for free at <https://openstax.org/books/anatomy-and-physiology/pages/1-introduction>.

13. Skeletal System

WTCS Learning Objectives

- Apply the rules of medical language to build, analyze, spell, pronounce, abbreviate, and define terms as they relate to the musculoskeletal system
- Identify meanings of key word components of the musculoskeletal system
- Categorize diagnostic, therapeutic, procedural or anatomic terms related to the musculoskeletal system
- Use terms related to the musculoskeletal system
- Use terms related to the diseases and disorders of the musculoskeletal system

Skeletal System Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the Musculoskeletal System.



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-86>

Introduction to the Skeletal System

The skeletal system forms the framework of the body. It is the body system composed of bones, cartilage and ligaments. Each bone serves a particular function and varies in size, shape and strength. Bones are weight-bearing structures in your body and can therefore change in thickness as you gain or lose weight. The skeletal system performs the following critical functions for the human body:

- supports the body
- facilitates movement
- protects internal organs
- produces blood cells
- stores and releases minerals and fat

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#oembed-1>

Media 13.1. [The Skeletal System: Crash Course A&P #19](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Skeletal System Medical Terms



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-87>

Anatomy (Structures) of the Skeletal System

The skeletal system includes all of the bones, cartilages, and ligaments of the body that support and give shape to the body and body structures. The **skeleton** consists of the bones of the body. For adults, there are 206 bones in the skeleton. Younger individuals have higher numbers of bones because some bones fuse together during childhood and adolescence to form an adult bone. The primary functions of the skeleton are to provide a rigid, internal structure that can support the weight of the body against the force of gravity, and to provide a structure upon which muscles can act to produce movements of the body.

In addition to providing for support and movements of the body, the skeleton has protective and storage functions. It protects the internal organs, including the brain, spinal cord, heart, lungs, and pelvic organs. The bones of the skeleton serve as the primary storage site for important minerals such as calcium and phosphate. The bone marrow found within bones stores fat and houses the blood-cell producing tissue of the body.

The skeleton is subdivided into two major divisions: the **axial** and **appendicular**.

The Axial Skeleton

The **axial skeleton** forms the vertical, central axis of the body and includes all bones of the head, neck, chest, and back (see Figure 13.1). It serves to protect the brain, spinal cord, heart, and lungs. It also serves as the attachment site for

muscles that move the head, neck, and back, and for muscles that act across the shoulder and hip joints to move their corresponding limbs.

The axial skeleton of the adult consists of 80 bones including the **skull**, the **vertebral column**, and the **thoracic cage**. The skull is formed by 22 bones. Also associated with the head are an additional seven bones, including the **hyoid bone** and the **ear ossicles** (three small bones found in each middle ear). The vertebral column consists of 24 bones, each called a **vertebra**, plus the **sacrum** and **coccyx**. The thoracic cage includes the 12 pairs of **ribs**, and the **sternum**, the flattened bone of the anterior chest.

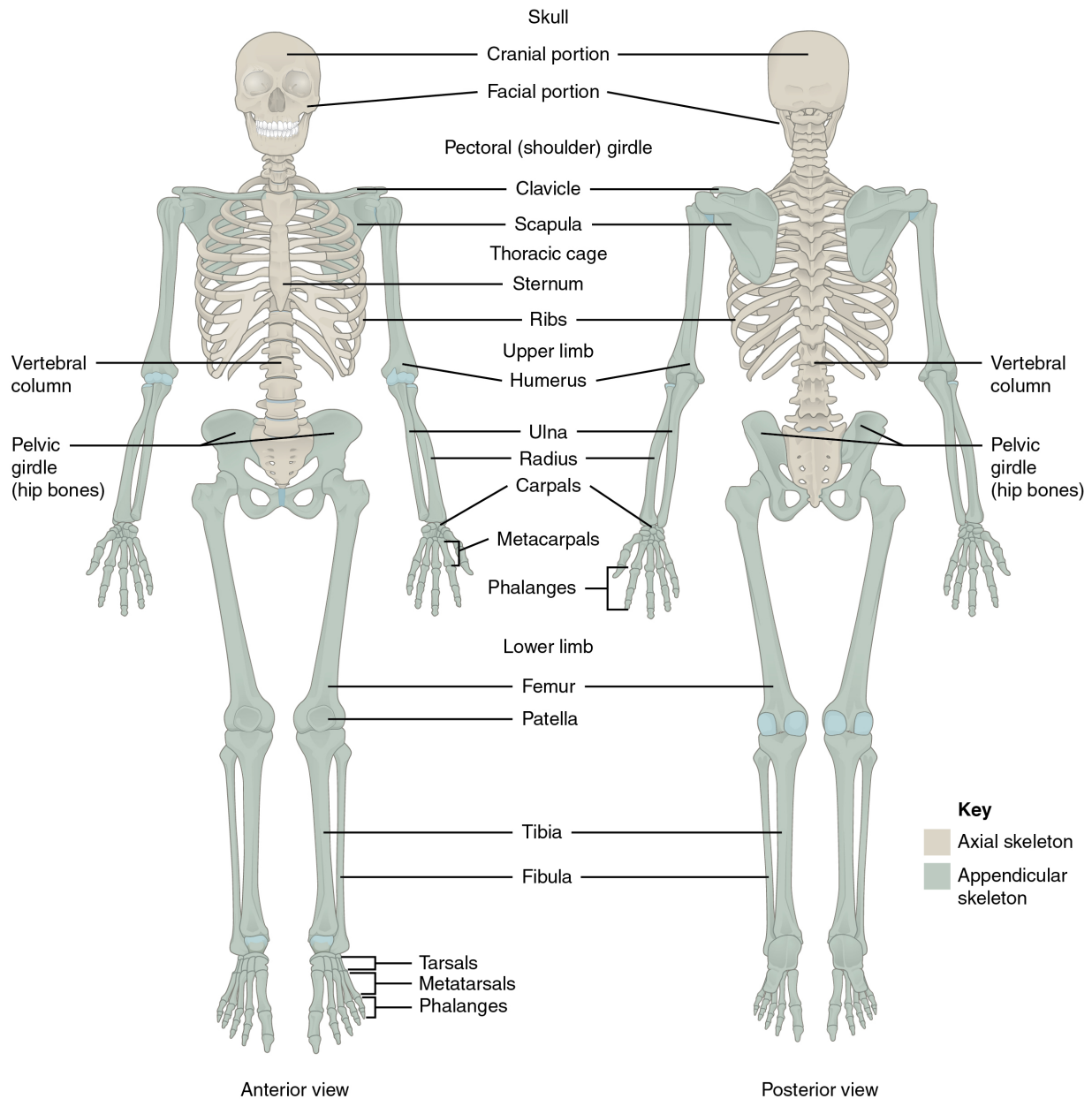


Figure 13.1 Axial and Appendicular Skeleton. The axial skeleton supports the head, neck, back, and chest and thus forms the vertical axis of the body. It consists of the skull, vertebral column (including the sacrum and coccyx), and the thoracic cage, formed by the ribs and sternum. The appendicular skeleton is made up of all bones of the upper and lower limbs. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

The **cranium** or skull supports the face and protects the brain. It is subdivided into the bones of the skull and the bones of the face.

Bones of the Skull

- **Frontal** – forms the forehead
- **Parietal** – the upper lateral sides of the cranium
- **Occipital** – the posterior skull and base of the cranial cavity
- **Temporal** – the lower lateral sides of the cranium
- **Sphenoid** – the 'keystone' bone that forms part of the base of skull and eye sockets
- **Ethmoid** – forms part of the nose and orbit and base of cranium
- **Auditory ossicles** – the small bones of the middle ear
- **External auditory meatus** – the external opening of ear and temporal bone

Bones of the Face

- **Zygomatic** – the cheekbone
- **Maxillary** – the upper jaw and hard palate
- **Palatine** – the lateral walls of the nose
- **Lacrimal** – the walls of the orbit
- **Inferior conchae** – the lower lateral wall of the nasal cavity
- **Vomer** – the separates the left and right nasal cavity
- **Mandible** – the lower jaw bone (The only movable bone of the skull)
- **Hyoid** – the bone located between the mandible and larynx, not connected to other bones

Bones of the Vertebral Column

The vertebral column is also known as the spinal column or spine (see Figure 13.2). It consists of a sequence of vertebrae (singular = vertebra), each of which is separated and united by an **intervertebral disc**. Together, the vertebrae and intervertebral discs form the vertebral column. It is a flexible column that supports the head, neck, and body and allows for their movements. It also protects the spinal cord, which passes down the back through openings in the vertebrae.

Did You Know?

The axial skeleton has 80 bones and includes bones of the skull (and face), vertebral column, and thoracic cage.

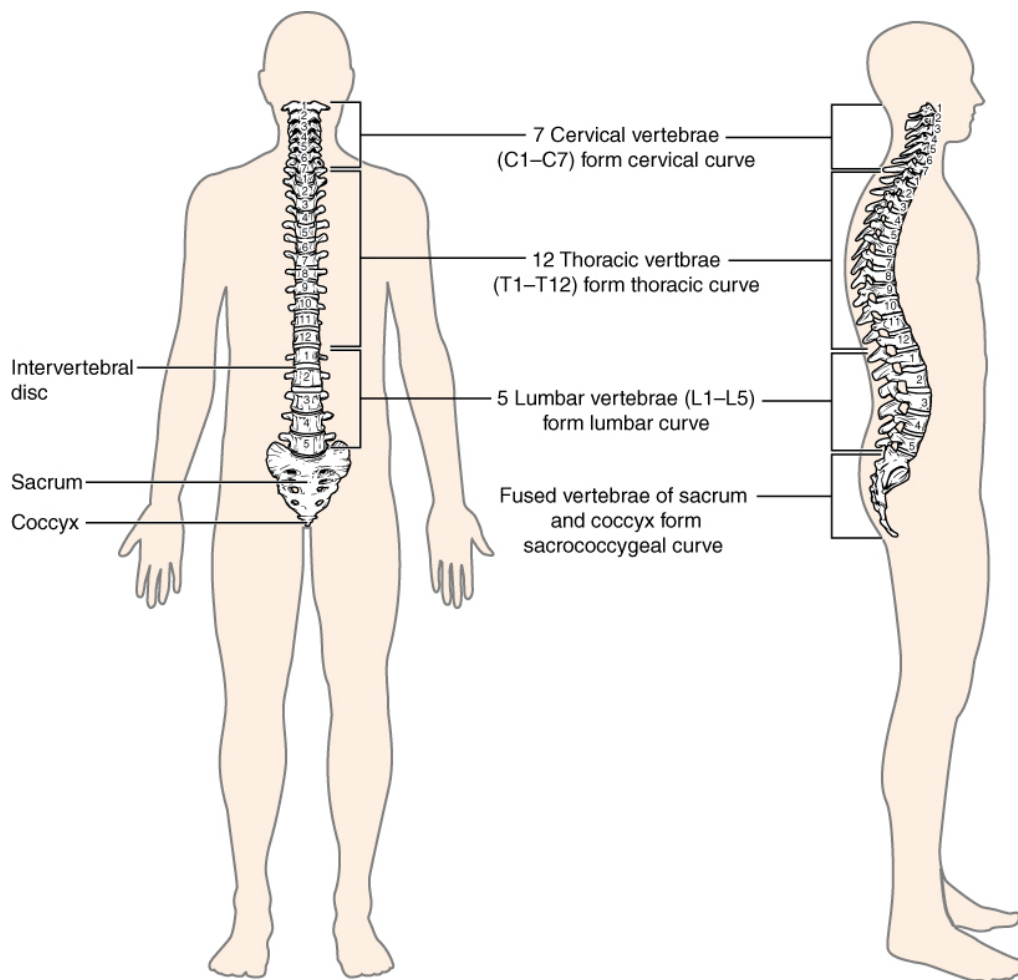


Figure 13.2 Vertebral Column. The adult vertebral column consists of 24 vertebrae, plus the sacrum and coccyx. The vertebrae are divided into three regions: cervical C1–C7 vertebrae, thoracic T1–T12 vertebrae, and lumbar L1–L5 vertebrae. The vertebral column is curved, with two primary curvatures (thoracic and sacrococcygeal curves) and two secondary curvatures (cervical and lumbar curves). From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Types of Vertebrae

- **Cervical** – C1 to C7 – the first 7 vertebrae in the neck region
- **Thoracic** – T1 to T12 – the next 12 vertebrae that forms the outward curvature of the spine
- **Lumbar** – L1 to L5 – the next 5 vertebrae that forms the inner curvature of spine
- **Sacrum** – the triangular-shaped bone at the base of the spine
- **Coccyx** – the tailbone

Bones of the Thoracic Cavity

The thoracic cage (rib cage) forms the thorax (chest) portion of the body. It consists of the 12 pairs of ribs with their costal cartilages and the sternum (see Figure 13.3). The ribs are anchored posteriorly to the 12 thoracic vertebrae (T1–T12). The thoracic cage protects the heart and lungs.

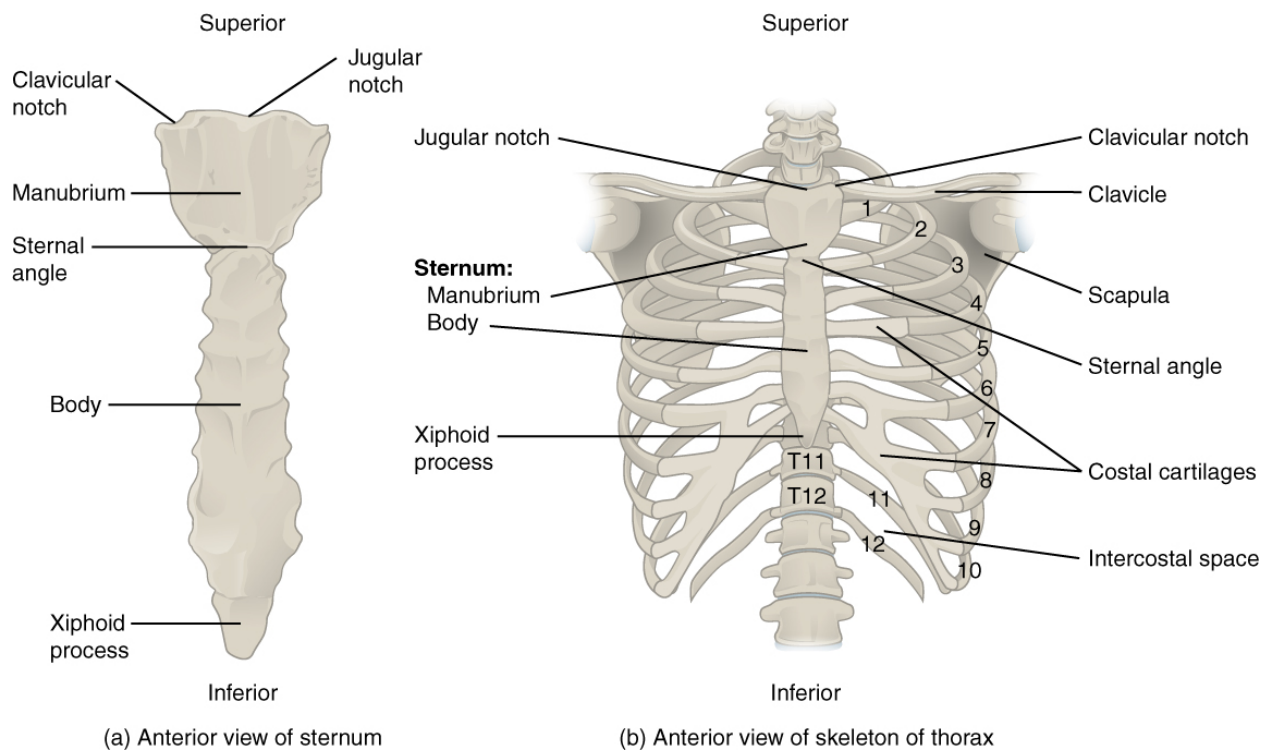


Figure 13.3 Thoracic Cage. The thoracic cage is formed by the (a) sternum and (b) 12 pairs of ribs with their costal cartilages. The ribs are anchored posteriorly to the 12 thoracic vertebrae. The sternum consists of the manubrium, body, and xiphoid process. The ribs are classified as true ribs (1–7) and false ribs (8–12). The last two pairs of false ribs are also known as floating ribs (11–12). From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Ribs

There are 12 sets of **ribs** and can be divided as such:

- 7 **true ribs** as they are attached to the front of the sternum
- 3 **false ribs** as they are attached to the cartilage that joins the sternum
- 2 **floating ribs** as they are not attached to the front of the sternum

Sternum

The **sternum**, also known as the breast bone, is divided into 3 parts:

- **manubrium** – the upper portion of the breast bone
- **body** – the middle portion of the breast bone
- **xiphoid process** – the lower portion of the breast bone and is made up of cartilage

Concept Check

Answer the following questions:

- What is the medical term for the upper jaw bone and for the lower jaw bone?
- How many bones make up the cervical region of the vertebral column?

The Appendicular Skeleton

The **appendicular skeleton** includes all bones of the upper and lower limbs, plus the bones that attach each limb to the axial skeleton. There are 126 bones in the appendicular skeleton of an adult.

Did You Know?

The appendicular skeleton has 126 bones. It is divided into the bones of the upper limbs and lower limbs that attach each limb to skeleton. (Betts, et al., 2021)

Bones of the Pectoral Girdle

- **Scapula** – the shoulder blades
- **Clavicle** – the collar bones. It connects the sternum to the scapula
- **Acromion** – the extension that forms the bony point of the shoulder

Bones of the Upper Limbs

The bones of the upper limbs include the bones of the arms, wrists, and hands.

Bones of the Arm

- **Humerus** – the bone in upper arm
- **Radius** – the bone that runs thumb-side of the forearm
- **Ulna** – the bone that runs on the side of the little finger of the forearm

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#oembed-2>

Media 13.2. [Radius and Ulna](#) [Online video]. Copyright 2013 by [UCDenver Anatomy Lab 3244](#).

Bones of the Wrist and Hand

- **Carpals** – the wrist bones
- **Metacarpals** – the bones in the palm of hand
- **Phalanges** – the finger and toe bones

Each phalanx has three bones: the distal, medial, and proximal. The exception is the thumb and big toe which has two bones: distal and proximal. See Fig 13.4 below. There are 30 bones in each upper limb. Can you count them on your limb?

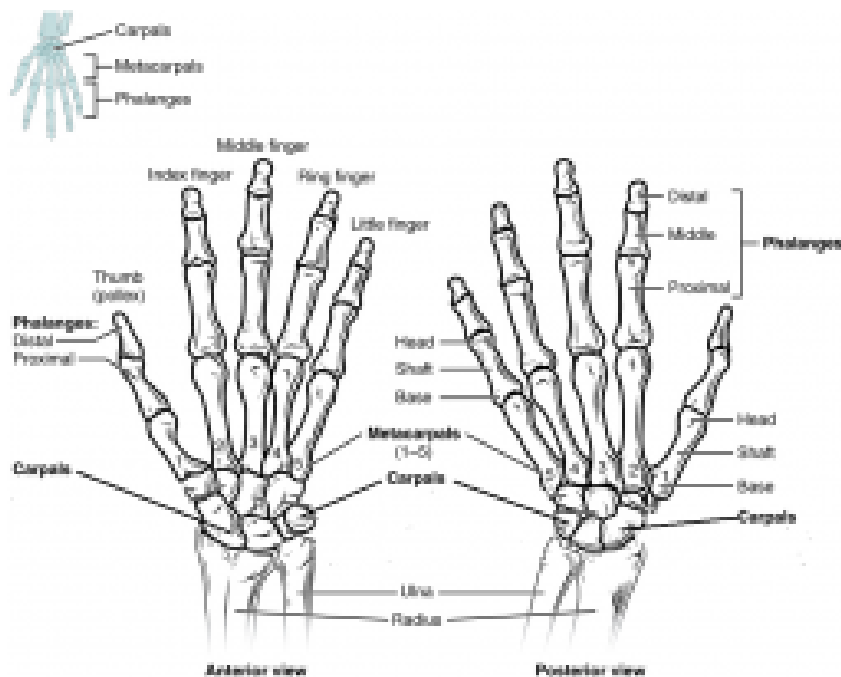


Figure 13.4 Bones of the Hands. From Betts, et al., 2021. Licensed under [CC BY 4.0](#).

Bones of the Pelvic Region

The bones of the pelvic region protect the reproductive, urinary, and excretory organs.

- **Pelvic girdle** – the hip or coxal bone. It is formed by the fusion of three bones during adolescence
- **Ilium** – the largest part of the hip bone
- **Ischium** – the lower portion of pelvic girdle
- **Pubis** – the anterior portion of pelvic girdle
- **Pelvis** – consists of four bones: the left and right hip bones as well as the sacrum and coccyx
- **Acetabulum** – the large socket in the pelvic bones that holds the head of the femur

The shape of the pelvic girdle is different for males than females. In the male, it is a funnel shape. In the female it is shaped like a basin to accommodate for the fetus during pregnancy (see Figure 13.5).

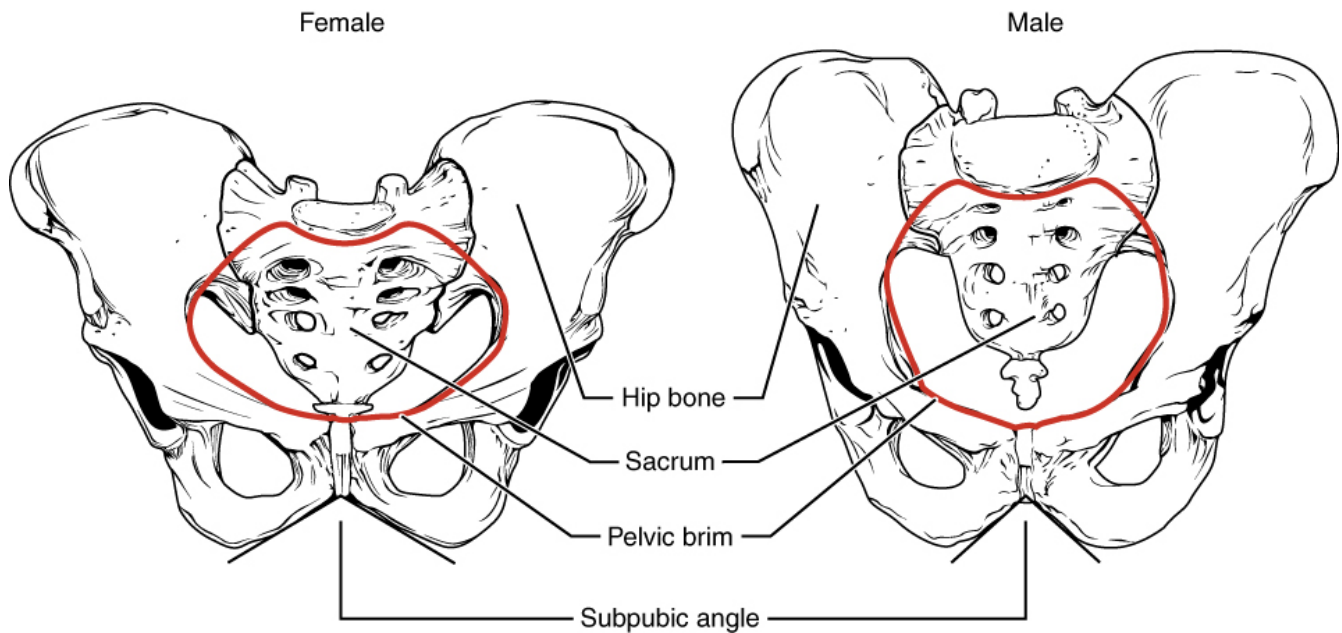


Figure 13.5 Female and male pelvis, showing the hip bone, sacrum, pelvic brim and subpubic angle. From Betts et al. 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Bones of the Lower Limbs

The bones of the lower limb include bones of the leg and the feet.

Bones of the Leg

- **Femur** – the thigh bone and is also referred to the upper leg bone. It is the longest and strongest bone in the human body
- **Patella** – the knee cap
- **Tibia** – the shin bone. It is a medial bone and the main weight-bearing bone of the lower leg
- **Fibula** – the smaller of the lower leg bone (see Figure 13.6)

Did you know?

The femur is the longest and strongest bone of the body, and accounts for approximately one-quarter of a person's

total height (Betts, et al., 2021).

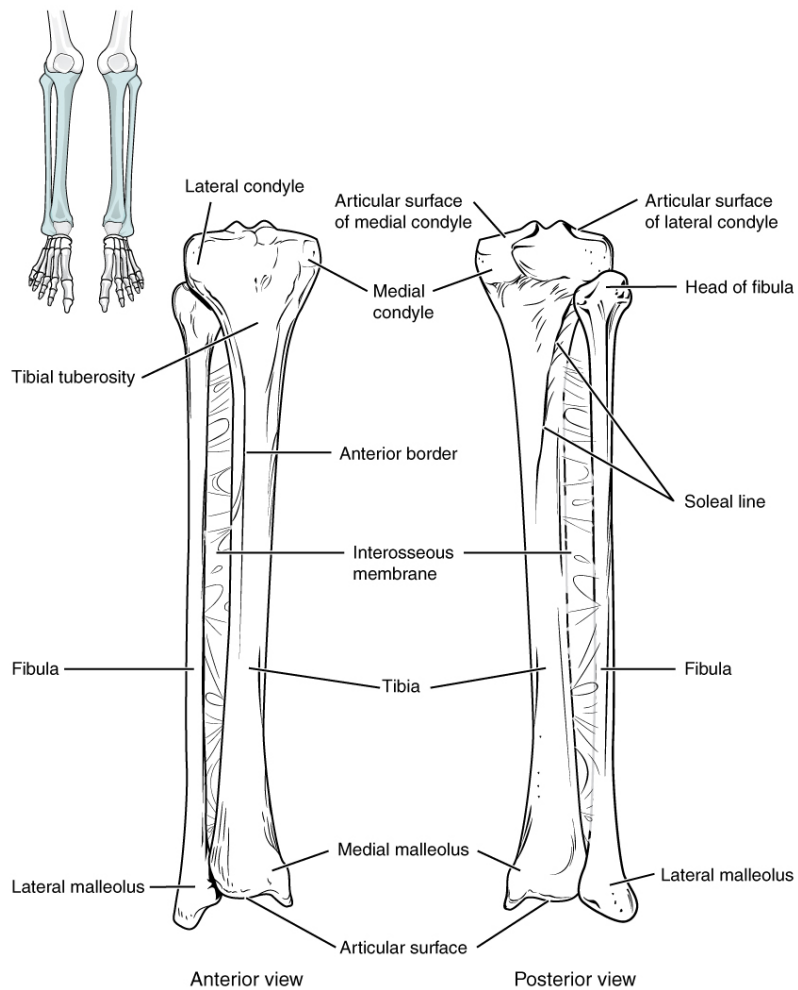


Figure 13.6 Tibia and Fibula. The tibia is the larger, weight-bearing bone located on the medial side of the leg. The fibula is the slender bone of the lateral side of the leg and does not bear weight. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Bones of the Ankles and Feet

- **Tarsals** – the ankle bones (7 total)
- **Malleous** – the bony protrusions of the ankle bones
- **Talus** – the superior ankle bones
- **Calcaneous** – the heel bones
- **Metatarsals** – the foot bones
- **Phalanges** – the bones of the toes (see Figure 13.7)

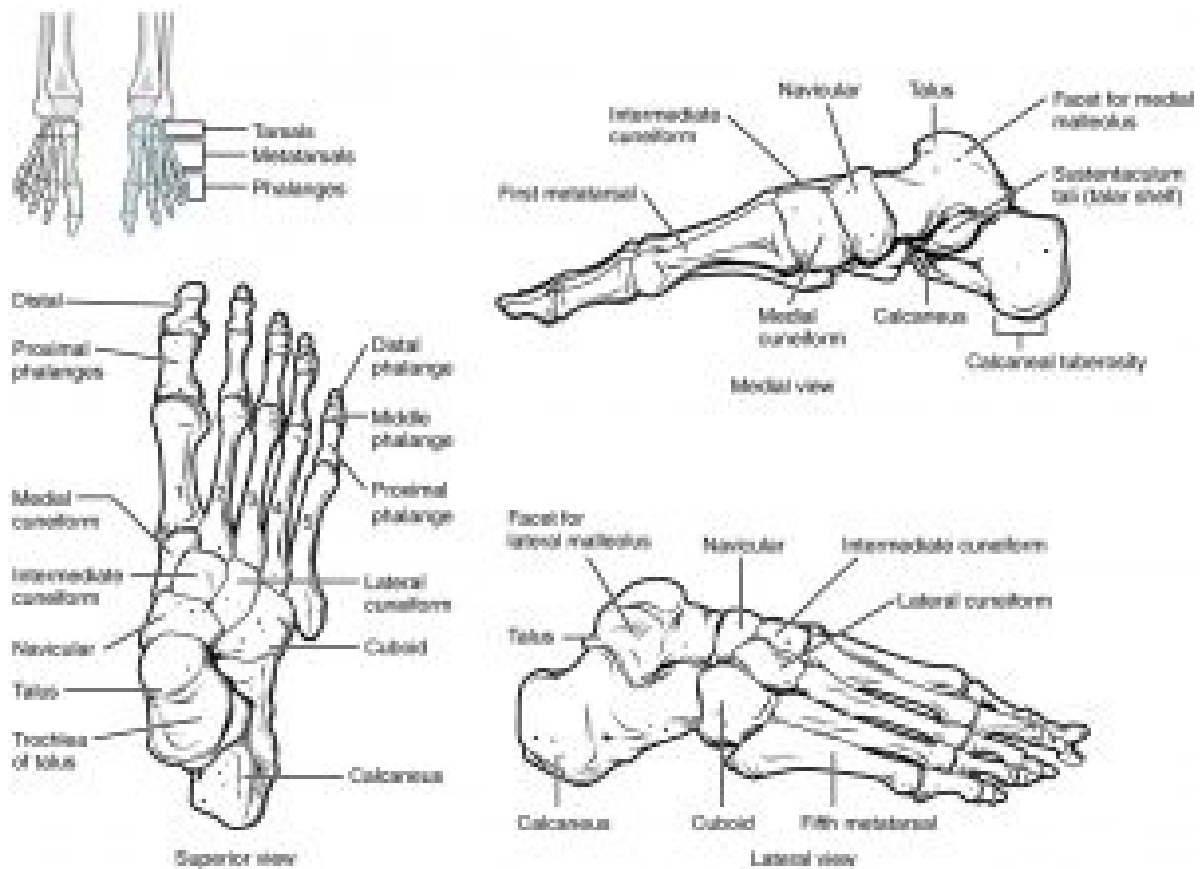


Figure 13.7 Bones of the Foot. The bones of the foot are divided into three groups. The posterior foot is formed by the seven tarsal bones. The mid-foot has the five metatarsal bones. The toes contain the phalanges. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Concept Check

Answer the following questions:

- Is the humerus the same as the funny bone?
- What is the medical term for the kneecap?

Anatomy Labeling Activity



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-88>

Physiology (Function) of the Skeletal System

The bones of the skeletal system is comprised of an inner spongy tissue referred to as bone marrow. There are two types of bone marrow, red and yellow. The red bone marrow produces the red blood cells and it does so by a process called **hematopoiesis**. The yellow bone marrow contains adipose tissues which can be a source of energy. The bones of the skeletal system also store minerals such as calcium and phosphate. These minerals are important for the physiological processes in the body and are released into the bloodstream when levels are low in the body.

Joints

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#oembed-3>

Media 13.3. [Joints: Crash Course A&P #20](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Most bones connect to at least one other bone in the body. The area where bones meet bones or where bones meet cartilage are called **articulations**. Joints can be classified based on their ability to move. At **movable** joints, the articulating surfaces of the adjacent bones can move smoothly against each other. However, other joints may be connected to each other by connective tissue or cartilage. These joints are designed for stability and provide for little or no movement. Importantly, joint stability and movement are related to each other. This means that stable joints allow for little or no mobility between the adjacent bones. Conversely, joints that provide the most movement between bones are the least stable.

Based on the **function of joints**, there are 3 types of joints:

Did You Know?

The left and right hip bones are connected by an amphiarthrosis joint.

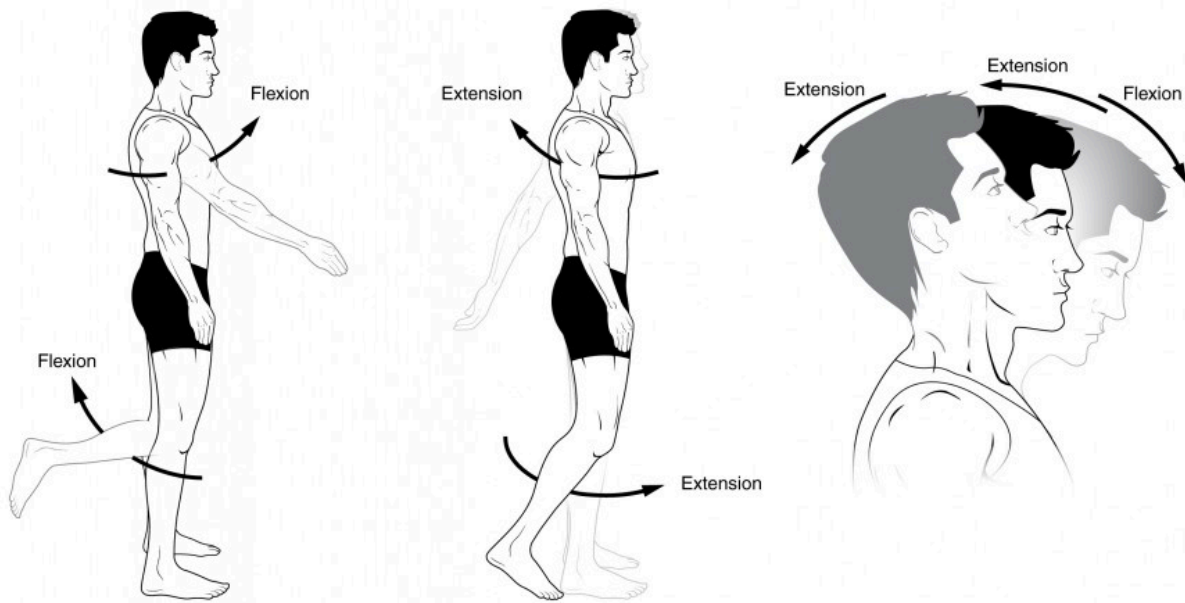
- **Synarthrosis** (sin-ahr-throh-seez) joints which allow no movement
 - example: joints of the skull
- **Amphiarthrosis** (am-fee-ahr-throh-sis) joints which allow some movement
 - example: joints of the pubic symphysis
- **Diarthrosis** (dahy-ahr-throh-seez) joints which allow for free movement
 - example: joints of the knee

Structures associated with joints are:

- **Cartilage** – the elastic connective tissue that is found at the ends of bones, nose tip, etc.
 - **Synovial membrane** – the lining or covering of synovial joints
 - **Synovial fluid** – the lubricating fluid found between synovial joints
 - **Ligaments** – the tough, elastic connective tissue that connects bone to bone
 - **Tendons** – the fibrous connective tissue that attaches muscle to bone
- **Bursa** – the closed, fluid-filled sacs that works as a cushion
 - **Meniscus** – C-shaped cartilage that act as shock absorbers between bones

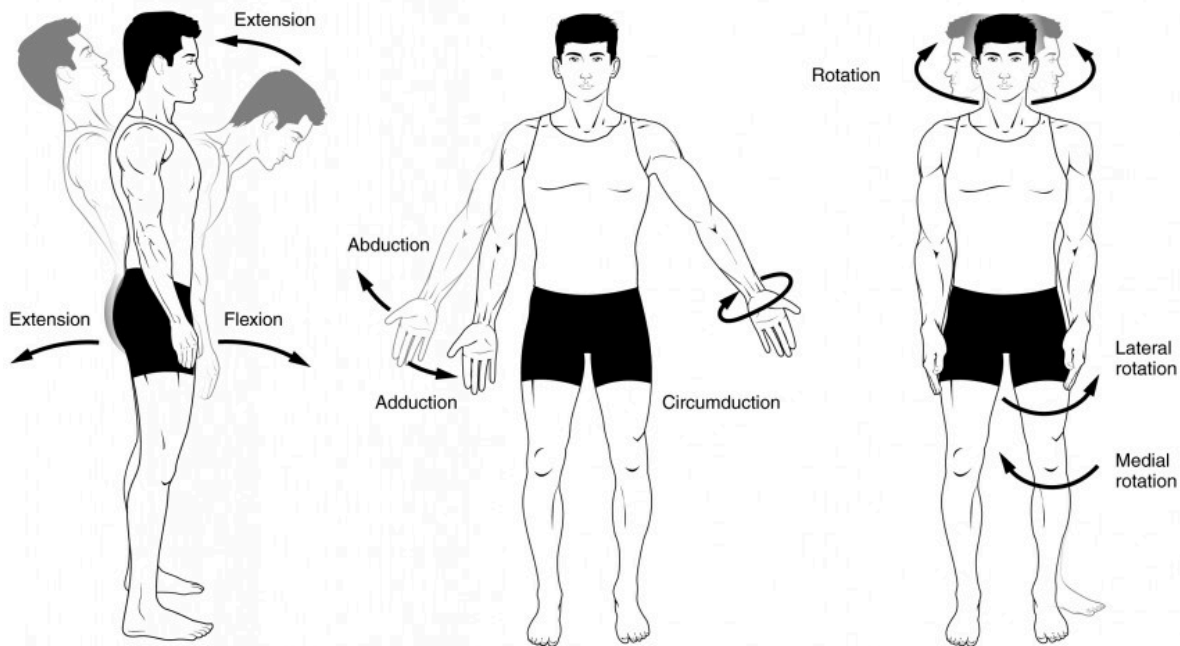
Body Movements

Synovial joints are movable joints and provide most of the body movements. Body movement occurs when the bones, joints and muscles work together.



(a) and (b) Angular movements: flexion and extension at the shoulder and knees

(c) Angular movements: flexion and extension of the neck



(d) Angular movements: flexion and extension of the vertebral column

(e) Angular movements: abduction, adduction, and circumduction of the upper limb at the shoulder

(f) Rotation of the head, neck, and lower limb

Figure 13.8 Movements of the Body, Part 1. Synovial joints give the body many ways in which to move. (a) and (b) Flexion and extension motions are in the sagittal (anterior and posterior) plane of motion. These movements take place at the shoulder, hip, elbow, knee, wrist, metacarpophalangeal, metatarsophalangeal, and interphalangeal joints. (c) and (d) Anterior bending of the head or vertebral column is flexion, while any posterior-going movement is extension. (e) Abduction and adduction are motions of the limbs, hand, fingers, or toes in the coronal (medial and lateral) plane of movement. Moving the limb or hand laterally away from the body, or spreading the fingers or toes, is abduction. Adduction brings the limb or hand toward or across the midline of the body, or brings the fingers or toes together. Circumduction is the movement of the limb, hand, or fingers in a circular pattern, using the sequential combination of flexion, adduction, extension, and abduction motions. Adduction/abduction and circumduction take place at the shoulder, hip, wrist, metacarpophalangeal, and metatarsophalangeal joints. (f) Turning of the head side to side or twisting of the body is rotation. Medial and lateral rotation of the upper limb at the shoulder or lower limb at the hip involves turning the anterior surface of the limb toward the midline of the body (medial or internal rotation) or away from the midline (lateral or external rotation). From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Flexion and Extension

Flexion and **extension** are movements that take place within the sagittal plane and involve anterior or posterior movements of the body or limbs. For the vertebral column, **flexion** (anterior flexion) is an anterior (forward) *bending* of the neck or body, while **extension** involves a posterior-directed motion, such as *straightening* from a flexed position or bending backward. **Lateral flexion** is the bending of the neck or body toward the right or left side. These movements of the vertebral column involve both the joints as well as the associated intervertebral disc.

In the limbs, flexion *decreases* the angle between the bones (bending of the joint), while extension *increases* the angle and straightens the joint (see Figure 13.8(a-d)). You will discover in the muscular system chapter that the associated muscles to these movements are flexor and extensor.

Abduction and Adduction

Abduction and **adduction** motions occur within the coronal plane and involve medial-lateral motions of the limbs, fingers, toes, or thumb. For example, abduction is raising the arm at the shoulder joint, moving it laterally away from the body, while adduction brings the arm down to the side of the body (see Figure 13.8(e)). In the muscular system chapter you will discover that the associated muscles to these movements are abductor and adductor.

Circumduction

Circumduction is the movement of a body region in a *circular* manner, in which one end of the body region being moved stays relatively stationary while the other end describes a circle. It involves the sequential combination of flexion, adduction, extension, and abduction at a joint (see Figure 13.8(e)).

Rotation

Rotation can occur within the vertebral column, at a **pivot joint**, or at a **ball-and-socket joint**. Rotation of the neck or body is the *twisting* movement produced by the summation of the small rotational movements available between adjacent vertebrae. At a pivot joint, one bone rotates in relation to another bone.

Rotation can also occur at the **ball-and-socket joints** of the shoulder and hip. Here, the humerus and femur rotate around their long axis, which moves the anterior surface of the arm or thigh either toward or away from the midline of the body (see see Figure 13.8(f)).

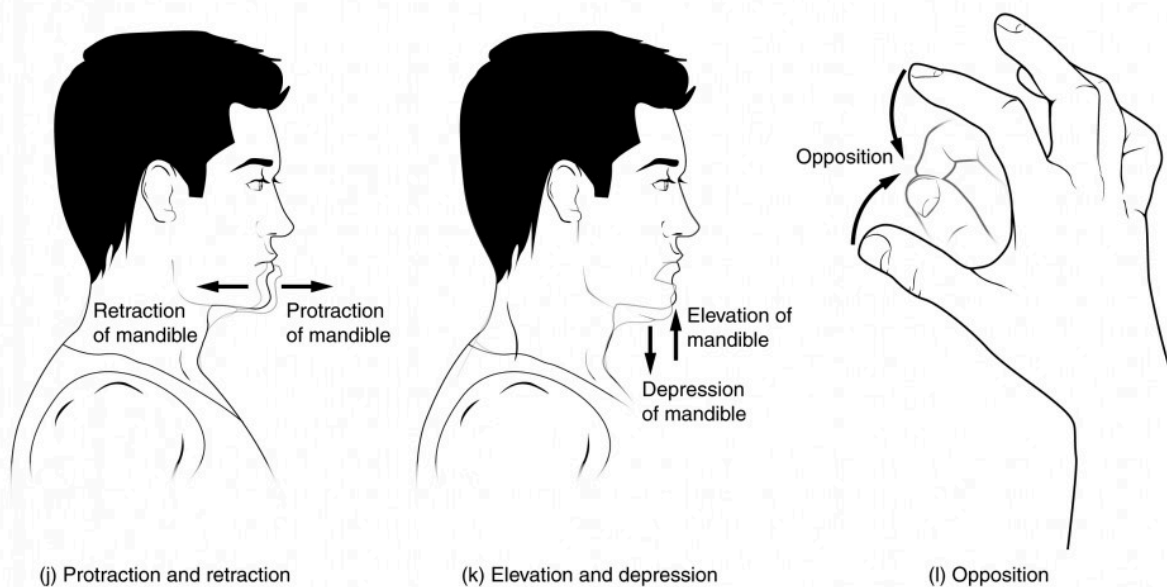
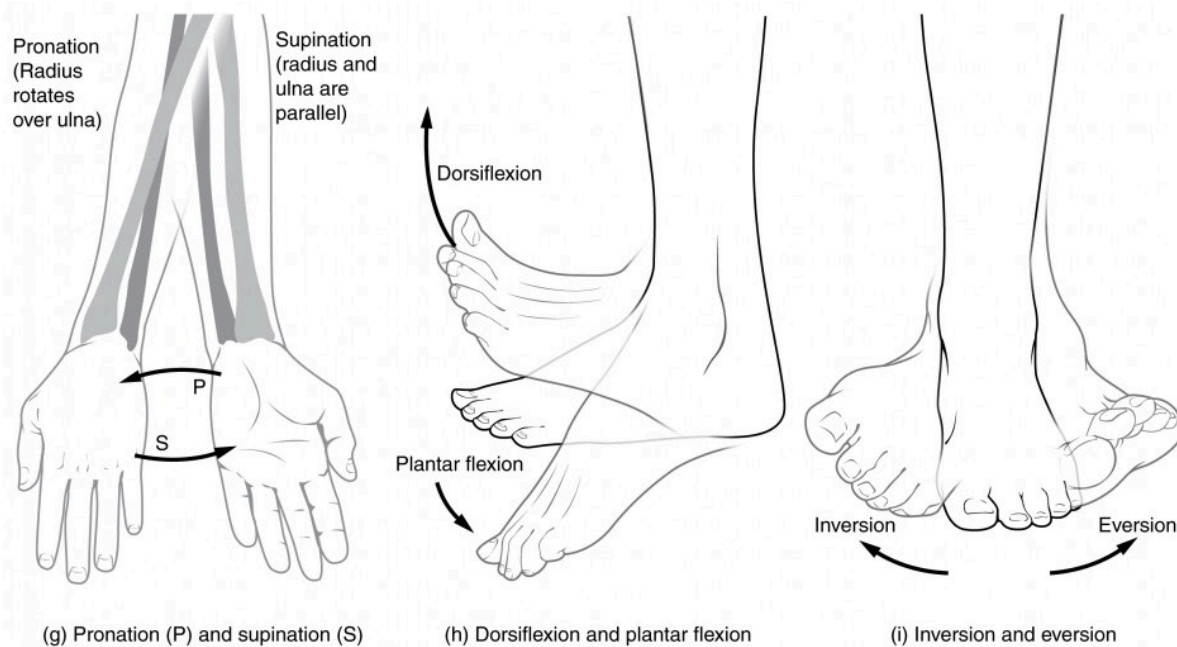


Figure 13.9 Movements of the Body, Part 2. (g) Supination of the forearm turns the hand to the palm forward position in which the radius and ulna are parallel, while forearm pronation turns the hand to the palm backward position in which the radius crosses over the ulna to form an “X.” (h) Dorsiflexion of the foot at the ankle joint moves the top of the foot toward the leg, while plantar flexion lifts the heel and points the toes. (i) Eversion of the foot moves the bottom (sole) of the foot away from the midline of the body, while foot inversion faces the sole toward the midline. (j) Protraction of the mandible pushes the chin forward, and retraction pulls the chin back. (k) Depression of the mandible opens the mouth, while elevation closes it. (l) Opposition of the thumb brings the tip of the thumb into contact with the tip of the fingers of the same hand and reposition brings the thumb back next to the index finger. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Supination and Pronation

Supination and pronation are movements of the forearm. In the anatomical position, the upper limb is held next to the body with the *palm facing forward*. This is the **supinated position** of the forearm. In this position, the radius and ulna

are parallel to each other. When the *palm of the hand faces backward*, the forearm is in the **pronated position**, and the radius and ulna form an X-shape.

Pronation is the movement that allows the palm of the hand to face *backward* while in *supination* the palm of the hand faces *forward*. It helps to remember that supination is the motion you use when scooping up soup with a spoon (see Figure 13.9(g)).

Dorsiflexion and Plantar Flexion

Dorsiflexion and **plantar flexion** are movements at the ankle joint, which is a hinge joint. Lifting the front of the foot, so that the top of the *foot moves (upward)* toward the anterior leg is dorsiflexion, while lifting the heel of the foot from the ground or pointing the *toes downward* is plantar flexion. These are the only movements available at the ankle joint (see Figure 13.9(h)).

Inversion and Eversion

Inversion and eversion are complex movements that involve the multiple plane joints among the tarsal bones of the posterior foot (intertarsal joints) and thus are not motions that take place at the ankle joint. **Inversion** is the turning of the foot to angle the bottom of the foot *toward the midline*, while **eversion** turns the bottom of the foot away from the midline. The foot has a greater range of inversion than eversion motion. These are important motions that help to stabilize the foot when walking or running on an uneven surface and aid in the quick side-to-side changes in direction used during active sports such as basketball, racquetball, or soccer (see Figure 13.9(i)).

Protraction and Retraction

Protraction and **retraction** are anterior-posterior movements of the scapula or mandible. Protraction of the scapula occurs when the *shoulder is moved forward*, as when pushing against something or throwing a ball. Retraction is the opposite motion, with the scapula being *pulled posteriorly* and medially, toward the vertebral column. For the mandible, protraction occurs when the lower jaw is pushed forward, to stick out the chin, while retraction pulls the lower jaw backward (see Figure 13.9(j)).

Depression and Elevation

Depression and **elevation** are downward and upward movements of the scapula or mandible. The *upward movement of the scapula* and shoulder is elevation, while a *downward movement* is depression. These movements are used to shrug your shoulders. Similarly, elevation of the mandible is the upward movement of the lower jaw used to close the mouth or bite on something, and depression is the downward movement that produces opening of the mouth (see Figure 13.9(k)).

Concept Check

- Differentiate between pronation and supination.

Skeletal System Movement Terms



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-89>

Medical Terms in Context



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-90>



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-91>

Common Skeletal System Abbreviations



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-130>

Common Diseases and Disorders

Osteoporosis

Osteoporosis is a bone disease that causes bones to become weak and thin over time (National Osteoporosis Foundation, 2021). This weakness can lead to fractures from simple movements and occur often in the wrist, shoulder, spine, and hip. To learn more about osteoporosis please visit the [National Osteoporosis Foundation website](#).

Arthritis

Arthritis often presents as **edema** , **arthralgia**, and **ankylosis** (Centers for Disease Control and Prevention, 2019). Common types of arthritis are **osteoarthritis** (OA), rheumatoid arthritis (RA), **fibromyalgia**, Gout and lupus. To learn more about arthritis visit the [CDC's Arthritis Basics](#) web page.

Osteoarthritis

Osteoarthritis (OA) is the most common form of arthritis, and over 32.5 million US adults have been diagnosed with OA (Centers for Disease Control and Prevention, 2020b). The breakdown of cartilage and bone occurs over time when joints are exposed to heavy workloads either through occupation, obesity and/or prior injury to a joint. Common symptoms are pain, stiffness and aching that worsens over time. While there is no cure, symptoms can be managed through exercise, medications and in severe cases joint replacements (Centers for Disease Control and Prevention, 2020b).

Rheumatoid arthritis

The CDC describes **rheumatoid arthritis (RA)** as an autoimmune and inflammatory disease. Autoimmune diseases are disorders in which the immune system over reacts and begins to attack itself. In the case of RA inflammation to the joint tissues of the hands, wrists and knees is painful and debilitating. Treatments may include immunosuppressive drugs and anti-inflammatory drugs (Betts, et al., 2021). RA can also affect other tissues throughout the body and cause problems in organs such as the lungs, heart, and eyes. RA can affect children and in this case it is referred to as **juvenile rheumatoid arthritis** (Centers for Disease Control and Prevention, 2020c).

Gout

According to the Arthritis Society, gout is an inflammatory arthritis caused when the immune system attacks the crystals that form when uric acid builds up in a joint. Gout has periods of **exacerbation** and remission and is commonly treated through lifestyle changes and medication. While any joint can be effected it is common in the lower extremities and most often in the big toe (Choy & MacMullan, 2017). To learn more about the causes and treatments please visit the [Arthritis Society's web page about gout](#).

Myasthenia Gravis

The National Institute of Neurological Disorders and Strokes describes **myasthenia gravis** as a "**chronic** autoimmune neuromuscular disorder that causes weakness in the skeletal muscle" (Office of Communications and Public Liaison, 2020). To learn more, visit the [National Institute of Neurological Disorders and Stroke's Myasthenia Gravis fact sheet](#).

Fibromyalgia

Fibromyalgia is a challenging disease to diagnose since symptoms manifest differently and are similar to other diseases. Symptoms may include chronic fatigue, emotional and mental stress, headaches, and increased pain sensitivity. Currently, the cause of fibromyalgia has not been identified (Centers for Disease Control and Prevention, 2020a). To learn more about the diagnosis and treatment for fibromyalgia please visit the [Centers for Disease Control and Prevention's fibromyalgia web page](#).

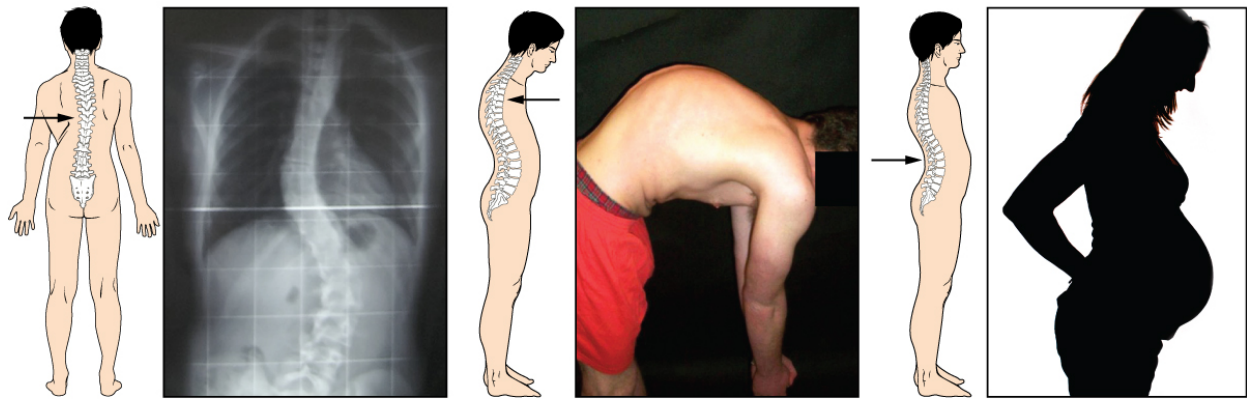
Osteomyelitis

Osteomyelitis is a bone infection caused when staphylococcus bacteria travels through the blood stream from an infection in one part of the body to the bone. Staphylococcus bacteria is found on the skin and it can transfer to the bone through a wound and/or surgical contamination. The risk increases as people age or if their immune system is compromised (Mayo Clinic Staff, 2021). To learn more about the causes, symptoms and treatments for osteomyelitis please visit [the Mayo Clinic's osteomyelitis web page](#).

Disorders of the Curvature of the Spine

Developmental anomalies, pathological changes, or obesity can enhance the normal vertebral column curves, resulting in the development of abnormal or excessive curvatures (see Figure 13.10). Disorders associated with the curvature of the spine include:

- **Kyphosis:** Also referred to as humpback, is an excessive posterior curvature of the thoracic region. This can develop when osteoporosis causes weakening and erosion of the anterior portions of the upper thoracic vertebrae, resulting in their gradual collapse (see Figure 13.11).
- **Lordosis:** Also referred to as swayback, is an excessive anterior curvature of the lumbar region and is most commonly associated with obesity or late pregnancy. The accumulation of body weight in the abdominal region results an anterior shift in the line of gravity that carries the weight of the body. This causes in an anterior tilt of the pelvis and a pronounced enhancement of the lumbar curve.
- **Scoliosis:** An abnormal, lateral curvature, accompanied by twisting of the vertebral column. Scoliosis is the most common vertebral abnormality among girls. The cause is usually unknown, but it may result from weakness of the back muscles, defects such as differential growth rates in the right and left sides of the vertebral column, or differences in the length of the lower limbs. When present, scoliosis tends to get worse during adolescent growth spurts. Although most individuals do not require treatment, a back brace may be recommended for growing children. In extreme cases, surgery may be required (Betts, et al., 2021).



(a) Scoliosis

(b) Kyphosis

(c) Lordosis

Figure 13.10 *Abnormal Curvatures of the Vertebral Column.* (a) Scoliosis is an abnormal lateral bending of the vertebral column. (b) An excessive curvature of the upper thoracic vertebral column is called kyphosis. (c) Lordosis is an excessive curvature in the lumbar region of the vertebral column. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

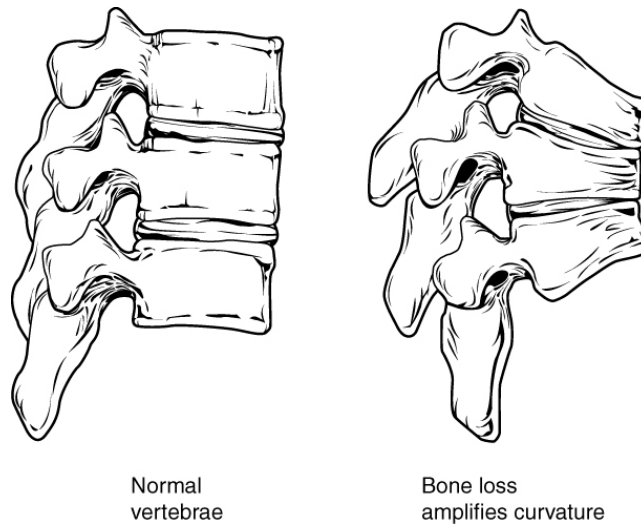


Figure 13.11. *Osteoporosis.* Osteoporosis is an age-related disorder that causes the gradual loss of bone density and strength. When the thoracic vertebrae are affected, there can be a gradual collapse of the vertebrae. This results in kyphosis, an excessive curvature of the thoracic region. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Fractures

A **fracture** is a broken bone. It will heal whether or not a physician resets it in its anatomical position. If the bone is not reset correctly, the healing process will keep the bone in its deformed position. **Crepitation or crepitus** is the creaking or popping sound that is heard when fractured bones move against each other. Fractures are classified by their

complexity, location, and other features (see Figure 13.12). Some fractures may be described using more than one term because it may have the features of more than one type (e.g., an open transverse fracture) (Betts, et al., 2021).

Types of fractures include:

- **Closed or simple** – bones are broken but does not protrude the skin
- **Open or compound** – bones are broken and pierce through the skin
- **Transverse** – bone is broken straight across
- **Spiral** – bone has twisted apart
- **Comminuted** – bones are broken and crushed into pieces
- **Impacted** – One fragment is driven into the other, usually as a result of compression
- **Greenstick** – bones are partially broken; occurs mainly in children
- **Oblique** – bones are broken at an angle
- **Colles** – bones are broken and occurs at the wrist or distal radius
- **Stress** – small crack in bone

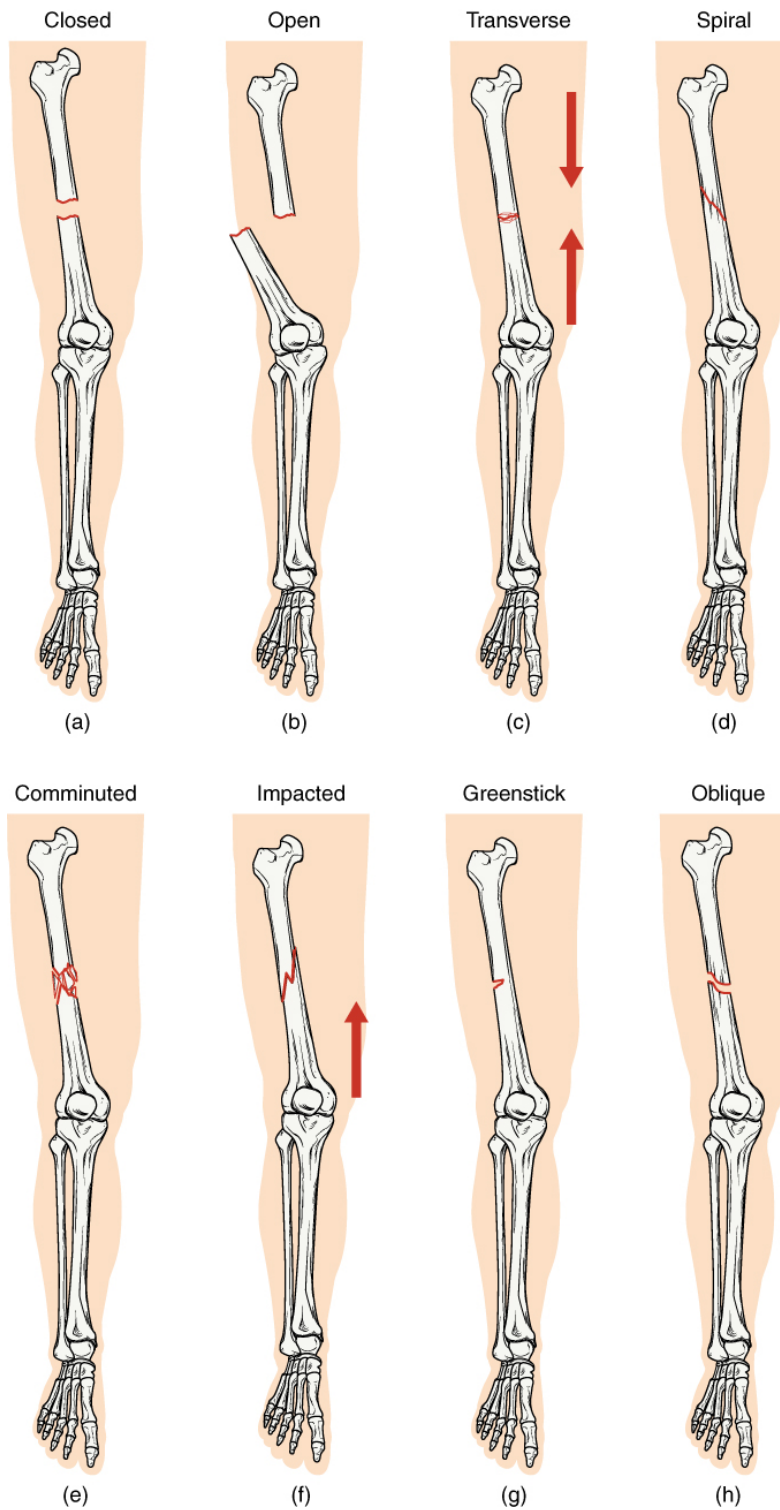


Figure 13.12. Types of Fractures. Compare healthy bone with different types of fractures: (a) closed fracture, (b) open fracture, (c) transverse fracture, (d) spiral fracture, (e) comminuted fracture, (f) impacted fracture, (g) greenstick fracture, and (h) oblique fracture. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Bone Cancer

There are three types of primary bone cancers: osteosarcoma, Ewing Sarcomas and chondrosarcoma. These are considered primary cancers because they originate in the bones. Osteosarcoma and Ewing Sarcomas are cancers found in children, teenagers, and young adults. Ewing Sarcomas is considered to be the more aggressive of the two cancers since it tends to **metastasize** quickly. Osteosarcoma is the most common type of bone cancer and it begins in the tissues of growing bones. Chondrosarcoma develops in cells that produce cartilage and affects adults (Mayo Clinic, 2021). To learn more, visit the [Mayo Clinic web page on bone cancer](#).

Diagnostic Procedures

Common diagnostic procedures related specifically to the skeletal system include x-rays, bone mineral density testing, and arthroscopy.

- **X-rays** are common diagnostic tests used to confirm or rule out fractures and broken bones. The radiation dose is low so it is considered a safe diagnostic test (U.S. Food and Drug Administration, 2020).
- **Dual x-ray absorptiometry (BMD)**, also called a bone mineral density test, is a test to determine osteoporosis by measuring the amount of bone mineral in a particular amount of bone (National Cancer Institute, 2021).
- **Arthroscopy** is a common procedure performed by orthopedic surgeons to view the inside of a joint to diagnose and/or to repair joint problems. The patient is given a local anesthetic and the surgeon inserts an **arthroscope** through an incision in the skin. Depending on what the surgeons finds, a repair of the joint may take place during the procedure (Mayo Clinic Staff, 2018a).

Medical Specialties Related to the Skeletal System

Orthopedic Surgeon

Orthopedic Surgeons are medical doctors who complete specialized training in the prevention, diagnosis, treatment and surgery of disorders and diseases related to the musculoskeletal systems (American Academy of Orthopedic Surgeons, 2021). For more details please visit the [American Academy of Orthopaedic Surgeons's page on Orthopaedic Surgeons](#).

Rheumatologist

Rheumatologists are medical doctors who have additional training as internists with a sub-specialty in rheumatology. Many rheumatology disorders have an underlying autoimmune disorders. Subsequently, rheumatologists are interested in autoimmune disorders and their impact on multiple body systems including the musculoskeletal systems (American College of Rheumatology 2018). For more details please follow the link to the [American College of Rheumatology's web page called 'What is a Rheumatologist?'](#)

Doctor of Chiropractic (DC)/Chiropractor

A Doctor of Chiropractic (DC) completes a four-year doctoral graduate school program with at least 4,200 hours of clinical experience, and laboratory and course work. Chiropractors are trained in the prevention, assessment and treatment of the spine, muscular system and nervous system. Chiropractors focus on spinal adjustments, nutrition, and preventing injury without the use of pharmaceuticals or surgical procedures (American Chiropractic Association, 2021). To learn more visit the [American Chiropractic Association website](#).

Physiotherapist

A physiotherapist has a Doctoral of Physical Therapy degree and has successfully completed the National Physical Therapy Examination. Physiotherapists use an evidenced-based approach when assessing and designing treatment plans for their clients. Treatments may include exercises, massage, joint manipulation, and occupational retraining (U.S. Bureau of Labor Statistics, 2021). To learn more please visit the [U.S. Bureau of Labor Statistics web page on physical therapists](#).

Occupational Therapist

Occupational therapist helps people across the lifespan to do the things they want and need to do through the therapeutic use of daily activities (occupations). Occupational therapy practitioners enable people of all ages to live life to its fullest by helping them promote health, and prevent—or live better with—injury, illness, or disability. To learn more please visit the [American Occupational Therapy Association webpage](#).

Certified Occupational Therapy Assistant

Certified occupational therapy assistants and aides help patients develop, recover, improve, as well as maintain the skills needed for daily living and working. To learn more please visit the [Occupational Outlook Handbook: Occupational Therapy Assistants and Aides](#).

Physical Therapist

Physical therapists help people to maximize their quality of life. They work with people of all ages and abilities, and in a variety of settings. They help people rehabilitate from devastating injuries, manage chronic conditions, avoid surgery and prescription drugs, and create healthy habits. To learn more please visit: [American Physical Therapy Association](#)

Physical Therapist Assistants

Assist physical therapists in providing physical therapy treatments and procedures. May, in accordance with state laws,

assist in the development of treatment plans, carry out routine functions, document the progress of treatment, and modify specific treatments in accordance with patient status and within the scope of treatment plans established by a physical therapist. Generally requires formal training. To learn more please visit: [Physical Therapist Assistants](#)

Test Yourself



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=153#h5p-92>

References

- American Academy of Orthopaedic Surgeons. (2021). *Orthopaedic Surgeons: Restoring mobility and keeping our nation in motion*. <https://www.aaos.org/about/what-is-an-orthopaedic-surgeon/>
- American Chiropractic Association. (2021). *Key Facts and Figures About the Chiropractic Profession*. <https://www.acatoday.org/News-Publications/Newsroom/Key-Facts>
- American College of Rheumatology. (2018). *What is a Rheumatologist?* <https://www.rheumatology.org/I-Am-A/Patient-Caregiver/Health-Care-Team/What-is-a-Rheumatologist>
- American Occupational Therapy Association. (2021). *What is Occupational Therapy*. <https://www.aota.org/conference-events/otmonth/what-is-ot.aspx>
- American Physical Therapy Association. (2021). *Careers in Physical Therapy*. <https://www.apta.org/your-career/careers-in-physical-therapy>
- Centers for Disease Control and Prevention. (2019). *Arthritis basics*. CDC Arthritis Program. <https://www.cdc.gov/arthritis/basics/index.html>
- Centers for Disease Control and Prevention. (2020a). *Fibromyalgia*. CDC Arthritis Program. <https://www.cdc.gov/arthritis/basics/fibromyalgia.htm>
- Centers for Disease Control and Prevention. (2020b). *Osteoarthritis (OA)*. CDC Arthritis Program. <https://www.cdc.gov/arthritis/basics/osteoarthritis.htm>
- Centers for Disease Control and Prevention. (2020c). *Rheumatoid arthritis*. CDC Arthritis Program. <https://www.cdc.gov/arthritis/basics/rheumatoid-arthritis.html>
- Choy, G., & MacMullan, P. (2017). *Gout*. Arthritis Society. [https://arthritis.ca/about-arthritis/arthritis-types-\(a-z\)/types/gout](https://arthritis.ca/about-arthritis/arthritis-types-(a-z)/types/gout)
- Mayo Clinic Staff. (2018). *Osteomyelitis*. Mayo Clinic Patient Care and Health Information. <https://www.mayoclinic.org/diseases-conditions/osteomyelitis/symptoms-causes/syc-20375913>
- Mayo Clinic Staff. (2018a). *Arthroscopy*. Mayo Clinic Patient Care and Health Information. <https://www.mayoclinic.org/tests-procedures/arthroscopy/about/pac-20392974>
- Mayo Clinic Staff. (2021). *Bone Cancer*. Mayo Clinic Patient Care and Health Information. <https://www.mayoclinic.org/diseases-conditions/bone-cancer/symptoms-causes/syc-20350217>
- National Osteoporosis Foundation. (2021). *What is osteoporosis and what causes it?* <https://www.nof.org/patients/what-is-osteoporosis/>
- Occupational Therapy Assistants and Aides. (Sept 2021). *Occupational Outlook Handbook*. <https://www.bls.gov/ooh/healthcare/occupational-therapy-assistants-and-aides.htm>

Office of Communications and Public Liaison. (2020). *Myasthenia gravis fact sheet*. National Institute of Neurological Disorders and Stroke. <https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Myasthenia-Gravis-Fact-Sheet>

National Cancer Institute. *Dual x-ray absorptiometry*. National Institutes of Health. <https://www.cancer.gov/publications/dictionaries/cancer-terms/def/dual-x-ray-absorptiometry>

U.S. Bureau of Labor Statistics. (2021). *Occupational Therapists*. <https://www.bls.gov/ooh/healthcare/physical-therapists.htm#tab-1>

U.S. Bureau of Labor Statistics. (2021). *Physical Therapist Assistants*. <https://www.bls.gov/oes/current/oes312021.htm#nat>

U.S. Food and Drug Administration. (2020). *Medical X-ray Imaging*. <https://www.fda.gov/radiation-emitting-products/medical-imaging/medical-x-ray-imaging>

Unless otherwise indicated, this chapter contains material adapted from *Anatomy and Physiology* (on [OpenStax](#)), by Betts, et al. and is used under a [CC BY 4.0 international license](#). Download and access this book for free at <https://openstax.org/books/anatomy-and-physiology/pages/1-introduction>.

14. Muscular System

Learning Objectives

- Identify the anatomy of the muscular system
- Describe the main functions of the muscular system
- Spell the medical terms of the muscular system and use correct abbreviations
- Explore common diseases, disorders, and procedures related to the muscular system
- Identify the medical specialties associated with the muscular system

Muscular System Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the Muscular System.



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=156#h5p-93>

Introduction to the Muscular System

When most people think of muscles, they think of the muscles that are visible just under the skin, particularly of the limbs. These are skeletal muscles, so-named because most of them move the skeleton. But there are two additional types of muscles: the smooth muscle and the cardiac muscle. The body has over 600 muscles which contribute significantly to the body's weight.

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=156#oembed-1>

Media 14.1 [Muscles, Part 2 – Organismal Level: Crash Course A&P #22](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Muscular System Medical Terms



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=156#h5p-94>

Anatomy (Structures) of the Muscular System

Muscle is one of the four primary tissue types of the body, and it is made up of specialized cells called fibers. The body contains three types of muscle tissue: **skeletal muscle**, **cardiac muscle**, and **smooth muscle** (see Figure 14.1). All three muscle tissues have some properties in common; they all exhibit a quality called **excitability** as their plasma membranes can change their electrical states (from polarized to depolarized) and send an electrical wave called an action potential along the entire length of the membrane. Fascia is fibrous connective tissue that encloses muscles.

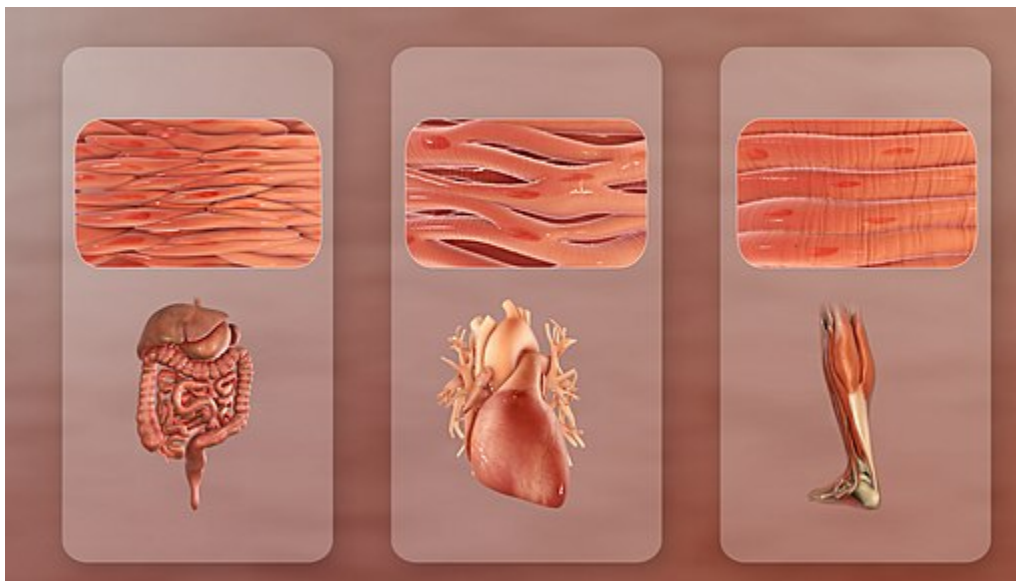


Figure 14.1 The Three Types of Muscle Tissue. The body contains three types of muscle tissue: (a) smooth muscle, (b) cardiac or heart, and (c) skeletal. www.scientificanimations.com, CC BY-SA 4.0, via Wikimedia Commons

Three Types of Muscle Tissues

- **Smooth** – mainly associated with the walls of the internal organs. Also known as visceral muscles and are responsible for involuntary muscle movement – such as breathing, etc.
- **Cardiac** – heart muscle or myocardium. Its appearance is similar to a skeletal muscle and is responsible for the pumping of blood. It gives the heart beat.
- **Skeletal** – closely associated with the skeletal system. Also known as striated muscles and are responsible for voluntary muscle movement – such as swallowing, etc.

Smooth Muscle

Smooth muscle, so named because the cells do not have striations, is present in the walls of hollow organs like the urinary bladder, uterus, stomach, intestines, and in the walls of passageways, such as the arteries and veins of the circulatory system, and the tracts of the respiratory, urinary, and reproductive systems. Smooth muscle is also present in the eyes, where it functions to change the size of the iris and alter the shape of the lens; and in the skin where it causes hair to stand erect in response to cold temperature or fear.

Cardiac Muscle

Cardiac muscle tissue is only found in the heart. Highly coordinated contractions of cardiac muscle pump blood into the vessels of the circulatory system. Similar to skeletal muscle, cardiac muscle is striated and organized into **sarcomeres**, possessing the same

Did You Know?

The gluteus maximus is the largest muscle and the heart is the hardest working muscle.

banding organization as skeletal muscle (see Figure 14.1). Cardiac muscle fibers cells also are extensively branched and are connected to one another at their ends by intercalated discs. An **intercalated disc** allows the cardiac muscle cells to contract in a wave-like pattern so that the heart can work as a pump.

Skeletal Muscle

Skeletal muscles act not only to produce movement but also to stop movement, such as resisting gravity to maintain posture. Small, constant adjustments of the skeletal muscles are needed to hold a body upright or balanced in any position. Muscles also prevent excess movement of the bones and joints, maintaining skeletal stability and preventing skeletal structure damage or deformation.

Skeletal muscles are located throughout the body at the openings of internal tracts to control the movement of various substances. These muscles allow functions, such as swallowing, urination, and defecation, to be under voluntary control. Skeletal muscles also protect internal organs (particularly abdominal and pelvic organs) by acting as an external barrier or shield to external trauma and by supporting the weight of the organs.

Skeletal muscles contribute to the maintenance of **homeostasis** in the body by generating heat. This heat is very noticeable during exercise, when sustained muscle movement causes body temperature to rise, and in cases of extreme cold, when shivering produces random skeletal muscle contractions to generate heat.

Concept Check

- Compare and contrast the 3 types of muscles tissues.
- Where in the body do you find each of the muscle types?

Physiology (Function) of the Muscular System

The main function of the muscular system is to assist with **movement**. Muscles work as **antagonistic** pairs. As one muscle contracts, the other muscle relaxes. This contraction pulls on

the bones and assists with movement. Contraction is the shortening of the muscle fibers while relaxation lengthens the fibers. This sequence of relaxation and contraction is influenced by the nervous system.

Muscles also work to keep the **posture** of the body. This is done through muscle contraction where the trunk is kept straight either when sitting or standing.



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=156#oembed-2>

Media 14.2 [Review of joint movements with Dr. Mike](#). Copyright 2021, Dr. Matt & Dr. Mike.

ACTION

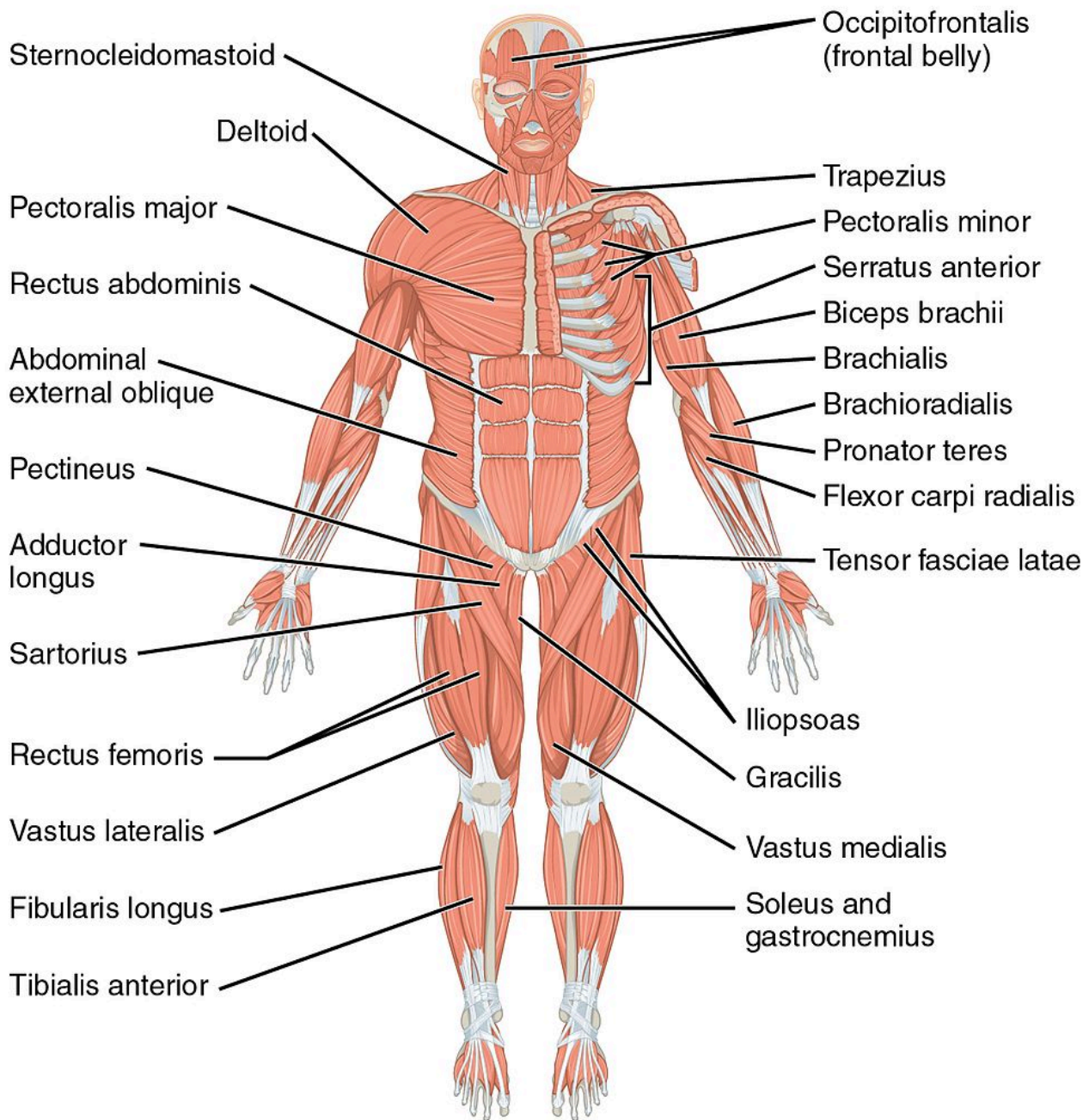
MEANING

flexion	Decreasing the angle between two bones; bending a limb.
extension	Increasing the angle between two bones; straightening out a limb.
abduction	Movement away from the midline of the body
adduction	Movement toward the midline of the body
rotation	Circular movement around an axis (central point). Internal rotation is toward the center of the body and external rotation is away from the center of the body.
dorsiflexion	Decreasing the angle of the ankle joint so that the foot moves upward, toward the knee or ceiling. This is the opposite movement of stepping on the gas pedal when driving a car.
plantar flexion	Motion that moves the foot downward toward the ground as when pointing the toes or stepping on the gas pedal. Plant/o means sole of the foot.
supination	As applied to the hand and forearm, where the elbow is bent, the act of turning the palm up. As applied to the foot, it is outward roll of the foot/ankle during normal motion.
pronation	As applied to the hand and forearm, where the elbow is bent, the act of turning the palm down. As applied to the foot, it is inward roll of the foot/ankle during normal motion.

Naming of Muscles

There are many **nomenclatures** for naming muscles. Some of these include:

- **divisions** – biceps, triceps, quadriceps
- **size** – maximus (largest), minimus (smallest)
- **shape** – deltoid (triangular), trapezius (trapezoid)
- **action** – flexor (to flex), adductor (towards midline of body)



Major muscles of the body.
 Right side: superficial; left side:
 deep (anterior view)

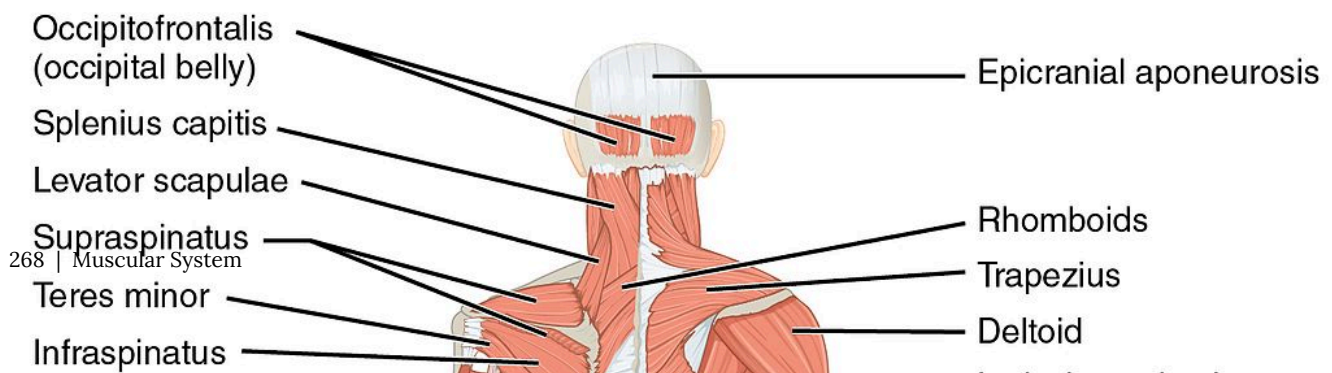


Figure 14.3. Overview of the Muscular System. On the anterior and posterior views of the muscular system above, superficial muscles (those at the surface) are shown on the right side of the body while deep muscles (those underneath the superficial muscles) are shown on the left half of the body. For the legs, superficial muscles are shown in the anterior view while the posterior view shows both superficial and deep muscles. From Betts, et al., 2021. Licensed under CC BY 4.0.

Muscular System Medical Abbreviations



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=156#h5p-95>

Common Diseases and Disorders

Muscular Dystrophy

Muscular dystrophies are rare inherited diseases that weaken muscles, decreasing the individual's mobility. There are several kinds of muscular dystrophy that affect different muscle groups and symptoms develop at different ages (Centers for Disease Control and Prevention, 2020). The most common kind of muscular dystrophy is Duchenne/Becker muscular dystrophy (DMD/BMD). This disease primarily effects boys and symptoms may include frequent falls and trouble keeping up with peers. Since all muscles are affected, the person will eventually require a wheelchair and assistance with breathing (Muscular Dystrophy Association, 2021). To learn more please visit the [Centers for Disease Control and Prevention muscular dystrophy webpage](#).

Cerebral Palsy

Cerebral Palsy (CP) is caused by an interruption to the normal development of a person's brain leading to weakness with muscles. Depending on the area of the brain that is affected, signs and symptoms will vary in the type and severity between individuals. Balance and coordination are often challenging due the inability to control muscles (Centers for Disease Control and Prevention, 2020). To learn more about Cerebral palsy please visit the [Centers for Disease Control and Prevention](#).

Carpal Tunnel Syndrome

Carpal tunnel syndrome may present with pain, numbness or weakness to the hand(s) caused by pressure on the median nerve. Some causes for this pressure are work related such as keyboarding with improper body mechanics, illness such as arthritis, and even pregnancy (National Institute of Neurological Disorders and Stroke, 2020). To learn more, visit the [National Institute of Neurological Disorders and Stroke webpage](#).

Paralysis

Paralysis is the loss of strength and control of the muscles in parts of the body. Paralysis can be localized where it affects specific areas such as the face, feet, vocal chords, etc., or it can be generalized where it affects a larger area of the body. There are various types of generalized paralysis, including:

- **Paresis** – a partial paralysis wherein there is still some control of the muscles
- **Paraplegia** – paralysis that affects both legs and lower part of the body.
- **Quadriplegia** – affects both arms, both legs and sometimes from the neck down
- **Hemiplegia** – affects one side of the body. For example, the arm and leg on the same side of the body (Cleveland Clinic, 2017)

To learn more about paralysis, please visit the Cleveland Clinic's [Paralysis information web page](#).

Sprain and Strain

A **sprain** is an injury to a joint whereby a ligament is stretched or torn.

A **strain** is an injury to a muscle whereby a tendon is stretched or torn.

Diagnostic Procedures

Electromyography (EMG) is a procedure that assesses the function of nerve cells that control muscles. Electrodes, either attached to the skin or inserted into the muscle, allow for the recording of electrical impulses. EMG can identify functional problems with the peripheral nerves, muscles, or with the signals between the nerves and the muscles. This is just one test in a series of tests that assist in the diagnosis of neuromuscular disorders (Mayo Clinic Staff, 2019). To learn more, please visit the [Mayo Clinic's Electromyography webpage](#).

Magnetic Resonance Imaging (MRI) (Fig 14.4) is a test that uses radio frequency waves and a magnetic field to produce clear images that aid in the diagnosis of a wide range of conditions (National Institute of Biomedical Imaging and Bioengineering, n.d.). Leung (2017) notes that there has been increased clinical use in using MRI for the treatment and monitoring of muscular disorders due to the high-quality MRI images that distinguish skeletal muscles from fat (para. 4). To learn more, please visit the [National Institute of Biomedical Imaging and Bioengineering MRI webpage](#).



Figure 14.4. Vantage Atlas MRI scanner from Toshiba. From Mos.ru, CC BY 4.0 via Wikimedia Commons

Range of Motion Testing is a diagnostic procedure used to determine the amount of movement around a specific joint.

Medical Terminology in Context



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=156#h5p-96>

Medical Specialties Related to Muscular System

Orthopedic Surgeon

Orthopedic Surgeons are medical doctors who complete specialized training in the prevention, diagnosis, treatment and surgery of disorders and diseases related to the musculoskeletal systems (American Academy of Orthopaedic Surgeons, 2021). For more details please visit the [American Academy of Orthopaedic Surgeons's page on Orthopaedic Surgeons](#).

Neurologist

Neurologists are medical doctors who complete an additional specialized training in the prevention, diagnosis, and

treatment of disorders and conditions related to the brain, spinal cord, nerves and muscles (American Academy of Neurology, 2021). For more details visit the [American Academy of Neurology's webpage](#).

Kinesiologist

Kinesiologists are regulated health-care professionals with a degree in kinesiology or related discipline. Kinesiologists work in a variety of settings that assist people with pain management, injury prevention, and health promotion through biomechanics (American Kinesiology Association, 2021). To explore career options for kinesiologists, visit the [American Kinesiology Association's Career Center webpage](#). To learn more about kinesiologists and careers in this field, visit the [Zippia Kinesiologist Overview webpage](#).

Occupational Therapist

Occupational therapist helps people across the lifespan to do the things they want and need to do through the therapeutic use of daily activities (occupations). Occupational therapy practitioners enable people of all ages to live life to its fullest by helping them promote health, and prevent—or live better with—injury, illness, or disability. To learn more please visit the [American Occupational Therapy Association webpage](#).

Certified Occupational Therapist Assistant

Certified occupational therapist assistants and aides help patients develop, recover, improve, as well as maintain the skills needed for daily living and working. To learn more please visit the [Occupational Outlook Handbook: Occupational Therapy Assistants and Aides](#).

Physical Therapist

Physical therapists help people to maximize their quality of life. They work with people of all ages and abilities, and in a variety of settings. They help people rehabilitate from devastating injuries, manage chronic conditions, avoid surgery and prescription drugs, and create healthy habits. To learn more please visit: [American Physical Therapy Association](#)

Physical Therapist Assistant

Assist physical therapists in providing physical therapy treatments and procedures. May, in accordance with state laws, assist in the development of treatment plans, carry out routine functions, document the progress of treatment, and modify specific treatments in accordance with patient status and within the scope of treatment plans established by a physical therapist. Generally requires formal training. To learn more please visit: [Physical Therapist Assistants](#)

Test Yourself



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=156#h5p-97>

References

American Academy of Neurology. (2021). What is a neurologist? <https://www.aan.com/tools-and-resources/medical-students/careers-in-neurology/what-is-a-neurologist/>

American Academy of Orthopaedic Surgeons. (2021). Orthopaedic Surgeons: Restoring mobility and keeping our nation in motion. <https://www.aaos.org/about/what-is-an-orthopaedic-surgeon/>

American Kinesiology Association. (2021). Career Center. <https://www.americankinesiology.org/SubPages/Pages/Careers%20In%20Kinesiology#rn>

American Occupational Therapy Association. (2021). What is Occupational Therapy. <https://www.aota.org/conference-events/otmonth/what-is-ot.aspx>

American Physical Therapy Association. (2021). Careers in Physical Therapy. <https://www.apta.org/your-career/careers-in-physical-therapy>

Centers for Disease Control and Prevention. (2020). What is cerebral palsy? CDC. <https://www.cdc.gov/ncbddd/cp/facts.html>

Centers for Disease Control and Prevention. (2020). What is muscular dystrophy? CDC. <https://www.cdc.gov/ncbddd/musculardystrophy/facts.html>

[CrashCourse]. (2015, July 15). Muscles, part 2 – organismal level: Crash course A&P #22 [Video]. YouTube. <https://youtu.be/I80Xx7pA9hQ>

Leung, J. (2016, November 25). Magnetic resonance imaging patterns of muscle involvement in genetic muscle diseases: a systematic review. *Journal of Neurology*, 264(7), 1320-1333. <https://dx.doi.org/10.1007%2Fs00415-016-8350-6>

Mayo Clinic Staff. (2019, May 21). Electromyography (EMG). Mayo Clinic Patient Care and Information. <https://www.mayoclinic.org/tests-procedures/emg/about/pac-20393913>

Muscular Dystrophy Association. (2021). Duchenne Muscular Dystrophy (DMD). <https://www.mda.org/disease/duchenne-muscular-dystrophy>

National Institute of Biomedical Imaging and Bioengineering. (n.d.) Magnetic Resonance Imaging (MRI). National Institutes of Health. <https://www.nibib.nih.gov/science-education/science-topics/magnetic-resonance-imaging-mri>

National Institute of Neurological Disorders and Stroke. (2020). Carpal Tunnel Syndrome Fact Sheet. National Institutes of Health. <https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Carpal-Tunnel-Syndrome-Fact-Sheet>

Occupational Therapy Assistants and Aides. (Sept 2021). Occupational Outlook Handbook. <https://www.bls.gov/ooh/healthcare/occupational-therapy-assistants-and-aides.htm>

U.S. Bureau of Labor Statistics. (2021). Occupational Therapists. <https://www.bls.gov/ooh/healthcare/physical-therapists.htm#tab-1>

U.S. Bureau of Labor Statistics. (2021). Physical Therapist Assistants. <https://www.bls.gov/oes/current/oes312021.htm#nat>

Unless otherwise indicated, this chapter contains material adapted from *Anatomy and Physiology* (on [OpenStax](#)), by Betts, et al. and is used under a [CC BY 4.0 international license](#). Download and access this book for free at <https://openstax.org/books/anatomy-and-physiology/pages/1-introduction>.

15. Sensory Systems

WTCS Learning Objectives

- Apply the rules of medical language to build, analyze, spell, pronounce, abbreviate, and define terms as they relate to the sensory system
- Identify meanings of key word components of the sensory system
- Categorize diagnostic, therapeutic, procedural or anatomic terms related to the sensory system
- Use terms related to the sensory system
- Use terms related to the diseases and disorders of the sensory system

Sensory System Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the Sensory System.



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-98>

Introduction to the Sensory Systems

Ask anyone what the senses are, and they are likely to list the five major senses as **taste, smell, touch, hearing, and sight**. However, these are not all of the senses. The most obvious omission from this list is **balance**. Touch can be further subdivided into pressure, vibration, stretch, and hair-follicle position, on the basis of the type of **mechanoreceptors** that perceive these touch sensations. Other overlooked senses include temperature perception by **thermoreceptors** and pain perception by **nociceptors**.

Within the realm of physiology, senses can be classified as either general or special. A **general sense** is one that is distributed throughout the body and has receptor cells within the structures of other organs. Mechanoreceptors in the skin, muscles, or the walls of blood vessels are examples of this type. General senses often contribute to the sense of touch, as described above, or to **proprioception** and **kinesthesia**, or to a **visceral** sense, which is most important to autonomic functions. A **special sense** is one that has a specific organ devoted to it, namely the eye, inner ear, tongue, or nose. The figure below shows the series of events that lead to stimulation of a sense organ.

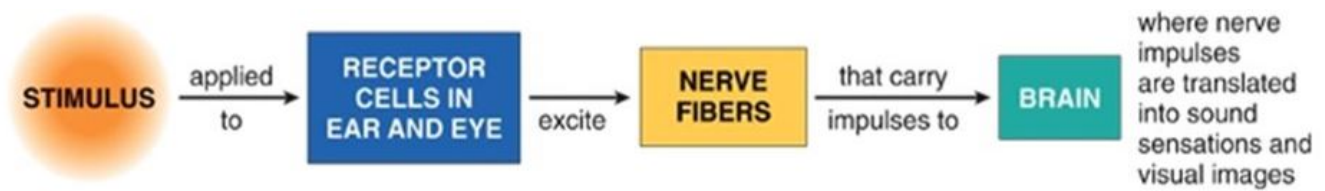


Figure 15.1. Pattern of events in the stimulation of a sense organ. From Chabner, D.E. (2017) *Language of Medicine*. Elsevier. p698. All Rights Reserved.

Gustation (Taste) and Olfaction (Smell)

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#oembed-1>

Media 15.1 [Taste & Smell: Crash Course A&P #16](#) [Online video]. Copyright 2015 from [CrashCourse](#).

Sensory System Medical Terms



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-99>

Gustation (Taste)

Gustation is the special sense associated with the tongue. The surface of the tongue, along with the rest of the oral cavity, is lined by a stratified squamous epithelium. Raised bumps called papillae contain the structures for gustatory transduction. There are **four types of papillae**, based on their appearance:

- circumvallate
- foliate

- filiform
- fungiform

Within the structure of the papillae are taste buds that contain specialized gustatory receptor cells for the transduction of taste stimuli. These receptor cells are sensitive to the chemicals contained within foods that are ingested, and they release **neurotransmitters** based on the amount of the chemical in the food. Neurotransmitters from the gustatory cells can activate sensory neurons in the facial, **glossopharyngeal**, and vagus cranial nerves.

Only a few recognized **submodalities** exist within the sense of taste, or gustation. Until recently, only four tastes were recognized: **sweet**, **salty**, **sour**, and **bitter**. Research at the turn of the 20th century led to recognition of the fifth taste, **umami**, during the mid-1980s. Very recent research has suggested that there may also be a sixth taste for **fats**, or lipids.

Olfaction (Smell)

Like taste, **olfaction**, is also responsive to chemical stimuli. The olfactory receptor neurons are located in a small region within the superior nasal cavity. The nasal epithelium, including the olfactory cells, can be harmed by airborne toxic chemicals.

Scent receptor messages travel to the cerebrum, specifically to the primary olfactory cortex that is located in the inferior and medial areas of the temporal lobe and additionally to the hypothalamus, where smells become associated with long-term memory and emotional response.

Concept Check

- Which parts of the brain are active with recording and associating scents with memories and emotions?
- Recall and list the four types of papillae (taste buds) found on the tongue.

Audition (Hearing), Equilibrium (Balance), and Somatosensation (Touch)

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#oembed-2>

Media 15.2 [Hearing & Balance: Crash Course A&P #17](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Audition (Hearing)

Hearing, or **audition**, is the **transduction** of sound waves into a neural signal that is made possible by the structures of the ear (see Figure 15.2).

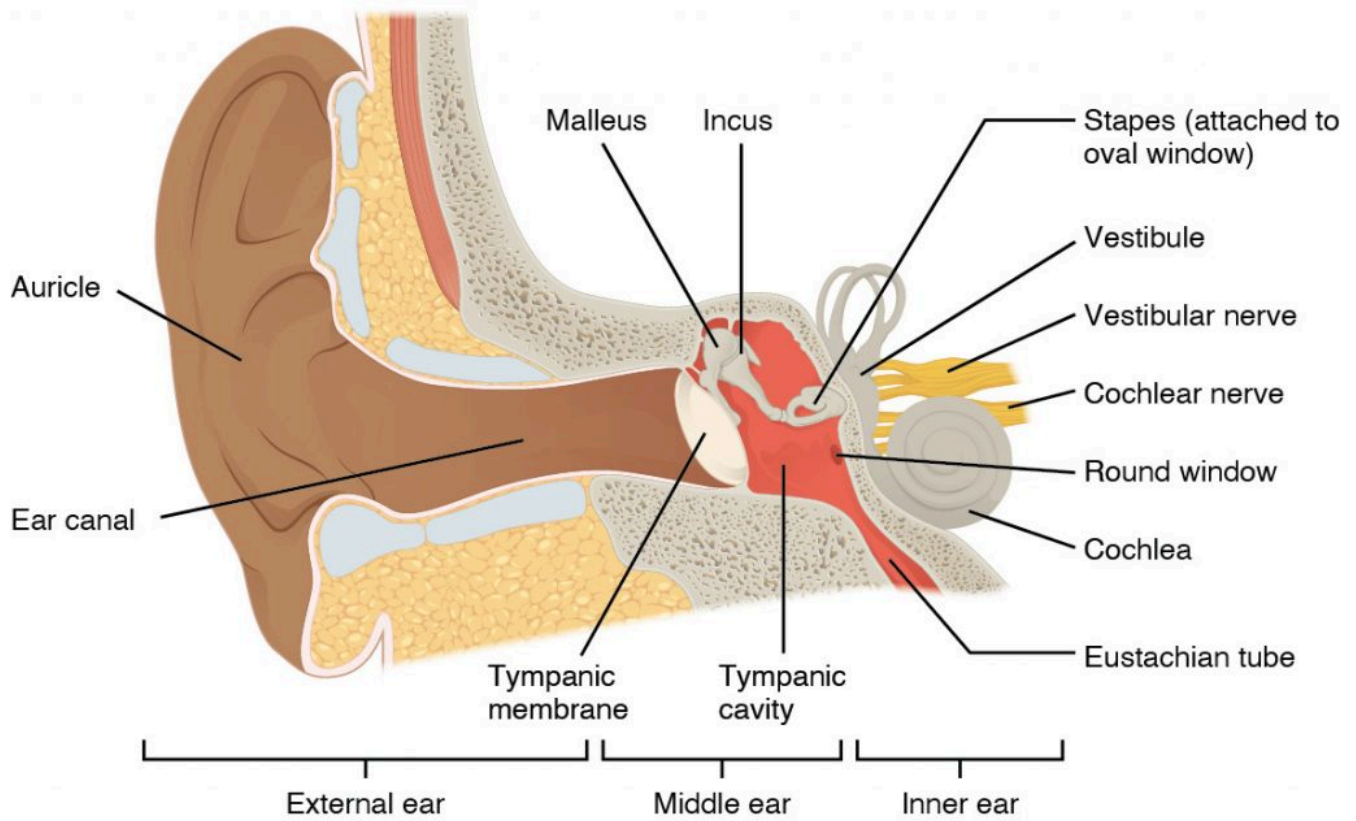


Figure 15.2 Structures of the Ear. The external ear contains the auricle, ear canal, and tympanic membrane. The middle ear contains the ossicles and is connected to the pharynx by the Eustachian tube. The inner ear contains the cochlea and vestibule, which are responsible for audition and equilibrium, respectively. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

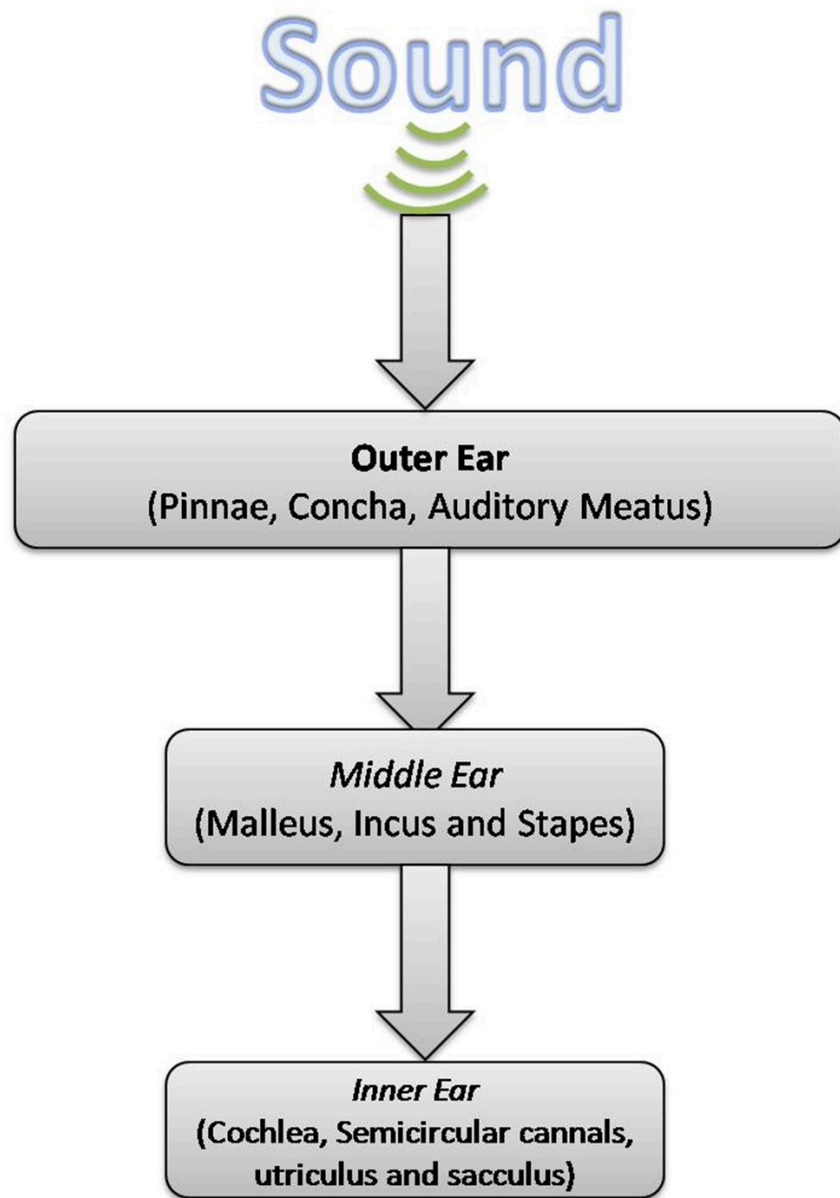


Figure 15.3 Pathway of sound vibrations from the outer ear to the bard (cerebral cortex).
Modified from Nzachariah3, CC BY 3.0, via Wikimedia Commons

- The **external ear** consists of the auricle sometimes referred to as the pinna, ear canal, and tympanic membrane.
 - The C-shaped curves of the auricle direct sound waves toward the **auditory canal**. The canal enters the skull through the external auditory meatus of the **temporal bone**. At the end of the auditory canal is the **tympanic membrane**, which vibrates after it is struck by sound waves.
- The **middle ear** consists of the ossicles, oval window, and tympanic membrane.
 - The three **ossicles** are the malleus, incus, and stapes, which are Latin names that roughly translate to hammer, anvil, and stirrup. The malleus is attached to the tympanic membrane and articulates with the incus. The incus, in turn, articulates with the stapes. The stapes is then attached to the inner ear, where the sound waves will be transduced into a neural signal. Vibrations of the ossicles travel through the **oval window**, moving fluid in a wave-like motion. The frequency of the fluid waves match the frequencies of the sound waves. The middle

ear is connected to the pharynx through the Eustachian tube, which helps equilibrate air pressure across the **tympanic membrane**. The tube is normally closed but will pop open when the muscles of the pharynx contract during swallowing or yawning.

- The **inner ear** is often described as a **bony labyrinth**, as it is composed of a series of canals embedded within the temporal bone.
 - It consists of the **cochlea that is responsible for hearing** and the **vestibule that is responsible for balance**. The neural signals from these two regions are relayed to the brain stem through separate fiber bundles. However, these two distinct bundles travel together from the inner ear to the brain stem as the **vestibulocochlear** nerve. Sound is transduced into neural signals within the cochlear region of the inner ear, which contains the sensory neurons of the spiral ganglia. These ganglia are located within the spiral-shaped cochlea of the inner ear. The cochlea is attached to the stapes through the oval window.

The image below is a cross-sectional view of the cochlea that shows the scala vestibuli and scala tympani run along both sides of the cochlear duct (see Figure 15.4). The cochlear duct contains several organs of Corti, which transduce the wave motion of the two scala into neural signals. The organs of Corti lie on top of the basilar membrane, which is the side of the cochlear duct located between the organs of Corti and the scala tympani. As the fluid waves move through the scala vestibuli and scala tympani, the basilar membrane moves at a specific spot, depending on the frequency of the waves. Higher frequency waves move the region of the basilar membrane that is close to the base of the cochlea. Lower frequency waves move the region of the basilar membrane that is near the tip of the cochlea.

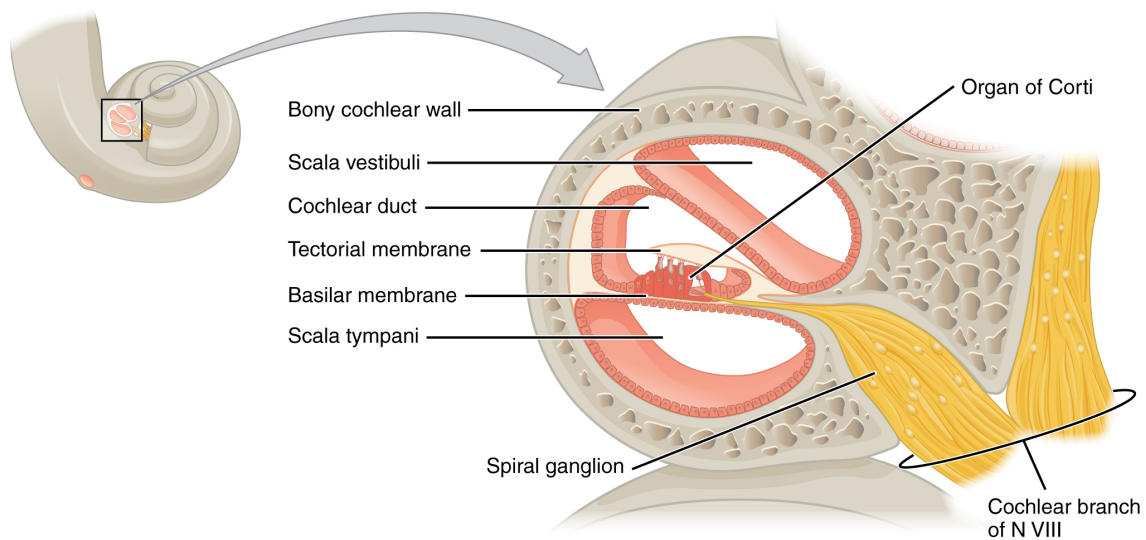


Figure 15.4 Cross Section of the Cochlea. The three major spaces within the cochlea are highlighted. The scala tympani and scala vestibuli lie on either side of the cochlear duct. The organ of Corti, containing the mechanoreceptor hair cells, is adjacent to the scala tympani, where it sits atop the basilar membrane. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

The cochlea encodes auditory stimuli for frequencies between 20 and 20,000 Hz, which is the range of sound that

human ears can detect. The unit of Hertz measures the frequency of sound waves in terms of cycles produced per second. Frequencies as low as 20 Hz are detected by hair cells at the apex, or tip, of the cochlea. Frequencies in the higher ranges of 20 KHz are encoded by hair cells at the base of the cochlea, close to the round and oval windows. Most auditory stimuli contain a mixture of sounds at a variety of frequencies and intensities (represented by the amplitude of the sound wave). The hair cells along the length of the cochlear duct, which are each sensitive to a particular frequency, allow the cochlea to separate auditory stimuli by frequency, just as a prism separates visible light into its component colors. [To learn more about hearing and the cochlea, watch this Medline Plus video.](#)

Equilibrium (Balance)

Along with audition, the **inner ear** is responsible for **encoding** information about **equilibrium**. The cells that sense head position, head movement, and body motion are located within the vestibule of the inner ear. Head position is sensed by otolith organs, whereas head movement is sensed by the semicircular canals (see Figure 15.5). The neural signals generated in the vestibular ganglion are transmitted through the vestibulocochlear nerve to the brain stem and cerebellum.

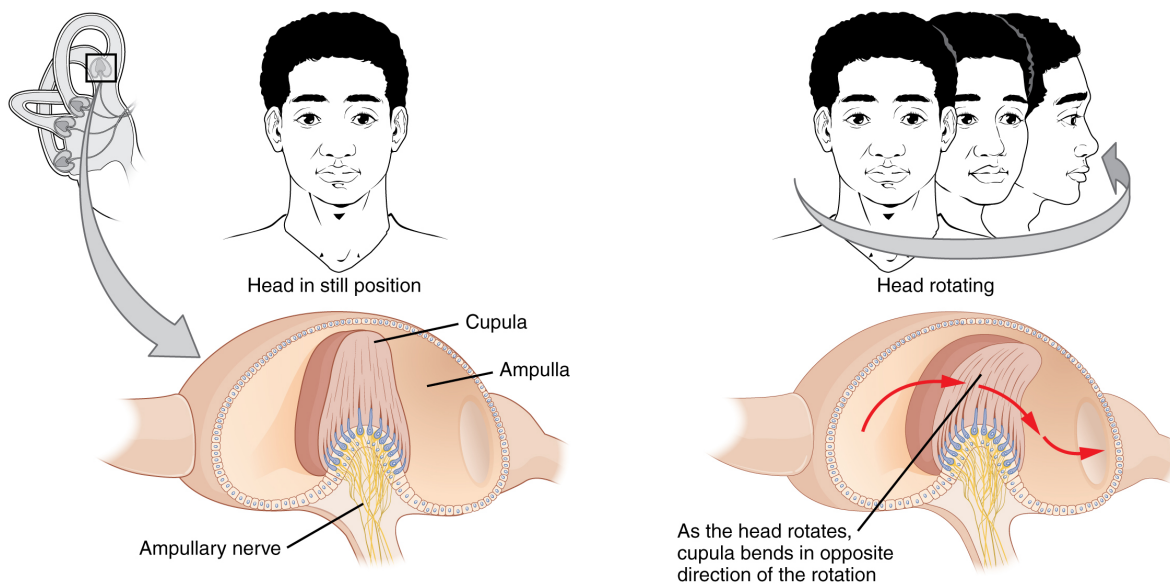


Figure 15.5 Rotational Coding by Semicircular Canals. Rotational movement of the head is encoded by the hair cells in the base of the semicircular canals. As one of the canals moves in an arc with the head, the internal fluid moves in the opposite direction, causing the cupula and stereocilia to bend. The movement of two canals within a plane results in information about the direction in which the head is moving, and activation of all six canals can give a very precise indication of head movement in three dimensions. From Betts, et al., 2021. Licensed under [CC BY 4.0](#).

Somatosensation (Touch)

Somatosensation is considered a general sense, as opposed to the special senses discussed in this section. Somatosensation is the group of **sensory modalities** that are associated with touch, **proprioception**, and **interoception**. These modalities include pressure, vibration, light touch, tickle, itch, temperature, pain, proprioception, and kinesthesia. This means that its receptors are not associated with a specialized organ, but are instead spread throughout the body in a variety of organs. Many of the somatosensory receptors are located in the skin, but receptors are also found in muscles, tendons, joint capsules, ligaments, and in the walls of visceral organs.

The two types of somatosensory signals that are transduced by free nerve endings are pain and temperature. Temperature receptors are stimulated when local temperatures differ from body temperature. Some thermoreceptors are sensitive to just cold and others to just heat. **Nociception** is the sensation of potentially damaging stimuli. Mechanical, chemical, or thermal stimuli beyond a set threshold will elicit painful sensations. Stressed or damaged tissues release chemicals that activate receptor proteins in the nociceptors.

Did You Know?

With the aging process humans lose sensory receptors cells including cells which detect pain and temperature changes.

Concept Check

- What structure exists within the ear to assist with maintaining **equilibrium**?
- What are the medical terms used to describe the sense of taste and touch?

Ear Anatomy Labeling Activity



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/ltcmedicalterminology/?p=164#h5p-100>

Vision (Sight)

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#oembed-3>

Media 15.3 [Vision: Crash Course A&P #18](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Vision is the special sense of sight that is based on the transduction of light stimuli received through the eyes. The eyes are located within either orbit in the skull. The bony orbits surround the eyeballs, protecting them and anchoring the soft tissues of the eye (see Figure 15.6). The eyelids, with lashes at their leading edges, help to protect the eye from abrasions by blocking particles that may land on the surface of the eye.

The inner surface of each lid is a thin membrane known as the palpebral conjunctiva. The conjunctiva extends over the **sclera**, connecting the eyelids to the eyeball. Tears are produced by the lacrimal gland, located beneath the lateral edges of the nose. Tears produced by this gland flow through the lacrimal duct to the medial corner of the eye, where the tears flow over the conjunctiva, washing away foreign particles.

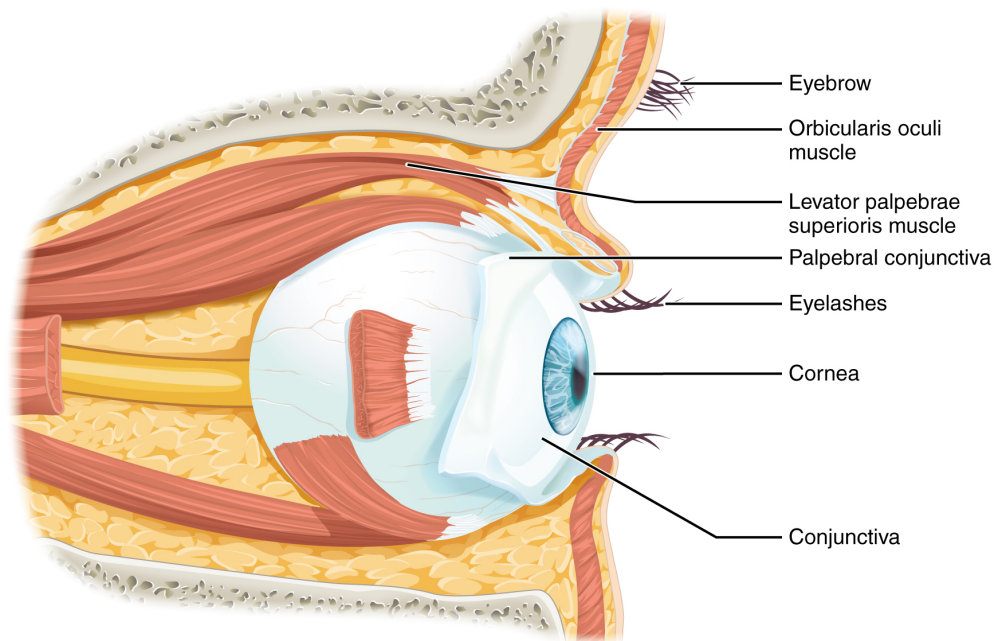


Figure 15.6 The Eye in the Orbit. The eye is located within the orbit and surrounded by soft tissues that protect and support its function. The orbit is surrounded by cranial bones of the skull. From Betts, et al., 2021. Licensed under [CC BY 4.0](#).

Movement of the eye within the orbit is accomplished by the contraction of **six extraocular** muscles that originate from the bones of the orbit and insert into the surface of the eyeball. Four of the muscles are arranged at the cardinal points around the eye and are named for those locations. They are the:

- superior rectus
- medial rectus
- inferior rectus
- lateral rectus.

When each of these muscles contract, the eye moves toward the contracting muscle. For example, when the superior rectus contracts, the eye rotates to look up.

The eye itself is a hollow sphere composed of **three layers** of tissue.

- The **outermost layer** is the fibrous tunic, which includes the white sclera and clear cornea. The sclera accounts for five sixths of the surface of the eye, most of which is not visible, though humans are unique compared with many other species in having so much of the “white of the eye” visible (see Figure 15.7). The transparent cornea covers the anterior tip of the eye and allows light to enter the eye.
- The **middle layer** of the eye is the vascular tunic, which is mostly composed of the choroid, ciliary body, and iris. The choroid is a layer of highly vascularized connective tissue that provides a blood supply to the eyeball. The choroid is posterior to the ciliary body, a muscular structure that is attached to the lens by zonule fibers. These two structures bend the lens, allowing it to focus light on the back of the eye. Overlaying the ciliary body, and visible in the anterior eye, is the iris—the colored part of the eye. The iris is a smooth muscle that opens or closes the pupil, which is the hole at the center of the eye that allows light to enter. The iris constricts the pupil in response to bright light and dilates the pupil in response to dim light.
- The **innermost layer** of the eye is the neural tunic, or retina, which contains the nervous tissue responsible for photoreception.

The eye is also divided into **two cavities**:

- The **anterior cavity**
 - The anterior cavity is the space between the cornea and lens, including the iris and ciliary body. It is filled with a watery fluid called the aqueous humor.
- The **posterior cavity**
 - The posterior cavity is the space behind the lens that extends to the posterior side of the interior eyeball, where the retina is located. The posterior cavity is filled with a more viscous fluid called the vitreous humor.

The **retina** is composed of several layers and contains specialized cells for the initial processing of visual stimuli. The photoreceptors (rods and cones) change their membrane potential when stimulated by light energy. The change in membrane potential alters the amount of neurotransmitter that the photoreceptor cells release onto bipolar cells in the outer synaptic layer. It is the bipolar cell in the retina that connects a photoreceptor to a retinal ganglion cell (RGC) in the inner synaptic layer. There, amacrine cells additionally contribute to retinal processing before an action potential is produced by the RGC. The axons of RGCs, which lie at the innermost layer of the retina, collect at the optic disc and leave the eye at the optic nerve (see Figure 15.7). Because these axons pass through the retina, there are no photoreceptors at the very back of the eye, where the optic nerve begins. This creates a “blind spot” in the retina, and a corresponding blind spot in our visual field.

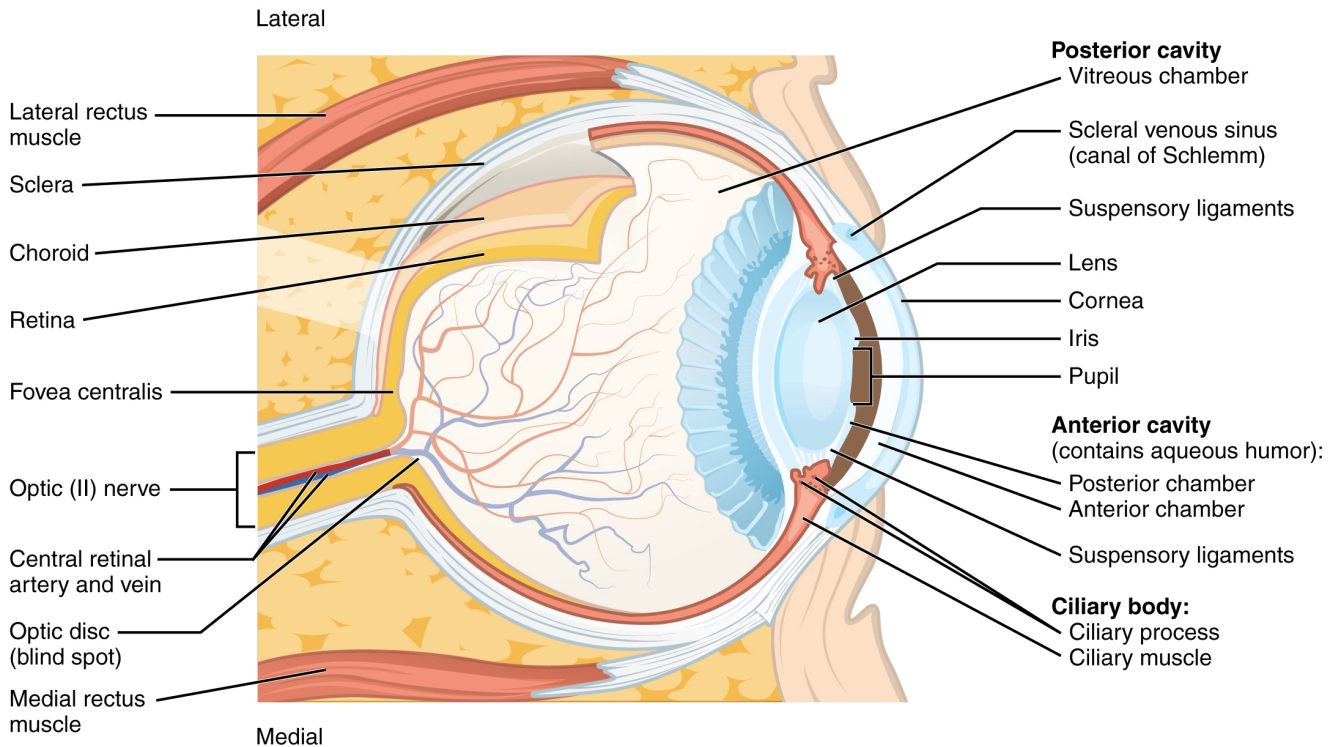


Figure 15.7 Structure of the Eye. The sphere of the eye can be divided into anterior and posterior chambers. The wall of the eye is composed of three layers: the fibrous tunic, vascular tunic, and neural tunic. Within the neural tunic is the retina, with three layers of cells and two synaptic layers in between. The center of the retina has a small indentation known as the fovea. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Photoreceptors in the retina (rods and cones) are located behind the axons, RGCs, bipolar cells, and retinal blood vessels. A significant amount of light is absorbed by these structures before the light reaches the photoreceptor cells. At the exact center of the retina is a small area known as the **fovea**. At the fovea, the retina lacks the supporting cells and blood vessels, and only contains photoreceptors. Therefore, **visual acuity**, is greatest at the fovea. This is because the fovea is where the least amount of incoming light is absorbed by other retinal structures (see Figure 15.7). As one moves in either direction from this central point of the retina, visual acuity drops significantly.

Example: Visual Acuity (VA) between the fovea and peripheral retina.

The difference in visual acuity between the fovea and peripheral retina is easily evidenced by looking directly at a word in the middle of this paragraph. The visual stimulus in the middle of the field of view falls on the fovea and is in the sharpest focus. **Without moving your eyes off that word, notice that words at the beginning or end of the paragraph are not in focus.** The images in your peripheral vision are focused by the peripheral retina, and have vague, blurry edges and words that are not as clearly identified. As a result, a large part of the neural function of the eyes is concerned with moving the eyes and head so that important visual stimuli are centered on the fovea.

There are **three types of cone opsins**, that are sensitive to different wavelengths of light and provide us with **color vision**. By comparing the activity of the three different cones, the brain can extract color information from visual stimuli (see Figure 15.8). For example, a bright blue light that has a wavelength of approximately 450 nm would activate the “**red**” cones minimally, the “**green**” cones marginally, and the “**blue**” cones predominantly. The relative activation of the three different cones is calculated by the brain, which perceives the color as blue. However, cones cannot react to low-intensity light, and rods do not sense the color of light. Therefore, our low-light vision is, in essence, in **grayscale**. In other words, in a dark room, everything appears as a shade of gray. If you think that you can see colors in the dark, it is most likely because your brain knows what color something is and is relying on that memory.

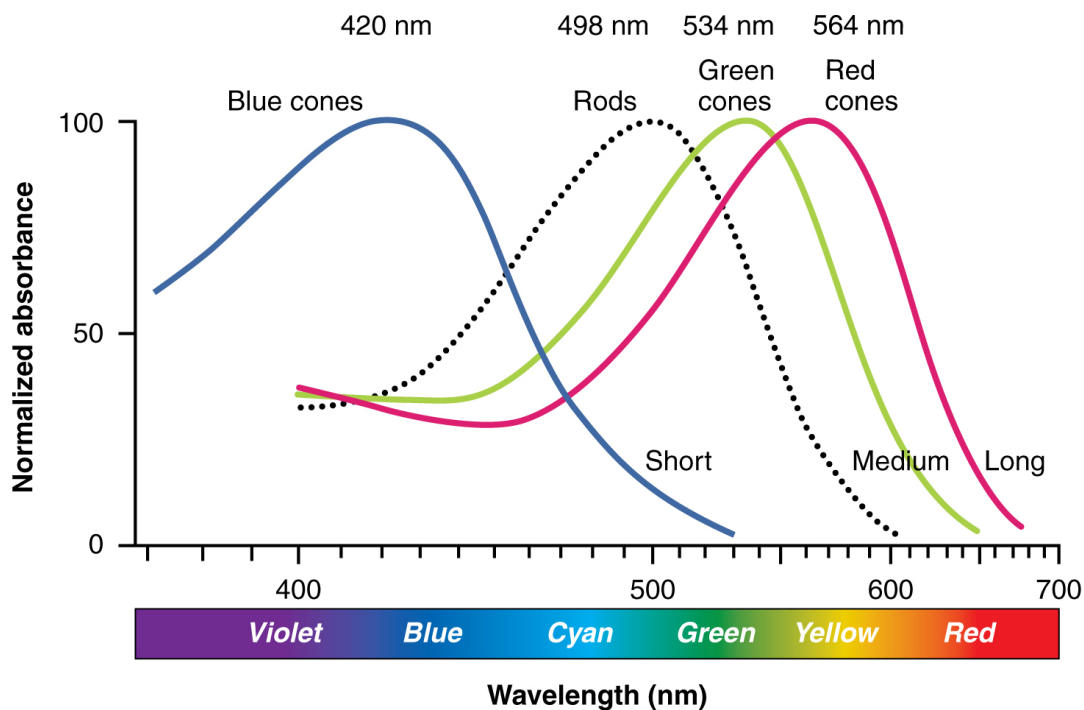


Figure 15.8 Comparison of Color Sensitivity of Photopigments. Comparing the peak sensitivity and absorbance spectra of the four photopigments suggests that they are most sensitive to particular wavelengths. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Sensory System Medical Terms Not Easily Broken Into Word Parts



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/ltcmedicalterminology/?p=164#h5p-103>

Anatomy Labeling Activity



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-101>



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-102>

Sensory System Terms not Easily Broken into Word Parts



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-103>

Common Abbreviations for the Sensory System



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-104>

Diseases and Disorders of the Sensory Systems

Olfactory Diseases and Disorders

Anosmia

Blunt force trauma to the face, such as that common in many car accidents, can lead to the loss of the olfactory nerve, and subsequently, loss of the sense of smell. This condition is known as **anosmia**. When the frontal lobe of

the brain moves relative to the ethmoid bone, the olfactory tract axons may be sheared apart. Professional fighters often experience anosmia because of repeated trauma to face and head. In addition, certain pharmaceuticals, such as antibiotics, can cause anosmia by killing all the olfactory neurons at once. If no axons are in place within the olfactory nerve, then the axons from newly formed olfactory neurons have no guide to lead them to their connections within the olfactory bulb. There are temporary causes of anosmia, as well, such as those caused by inflammatory responses related to respiratory infections or allergies.

Loss of the sense of smell can result in food tasting bland. A person with an impaired sense of smell may require additional spice and seasoning levels for food to be tasted. Anosmia may also be related to some presentations of mild depression, because the loss of enjoyment of food may lead to a general sense of despair. The ability of olfactory neurons to replace themselves decreases with age, leading to age-related anosmia. This explains why some elderly people salt their food more than younger people do. However, this increased sodium intake can increase blood volume and blood pressure, increasing the risk of cardiovascular diseases in the elderly (Betts, et al., 2021).

Ears, Nose, and Throat Diseases and Disorders

Otitis Media

Otitis Media is known as inflammation of the middle ear canal that involves the eardrum. It is commonly seen in younger children due to bacterial and viral infections. Symptoms include possible fever, cough and cold symptoms, hearing loss, irritability and **otalgia**. Treatment involves symptomatic control as well as antibiotic (Amoxicillin) use if necessary (Danishyar and Ashurst 2021). To learn more about [otitis media visit this webpage from the National Center for Biotechnology Information bookshelf](#).

Otitis Externa

Otitis Externa is inflammation of the external ear canal and is known as swimmer's ear because it is associated with its exposure to water. Its clinical presentation and management are the same as otitis media (Piercefield, et al., 2011). To learn more about **otitis externa** review this website from the [Centers for Disease Control and Prevention](#).

Conductive Hearing Loss

Hearing loss occurs when something disrupts sound through the mid and outer ear, such as physical damage to the ear drum (perforation). Hearing loss can be managed with pharmacotherapy, surgery or a combination of the two (Centers for Disease Control and Prevention, 2020).

Sensorineural Hearing Loss

This hearing loss results from damage to the neural structures. Tumors as well as exposure to loud noises (acute/chronic) can lead to this type of hearing loss (Centers for Disease Control and Prevention, 2020). To learn more about sensorineural hearing loss review the [Centers for Disease Control and Prevention's web page about sensorineural hearing loss](#).

Tinnitus

Tinnitus is a condition of perceived ringing in the ears. Tinnitus can be caused by many underlying health conditions, including inflammation or obstruction within the middle ear (American Tinnitus Association, 2019). [To hear what tinnitus can sound like, visit the American Tinnitus Association's webpage.](#)

Otosclerosis

This is hardening of the ear due to new bone formation of the inner ear ossicles. Its etiology is of idiopathic or hereditary origin. Clinical features are consistent with that of conductive hearing loss. Treatment for mild otosclerosis involves use of a hearing aid, while more severe otosclerosis is treated with a stapedectomy surgery (National Institute on Deafness and Other Communication Disorders, 2018). To learn more visit the [National Institute on Deafness and Other Communication Disorders webpage on Otosclerosis.](#)

Rhinitis

Is inflammation of the nasal cavity mucosal lining which can lead to congestion and rhinorrhea (runny nose). The causes are due to allergic reactions as well as viruses. Treatment regimens include symptomatic management, saline sprays and oral antihistamines (Naclerio, Bachert, & Baraniuk, 2010).

Eye Diseases and Disorders

Blindness

The term “blindness” may cover a broad spectrum of visual disability such as the inability to see because of injury, disease, or a congenital condition. The parameters for legal blindness are visual field is 20 degrees or narrower and/or visual acuity is 20/200 or less in the best seeing eye even after correction. Many of the conditions described below lead to visual disability, low vision, and legal blindness (Lee and Mesfin, 2020). To learn more about [blindness visit the National Library of Medicine's webpage.](#)

Cataract

A cataract is a clouding of the normally clear lens of your eye. For people who have cataracts, it's like seeing through cloudy lenses or windows. The lens of the eye loses its flexibility due to the aging process leading in some cases to senile cataracts. Infants sometime are born with congenital cataracts. Treatment usually involves surgery to remove the clouding of the lens (Mayo Clinic Staff, 2018). To learn more, visit the [Mayo Clinic's web page about cataracts.](#)

Conjunctivitis

This is a condition involving inflammation of the conjunctiva. Its common causes are due to allergens, chemicals, foreign objects, as well as bacterial and viral pathogens. The cause of conjunctivitis determines if it is transmissible from one individual to another. Pink eye caused by the adenovirus for example, is highly contagious compared to pollen which is not. Management involves treating the underlying cause of the conjunctivitis (Centers for Disease Control and

Prevention, 2019). To learn more about conjunctivitis please visit the [Centers for Disease Control and Prevention's web page about conjunctivitis](#).

Diabetic Retinopathy

This is a disease of the retina caused by diabetes mellitus. The retinal veins dilate leading to swelling as fluid leaks from blood vessels into the retina. It is estimated that 20% of newly diagnosed diabetics suffer from diabetic retinopathy (American Optometric Association, 2020). To learn more visit the [American Optometric Association 's website on diabetic retinopathy](#).

Glaucoma

This disease is part of a group of eye diseases which lead to progressive degeneration of the optic nerve. This, in turn, can lead to loss of nerve tissue that results in gradual irreversible vision loss and potential blindness if not detected and treated early. The most common form of glaucoma is primary open angle glaucoma. This form is associated with elevated pressure caused by a backup of fluid in the eye (National Eye Institute, 2020). To learn more visit the [National Eye Institute's webpage about glaucoma](#).

Macular Degeneration/ Age-related Macular Degeneration (AMD)

Progressive damage of a portion of the retina known as the macula. Severe central vision is lost with peripheral vision retained. This is the leading cause of blindness in Americans over the age of 65 (Centers for Disease Control and Prevention, 2020). To learn more visit the [Centers for Disease Control and Prevention webpage on AMD](#).

Nystagmus

This is condition whereby involuntary repetitive eye movements that make it impossible to fixate on a single object. The condition is often referred to dancing eyes (Dubow, 2020). To learn more information about nystagmus view [this website from All About Vision](#).

Retinal Detachment

This condition occurs when the retina gets pulled away or separated from its normal position. Flashing lights, **floaters** and what appears to be a grey curtain are all symptoms of a retinal tear, which can lead to a retinal detachment. An ophthalmologist is a retinal specialist who can repair the retinal detachment. If left untreated a retinal detachment could lead to blindness (National Eye Institute, 2020). To learn more visit the [National Eye Institute's page on retinal detachment](#).

Strabismus

This is a condition where the affected eye rotates due to mismatched eye coordination. Each eye is focused differently as described below:

- **Esotropia:** the convergence of one or both eyes medially.
- **Exotropia:** the deviation of one eye laterally.
- **Hypertropia:** the deviation of one eye superiorly.
- **Hypotropia:** the deviation of one eye inferiorly.

If not managed, the brain may reject input from one eye resulting in vision loss of the respective eye (amblyopia). **Amblyopia** is a condition also known as lazy eye which is caused when there is an imbalance of stimuli from the brain to the eyes (one eye receives more than the other).

Medical Terms in Context



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-105>



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-106>

Medical Specialties and Procedures Related to the Sensory Systems

Several medical specialties support the sensory systems. An **optometrist** is an eye specialist that examines and evaluates for ocular pathology and an optometrist prescribes corrective lenses. An **ophthalmologist** evaluates and manage eye pathology as well as perform surgery. An **otorhinolaryngologist** (ENT) is a physician that specializes in ears, nose and throat treatment and conditions. An **audiologist** evaluates and manages individuals with hearing loss.

Ophthalmic Medical Assistant

Ophthalmic Medical Assistants work in ophthalmic and optometric practices and in retail optical settings. Ophthalmic Assistants perform pre-screening and specialty testing, assist with dispensing glasses and contact lenses, and perform office management duties including maintaining patient information and billing and insurance processes.

Ophthalmic Technician

Optometric Technicians work under the supervision of an optometrist or ophthalmologist. Optometric Technicians assist an optometrist during eye exams and other optometric procedures, providing eye health tests and consultations.

Test Yourself



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=164#h5p-107>

References

- American Optometric Association. (2020). *Diabetic retinopathy*. <https://www.aoa.org/patients-and-public/eye-and-vision-problems/glossary-of-eye-and-vision-conditions/diabetic-retinopathy>
- American Tinnitus Association. (2019). Understanding the Facts. <https://www.ata.org/understanding-facts>
- CrashCourse. (2015, May 11). *Vision: Crash course A&P #18* [Online video]. YouTube. <https://www.youtube.com/watch?v=o0DYP-u1rNM>
- CrashCourse. (2015, April 27). *Taste & smell: Crash course A&P #16* [Online video]. YouTube. <https://www.youtube.com/watch?v=mFm3yAInslE>
- CrashCourse. (2015, May 4). *Hearing & balance: Crash course A&P #17* [Online video]. YouTube. <https://www.youtube.com/watch?v=Ie2j7GpC4JU>
- Centers for Disease Control and Prevention. (2019). *Conjunctivitis (pink eye)*. CDC. <https://www.cdc.gov/conjunctivitis/about/causes.html>
- Centers for Disease Control and Prevention. (2020). *Learn about age-related macular degeneration*. CDC. <https://www.cdc.gov/visionhealth/resources/features/macular-degeneration.html>
- Centers for Disease Control and Prevention. (2020). *Types of hearing loss*. CDC. <https://www.cdc.gov/ncbddd/hearingloss/types.html>
- Danishyar A, Ashurst JV. *Acute Otitis Media*. (Updated 2021 Mar 16). In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. <https://www.ncbi.nlm.nih.gov/books/NBK470332/>
- Dubow, B. (2020). *Nystagmus: Involuntary eye movements*. All About Vision. <https://www.allaboutvision.com/conditions/nystagmus.htm>
- Lee SY, Mesfin FB. *Blindness*. (Updated 2020 Oct 28). In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. <https://www.ncbi.nlm.nih.gov/books/NBK448182/>
- Mayo Clinic Staff. (2018). *Cataracts overview*. Mayo Clinic Patient Care & Health Information. <https://www.mayoclinic.org/diseases-conditions/cataracts/symptoms-causes/syc-20353790>
- Naclerio, R.M., Bachert, C., & Baraniuk, J.N. (2010). Pathophysiology of nasal congestion. *International Journal of General Medicine*, 3, 47-57. <https://dx.doi.org/10.2147%2Fijgm.s8088>
- National Institute on Deafness and Other Communication Disorders. (2018). *Otosclerosis*. National Institutes of Health. <https://www.nidcd.nih.gov/health/otosclerosis>
- National Eye Institute. (2020). *Glaucoma*. National Institutes of Health. <https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/glaucoma>

National Eye Institute. (2020). *Retinal detachment*. National Institutes of Health. <https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/retinal-detachment>

Piercefield, E.W., Collier, S.A., Hlavska, M.C., & Beach, M.J. (2011). *Estimated burden of acute otitis externa – United States, 2003-2007*. CDC Morbidity and Mortality Weekly Report. https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6019a2.htm?s_cid=mm6019a2_w

Unless otherwise indicated, this chapter contains material adapted from *Anatomy and Physiology* (on [OpenStax](#)), by Betts, et al. and is used under a [CC BY 4.0 international license](#). Download and access this book for free at <https://openstax.org/books/anatomy-and-physiology/pages/1-introduction>.

16. Nervous System

WTCS Learning Objectives

- Apply the rules of medical language to build, analyze, spell, pronounce, abbreviate, and define terms as they relate to the nervous system
- Identify meanings of key word components of the nervous system
- Categorize diagnostic, therapeutic, procedural or anatomic terms related to the nervous system
- Use terms related to the nervous system
- Use terms related to the diseases and disorders of the nervous system

Nervous System Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the Nervous System.



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-108>

Introduction to the Nervous System

The picture you have in your mind of the nervous system probably includes the **brain**, the **nervous tissue** contained within the cranium, and the **spinal cord**, the extension of nervous tissue within the vertebral column. That suggests it is made of two organs—and you may not even think of the spinal cord as an organ—but the nervous system is a very complex structure. Within the brain, many different and separate regions are responsible for many different and separate functions. It is as if the nervous system is composed of many organs that all look similar and can only be differentiated using tools such as the **microscope** or **electrophysiology**.

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#oembed-1>

Media 16.1 [The Nervous System, Part 1: Crash Course A&P #8](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Nervous System Medical Terms



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-109>

Anatomy (Structures) of the Nervous System

The Central and Peripheral Nervous Systems

The nervous system can be divided into two major regions: the central and peripheral nervous systems. The **central nervous system (CNS)** is the brain and spinal cord, and the **peripheral nervous system (PNS)** is everything else (see Figure 16.1). The brain is contained within the cranial cavity of the skull, and the spinal cord is contained within the vertebral cavity of the vertebral column. It is a bit of an oversimplification to say that the CNS is what is inside these two cavities and the peripheral nervous system is outside of them, but that is one way to start to think about it. In actuality, there are some elements of the peripheral nervous system that are within the cranial or vertebral cavities. The peripheral nervous system is so named because it is on the periphery—meaning beyond the brain and spinal cord. Depending on different aspects of the nervous system, the dividing line between central and peripheral is not necessarily universal.

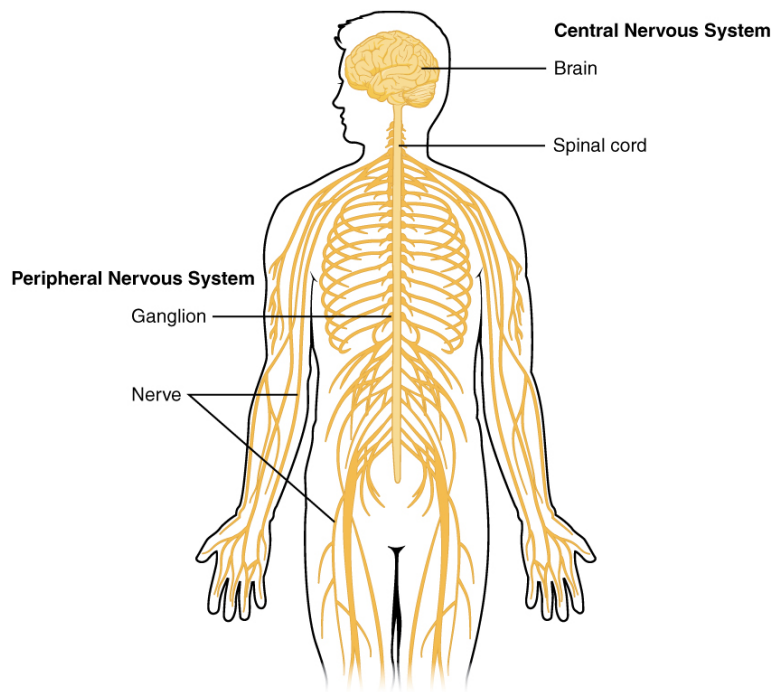


Figure 16.1 Central and Peripheral Nervous System. The structures of the PNS are referred to as ganglia and nerves, which can be seen as distinct structures. The equivalent structures in the CNS are not obvious from this overall perspective and are best examined in prepared tissue under the microscope. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Nervous tissue, present in both the CNS and PNS, contains two basic types of cells: neurons and glial cells. **Neurons** are the primary type of cell that most anyone associates with the nervous system. They are responsible for the computation and communication that the nervous system provides. They are electrically active and release chemical signals to target cells. Glial cells, or **glia**, are known to

play a supporting role for nervous tissue. Ongoing research pursues an expanded role that glial cells might play in signaling, but neurons are still considered the basis of this function. Neurons are important, but without glial support they would not be able to perform their function. A glial cell is one of a variety of cells that provide a framework of tissue that supports the neurons and their activities. The neuron is the more functionally important of the two, in terms of the communicative function of the nervous system. To describe the functional divisions of the nervous system, it is important to understand the structure of a neuron.

Neurons are cells and therefore have a **soma**, or cell body, but they also have extensions of the cell; each extension is generally referred to as a process. There is one important process that every neuron has called an **axon**, which is the fiber that connects a neuron with its target. Another type of process that branches off from the soma is the dendrite. **Dendrites** are responsible for receiving most of the input from other neurons.

Looking at nervous tissue, there are regions that predominantly contain cell bodies and regions that are largely composed of just axons. These two regions within nervous system structures are often referred to as **gray matter** (the regions with many cell bodies and dendrites) or **white matter** (the regions with many axons). Figure 16.2 demonstrates the appearance of these regions in the brain and spinal cord. The colors ascribed to these regions are what would be seen in “fresh,” or unstained, nervous tissue. Gray matter is not necessarily gray. It can be pinkish because of blood

Did You Know?

The brain has over 100 billion neurons.

content, or even slightly tan, depending on how long the tissue has been preserved. White matter is white because axons are insulated by a lipid-rich substance called myelin. Lipids can appear as white (“fatty”) material, much like the fat on a raw piece of chicken or beef. Actually, gray matter may have that color ascribed to it because next to the white matter, it is just darker—hence, gray.

The distinction between **gray matter** and **white matter** is most often applied to central nervous tissue, which has large regions that can be seen with the unaided eye. When looking at peripheral structures, often a microscope is used and the tissue is stained with artificial colors. That is not to say that central nervous tissue cannot be stained and viewed under a microscope, but unstained tissue is most likely from the CNS—for example, a frontal section of the brain or cross section of the spinal cord.

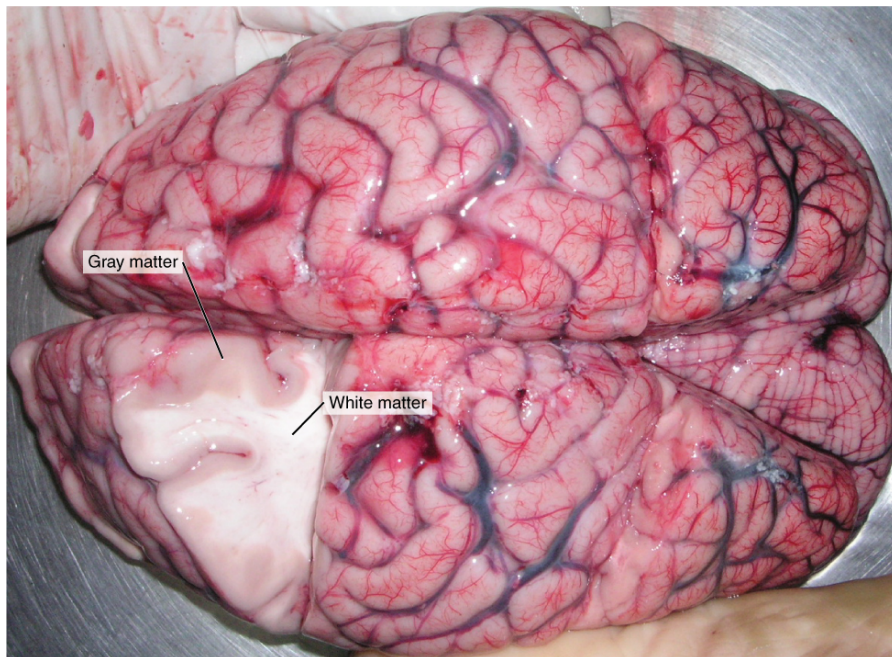


Figure 16.2 Gray Matter and White Matter. A brain removed during an autopsy, with a partial section removed, shows white matter surrounded by gray matter. Gray matter makes up the outer cortex of the brain. (credit: modification of work by “Suseno”/Wikimedia Commons). From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

The Adult Brain

The adult brain is separated into four major regions: the cerebrum, the diencephalon, the brain stem, and the cerebellum. The cerebrum is the largest portion and contains the cerebral cortex and subcortical nuclei. It is divided into two halves by the longitudinal fissure.

The Cerebrum

The iconic gray mantle of the human brain, which appears to make up most of the mass of the brain, is the **cerebrum** (see Figure 16.3). The wrinkled portion is the cerebral cortex, and the rest of the structure is beneath that outer covering. There is a large separation between the two sides of the cerebrum called the **longitudinal** fissure. It separates the cerebrum into two distinct halves, a right and left **cerebral hemisphere**. Deep within the cerebrum, the white matter of the corpus callosum provides the major pathway for communication between the two hemispheres of the cerebral cortex.

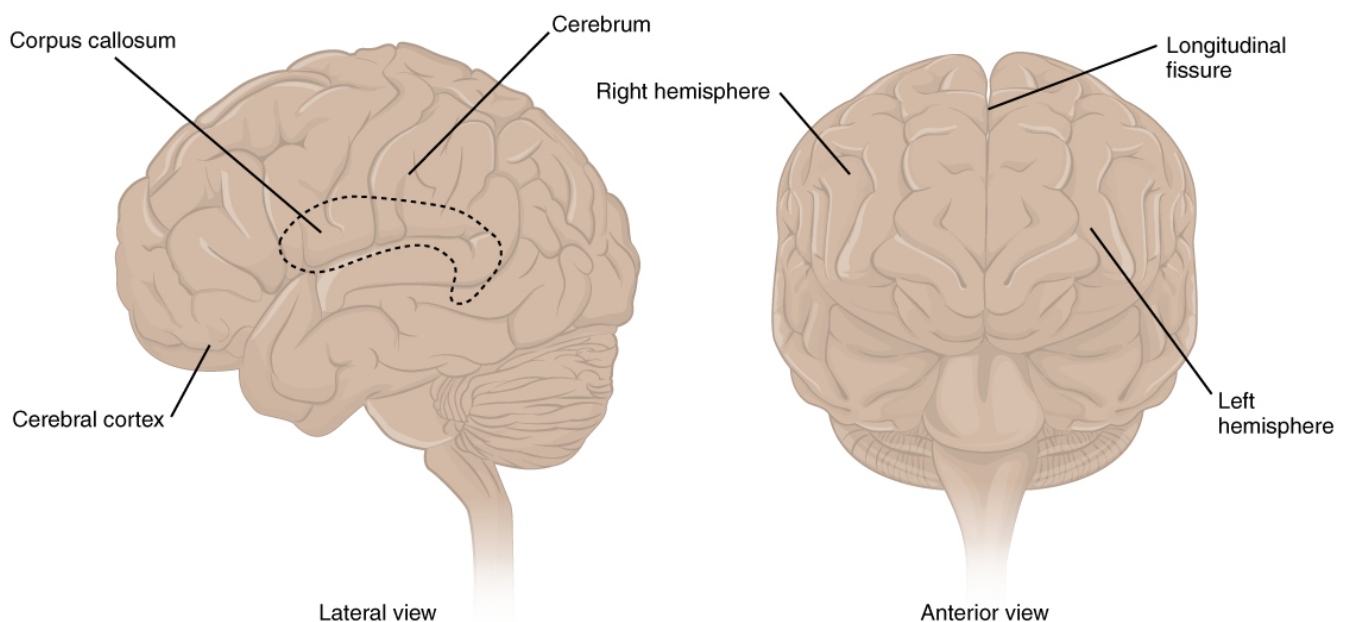


Figure 16.3 The Cerebrum. The cerebrum is a large component of the CNS in humans, and the most obvious aspect of it is the folded surface called the cerebral cortex. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Many of the higher neurological functions, such as memory, emotion, and consciousness, are the result of cerebral function. The complexity of the cerebrum is different across vertebrate species. The cerebrum of the most primitive vertebrates is not much more than the connection for the sense of smell. In mammals, the cerebrum comprises the outer gray matter that is the cortex (from the Latin word meaning “bark of a tree”) and several deep nuclei that belong to three important functional groups. The basal nuclei are responsible for cognitive processing, the most important function being that associated with planning movements. The basal forebrain contains nuclei that are important in learning and memory. The limbic cortex is the region of the cerebral cortex that part of the limbic system, a collection of structures involved in emotion, memory, and behavior.

Did You Know?

The brain is about

Cerebral Cortex

75% water and is the fattest organ in the body.

The cerebrum is covered by a continuous layer of gray matter that wraps around either side of the forebrain—the **cerebral cortex**. This thin, extensive region of wrinkled gray matter is responsible for the higher functions of the nervous system. A gyrus (plural = gyri) is the ridge of one of those wrinkles, and a sulcus (plural = sulci) is the groove between two gyri. The pattern of these folds of tissue indicates specific regions of the cerebral cortex.

The head is limited by the size of the birth canal, and the brain must fit inside the cranial cavity of the skull. Extensive folding in the cerebral cortex enables more gray matter to fit into this limited space. If the gray matter of the cortex were peeled off of the cerebrum and laid out flat, its surface area would be roughly equal to one square meter.

The folding of the cortex maximizes the amount of gray matter in the cranial cavity. During embryonic development, as the **telencephalon** expands within the skull, the brain goes through a regular course of growth that results in everyone's brain having a similar pattern of folds. The surface of the brain can be mapped on the basis of the locations of large gyri and sulci. Using these landmarks, the cortex can be separated into four major regions, or lobes (see Figure 16.4). The lateral sulcus that separates the temporal lobe from the other regions is one such landmark. Superior to the lateral sulcus are the **parietal lobe** and **frontal lobe**, which are separated from each other by the **central sulcus**. The posterior region of the cortex is the **occipital lobe**, which has no obvious anatomical border between it and the parietal or temporal lobes on the lateral surface of the brain. From the medial surface, an obvious landmark separating the parietal and occipital lobes is called the parieto-occipital sulcus. The fact that there is no obvious anatomical border between these lobes is consistent with the functions of these regions being interrelated.

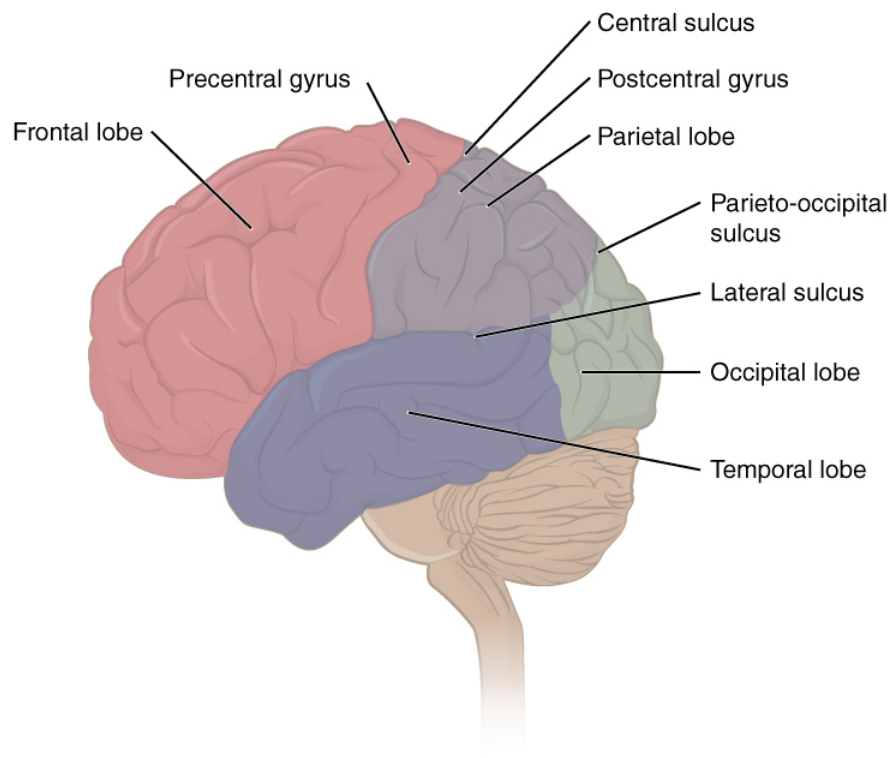


Figure 16.4 Lobes of the Cerebral Cortex. The cerebral cortex is divided into four lobes. Extensive folding increases the surface area available for cerebral functions. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Concept Check

- Identify the two major divisions of the nervous system.
- Describe the **cerebral cortex**.
- What are the halves of the cerebrum known as?

Thalamus

The **thalamus** is a collection of nuclei that relay information between the cerebral cortex and the periphery, spinal cord, or brain stem. All sensory information, except for the sense of smell, passes through the thalamus before processing by the cortex. For example, the portion of the thalamus that receives visual information will influence what visual stimuli are important, or what receives attention.

The cerebrum also sends information down to the thalamus, which usually communicates motor commands. This involves interactions with the cerebellum and other nuclei in the brain stem. The cerebrum interacts with the basal nuclei, which involves connections with the thalamus. The primary output of the basal nuclei is to the thalamus, which

relays that output to the cerebral cortex. The cortex also sends information to the thalamus that will then influence the effects of the basal nuclei.

Hypothalamus

Inferior and slightly anterior to the thalamus is the **hypothalamus** the other major region of the diencephalon. The hypothalamus is a collection of nuclei that are largely involved in regulating homeostasis. The hypothalamus is the executive region in charge of the **autonomic nervous system** and the endocrine system through its regulation of the anterior pituitary gland. Other parts of the hypothalamus are involved in memory and emotion as part of the limbic system.

Brain Stem

The midbrain and hindbrain (composed of the **pons** and the **medulla**) are collectively referred to as the brain stem (see Figure 16.5). The structure emerges from the ventral surface of the forebrain as a tapering cone that connects the brain to the spinal cord. Attached to the brain stem, but considered a separate region of the adult brain, is the cerebellum. The midbrain coordinates sensory representations of the visual, auditory, and somatosensory perceptual spaces. The pons is the main connection with the cerebellum. The pons and the medulla regulate several crucial functions, including the cardiovascular and respiratory systems and rates.

The cranial nerves connect through the brain stem and provide the brain with the sensory input and motor output associated with the head and neck, including most of the special senses. The major ascending and descending pathways between the spinal cord and brain, specifically the cerebrum, pass through the brain stem.

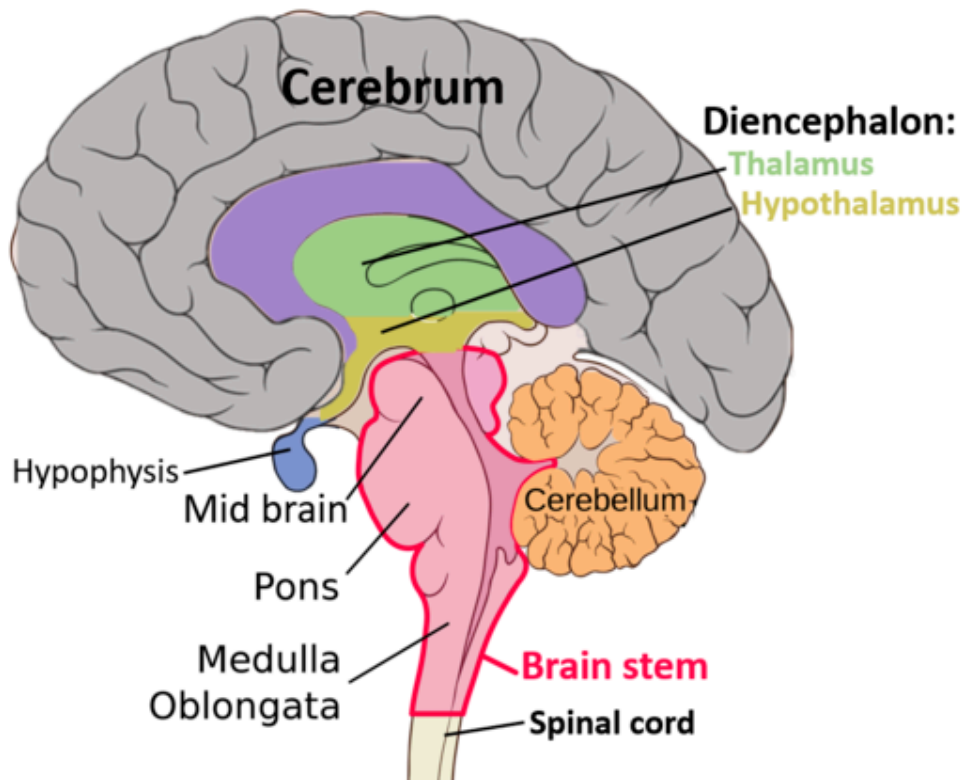


Figure 16.5 Parts of the Brain. The image highlights and names the most important structures of the brain in a sagittal(longitudinal) cross-section. Belomaad Biology Matura book, CC BY-SA 4.0, via Wikimedia Commons

Midbrain

The midbrain is the uppermost portion of the brainstem. It contains pathways connecting the cerebrum with lower portions of the brain and structures involved with seeing and hearing.

Pons

The **pons** is a part of the brainstem that literally means bridge. It contains nerve fiber tracts that connect the cerebellum and cerebrum with the rest of the brain. Nerves affecting the face and eye movement are located here.

Medulla

The medulla oblongata, also in the brainstem, connects the spinal cord with the rest of the brain. It is the region known as the **myelencephalon** in the embryonic brain. It contains centers that control respiration, heart rate, and the muscles of the blood vessel walls, which assist in determining blood pressure. Nerve tracts cross from right to left and left to right in the medulla oblongata. For example, nerve cells that control movement of the left side of the body are found in the right half of the cerebrum. These cells send out axons that cross over (decussate) to the opposite side of the brain in the medulla oblongata and then travel down the spinal cord.

The Cerebellum

The cerebellum functions to coordinate voluntary movements and to maintain balance and posture. It is covered in **gyri** and sulci like the cerebrum, and looks like a miniature version of that part of the brain (see Figure 16.6). The cerebellum is located under the posterior portion of the cerebrum (also called hindbrain). It accounts for approximately 10 percent of the mass of the brain.

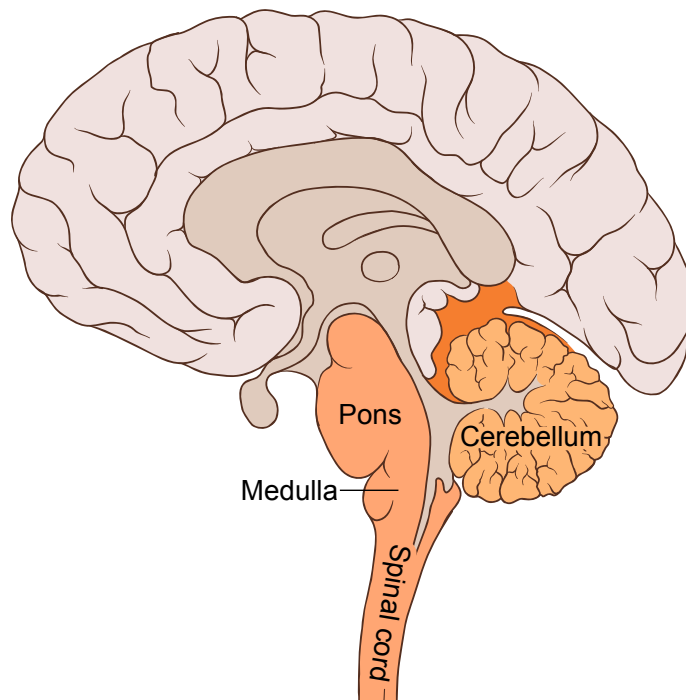


Figure 16.6 The Cerebellum. The cerebellum is situated on the posterior surface of the brain stem. Image by Patrick J. Lynch; CC BY 2.5, via Wikimedia Commons

Concept Check

- What is the primary processing purpose of the **medulla**?
- Identify the structure in the brain responsible for sensory feedback through the spinal cord. Suggest what may happen if this function failed.

The Spinal Cord

The description of the CNS is concentrated on the structures of the brain, but the spinal cord is another major organ of the system. Whereas the brain develops out of expansions of the neural tube into primary and then secondary vesicles, the spinal cord maintains the tube structure and is only specialized into certain regions. As the spinal cord continues to develop in the newborn, anatomical

features mark its surface. The anterior midline is marked by the anterior median fissure, and the posterior midline is marked by the posterior median sulcus. Axons enter the posterior side through the dorsal (posterior) nerve root, which marks the posterolateral sulcus on either side. The axons emerging from the anterior side do so through the ventral (anterior) nerve root. Note that it is common to see the terms dorsal (dorsal = “back”) and ventral (ventral = “belly”) used interchangeably with posterior and anterior, particularly in reference to nerves and the structures of the spinal cord. You should learn to be comfortable with both.

On the whole, the posterior regions are responsible for sensory functions and the anterior regions are associated with motor functions. This comes from the initial development of the spinal cord, which is divided into the basal plate and the alar plate. The basal plate is closest to the ventral midline of the neural tube, which will become the anterior face of the spinal cord and gives rise to motor neurons. The alar plate is on the dorsal side of the neural tube and gives rise to neurons that will receive sensory input from the periphery.

The length of the spinal cord is divided into regions that correspond to the regions of the vertebral column. The name of a spinal cord region corresponds to the level at which spinal nerves pass through the intervertebral foramina. Immediately adjacent to the brain stem is the following divisions of the spinal cord:

- cervical region
- thoracic region
- lumbar region
- sacral region

The spinal cord is not the full length of the vertebral column because the spinal cord does not grow significantly longer after the first or second year, but the skeleton continues to grow. The nerves that emerge from the spinal cord pass through the intervertebral **foramina** at the respective levels. As the vertebral column grows, these nerves grow with it and result in a long bundle of nerves that resembles a horse’s tail and is named the **cauda equina**. The sacral spinal cord is at the level of the upper lumbar vertebral bones. The spinal nerves extend from their various levels to the proper level of the vertebral column.

Neurons

Neurons are the cells considered to be the basis of nervous tissue. They are responsible for the electrical signals that communicate information about sensations, and that produce movements in response to those stimuli, along with inducing thought processes within the brain. An important part of the function of neurons is in their structure, or shape. The three-dimensional shape of these cells makes the immense numbers of connections within the nervous system possible.

Parts of a Neuron

As you learned in the first section, the main part of a neuron is the **cell body**, which is also known as the soma (soma = “body”). The cell body contains the nucleus and most of the major organelles. But what makes neurons special

Did You Know?

The bundle of nerve fibers making up the spinal cord is no thicker than the human thumb.

is that they have many extensions of their cell membranes, which are generally referred to as processes. Neurons are usually described as having one, and only one, axon—a fiber that emerges from the cell body and projects to target cells. That single axon can branch repeatedly to communicate with many **target** cells. It is the axon that **propagates** the nerve impulse, which is communicated to one or more cells. The other processes of the neuron are dendrites, which receive information from other neurons at specialized areas of contact called synapses. The dendrites are usually highly branched processes, providing locations for other neurons to communicate with the cell body. Information flows through a neuron from the dendrites, across the cell body, and down the axon. This gives the neuron a polarity—meaning that information flows in this one direction. Figure 16.7 shows the relationship of these parts to one another.

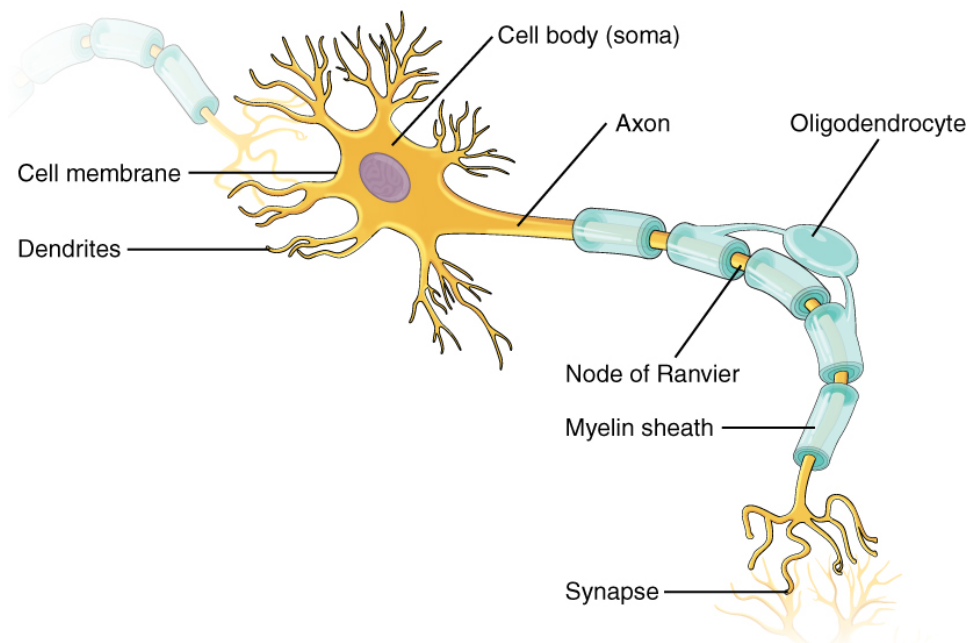


Figure 16.7 Parts of a Neuron. The major parts of the neuron are labeled on a multipolar neuron from the CNS. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Many axons are wrapped by an insulating substance called myelin, which is actually made from glial cells. Myelin acts as insulation much like the plastic or rubber that is used to insulate electrical wires. A key difference between **myelin** and the insulation on a wire is that there are gaps in the myelin covering of an axon. Each gap is called a node of Ranvier and is important to the way that electrical signals travel down the axon. The length of the axon between each gap, which is wrapped in myelin, is referred to as an axon segment. At the end of the axon is the axon terminal, where there are usually several branches extending toward the target cell, each of which ends in an enlargement called a synaptic end bulb. These bulbs are what make the connection with the target cell at the synapse.

Types of Neurons

There are many neurons in the nervous system—a number in the trillions. And there are many different types of neurons. They can be classified by many different criteria. The first way to classify them is by the number of processes attached to the cell body. Using the standard model of neurons, one of these processes is the axon, and the rest are dendrites. Because information flows through the neuron from dendrites or cell bodies toward the axon, these names are based on the neuron’s polarity.

Glial Cells

Glial cells, or neuroglia or simply glia, are the other type of cell found in nervous tissue. They are considered to be supporting cells, and many functions are directed at helping neurons complete their function for communication. The name glia comes from the Greek word that means “glue,” and was coined by the German pathologist Rudolph Virchow, who wrote in 1856: “This connective substance, which is in the brain, the spinal cord, and the special sense nerves, is a kind of glue (neuroglia) in which the nervous elements are planted.” Today, research into nervous tissue has shown that there are many deeper roles that these cells play. And research may find much more about them in the future.

There are six types of glial cells. Four of them are found in the CNS and two are found in the PNS. Table 16.1 outlines some common characteristics and functions.

Table 16.1: Glial Cell Types by Location and Basic Function. From Betts, et al., 2021. Licensed under [CC BY 4.0](#).

CNS GLIA	PNS GLIA	BASIC FUNCTION
Astrocyte	Satellite cell	Support
Oligodendrocyte	Schwann cell	Insulation, myelination
Microglia	–	Immune surveillance and phagocytosis
Ependymal cell	–	Creating CSF

Glial Cells of the CNS

One cell providing support to neurons of the CNS is the astrocyte, so named because it appears to be star-shaped under the microscope (astro- = “star”). **Astrocytes** have many processes extending from their main cell body (not axons or dendrites like neurons, just cell extensions). Those processes extend to interact with neurons, blood vessels, or the connective tissue covering the CNS that is called the pia mater (see Figure 16.8). Generally, they are supporting cells for the neurons in the central nervous system. Some ways in which they support neurons in the central nervous system are by maintaining the concentration of chemicals in the extracellular space, removing excess signaling molecules, reacting to tissue damage, and contributing to the **blood-brain barrier** (BBB). The blood-brain barrier is a physiological barrier that keeps many substances that circulate in the rest of the body from getting into the central nervous system, restricting what can cross from circulating blood into the CNS. Nutrient molecules, such as glucose or amino acids, can pass through the BBB, but other molecules cannot. This actually causes problems with drug delivery to the CNS. Pharmaceutical companies are challenged to design drugs that can cross the BBB as well as have an effect on the nervous system.

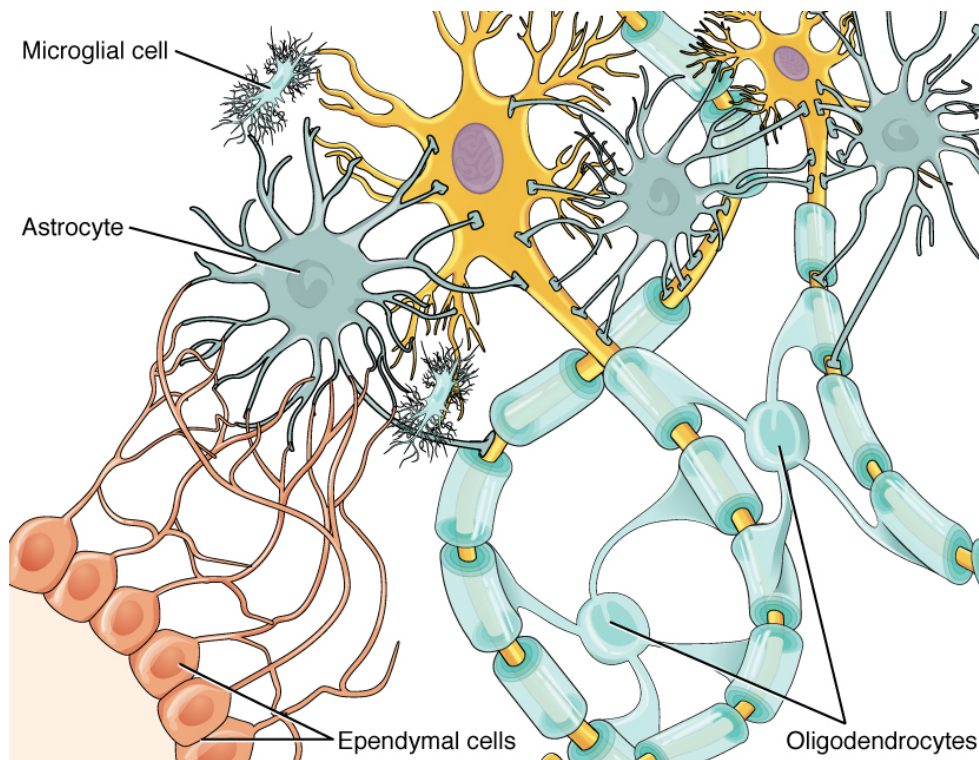


Figure 16.8 Glial Cells of the CNS. The CNS has astrocytes, oligodendrocytes, microglia, and ependymal cells that support the neurons of the CNS in several ways. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Like a few other parts of the body, the brain has a privileged blood supply. Very little can pass through by diffusion. Most substances that cross the wall of a blood vessel into the CNS must do so through an active transport process. Because of this, only specific types of molecules can enter the CNS. Glucose—the primary energy source—is allowed, as are amino acids. Water and some other small particles, like gases and ions, can enter. But most everything else cannot, including white blood cells, which are one of the body’s main lines of defense. While this barrier protects the CNS from exposure to toxic or pathogenic substances, it also keeps out the cells that could protect the brain and spinal cord from disease and damage. The BBB also makes it harder for pharmaceuticals to be developed that can affect the nervous system. Aside from finding efficacious substances, the means of delivery is also crucial.

Oligodendrocyte, sometimes called just “oligo,” which is the glial cell type that insulates axons in the CNS. The name means “cell of a few branches” (oligo- = “few”; dendro- = “branches”; -cyte = “cell”).

Microglia are smaller than most of the other glial cells. Ongoing research into these cells, although not entirely conclusive, suggests that they may originate as white blood cells, called macrophages, that become part of the CNS during early development. Their function is related to what macrophages do in the rest of the body. When macrophages encounter diseased or damaged cells in the rest of the body, they ingest and digest those cells or the pathogens that cause disease. Microglia are the cells in the CNS that can do this in normal, healthy tissue, and they are therefore also referred to as CNS-resident macrophages.

The **ependymal** cell is a glial cell that filters blood to make cerebrospinal fluid (CSF), the fluid that circulates through the CNS. Because of the privileged blood supply inherent in the BBB, the extracellular space in nervous tissue does not easily exchange components with the blood. Ependymal cells line each ventricle, one of four central cavities that are remnants of the hollow center of the neural tube formed during the embryonic development of the brain. They also have cilia on their apical surface to help move the CSF through the ventricular space. The relationship of these glial cells to the structure of the CNS is seen in Figure 16.8.

Glial Cells of the PNS

One of the two types of glial cells found in the PNS is the **satellite** cell. Satellite cells are found in sensory and autonomic ganglia, where they surround the cell bodies of neurons. This accounts for the name, based on their appearance under the microscope. They provide support, performing similar functions in the periphery as astrocytes do in the CNS—except, of course, for establishing the BBB.

The second type of glial cell is the **Schwann** cell, which insulate axons with myelin in the periphery. Schwann cells are different than oligodendrocytes, in that a Schwann cell wraps around a portion of only one axon segment and no others. Oligodendrocytes have processes that reach out to multiple axon segments, whereas the entire Schwann cell surrounds just one axon segment. The nucleus and cytoplasm of the Schwann cell are on the edge of the myelin sheath. The relationship of these two types of glial cells to ganglia and nerves in the PNS is seen in Figure 16.9.

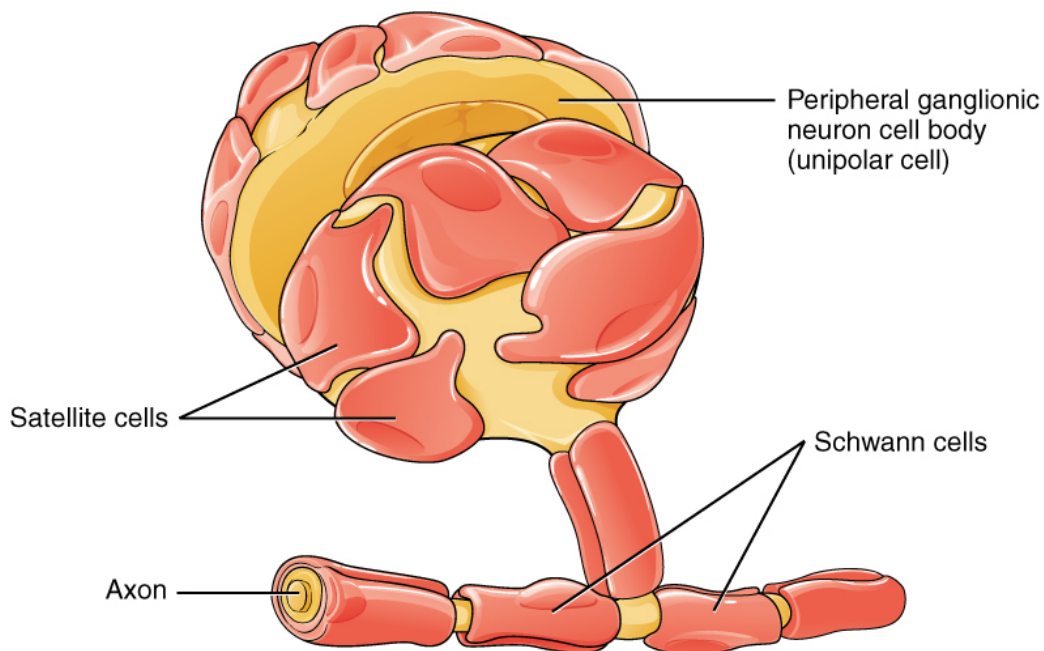


Figure 16.9 Glial Cells of the PNS. The PNS has satellite cells and Schwann cells. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Myelin

The appearance of the myelin sheath can be thought of as similar to the pastry wrapped around a hot dog for “pigs in a blanket” or a similar food. The glial cell is wrapped around the axon several times with little to no cytoplasm between the glial cell layers. For **oligodendrocytes**, the rest of the cell is separate from the myelin sheath as a cell process extends back toward the cell body. A few other processes provide the same insulation for other axon segments in the area. For Schwann cells, the outermost layer of the cell membrane contains cytoplasm and the nucleus of the cell as a bulge on

one side of the myelin sheath. During development, the glial cell is loosely or incompletely wrapped around the axon. The edges of this loose enclosure extend toward each other, and one end tucks under the other. The inner edge wraps around the axon, creating several layers, and the other edge closes around the outside so that the axon is completely enclosed.

Anatomy Labeling Activity



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-110>

Physiology (Function) of the Nervous System

The nervous system is involved in receiving information about the environment around us (sensation) and generating responses to that information (motor responses). The nervous system can be divided into regions that are responsible for sensation (sensory functions) and for the response (motor functions). But there is a third function that needs to be included. Sensory input needs to be integrated with other sensations, as well as with memories, emotional state, or learning (cognition). Some regions of the nervous system are termed integration or association areas. The process of integration combines sensory perceptions and higher cognitive functions such as memories, learning, and emotion to produce a response.

Sensation

The first major function of the nervous system is sensation—receiving information about the environment to gain input about what is happening outside the body (or, sometimes, within the body). The sensory functions of the nervous system register the presence of a change from homeostasis or a particular event in the environment, known as a stimulus. The senses we think of most are the “big five”: taste, smell, touch, sight, and hearing. The stimuli for taste and smell are both chemical substances (molecules, compounds, ions, etc.), touch is physical or mechanical stimuli that interact with the skin, sight is light stimuli, and hearing is the perception of sound, which is a physical stimulus similar to some aspects of touch. There are actually more senses than just those, but that list represents the major senses. Those five are all senses that receive stimuli from the outside world, and of which there is conscious perception. Additional sensory stimuli might

be from the internal environment (inside the body), such as the stretch of an organ wall or the concentration of certain ions in the blood.

Response

The nervous system produces a response on the basis of the stimuli perceived by sensory structures. An obvious response would be the movement of muscles, such as withdrawing a hand from a hot stove, but there are broader uses of the term. The nervous system can cause the contraction of all three types of muscle tissue. For example, skeletal muscle contracts to move the skeleton, cardiac muscle is influenced as heart rate increases during exercise, and smooth muscle contracts as the digestive system moves food along the digestive tract. Responses also include the neural control of glands in the body as well, such as the production and secretion of sweat by the sweat glands found in the skin to lower body temperature.

Responses can be divided into those that are voluntary or conscious (contraction of skeletal muscle) and those that are involuntary (contraction of smooth muscles, regulation of cardiac muscle, activation of glands). Voluntary responses are governed by the somatic nervous system and involuntary responses are governed by the autonomic nervous system, which are discussed in the next section.

Integration

Stimuli that are received by sensory structures are communicated to the nervous system where that information is processed. This is called integration. Stimuli are compared with, or integrated with, other stimuli, memories of previous stimuli, or the state of a person at a particular time. This leads to the specific response that will be generated. Seeing a baseball pitched to a batter will not automatically cause the batter to swing. The trajectory of the ball and its speed will need to be considered. Maybe the count is three balls and one strike, and the batter wants to let this pitch go by in the hope of getting a walk to first base. Or maybe the batter's team is so far ahead, it would be fun to just swing away.

Controlling the Body

The nervous system can be divided into two parts mostly on the basis of a functional difference in responses. The **somatic nervous system (SNS)** is responsible for conscious perception and voluntary motor responses. Voluntary motor response means the contraction of skeletal muscle, but those contractions are not always voluntary in the sense that you have to want to perform them. Some somatic motor responses are reflexes, and often happen without a conscious decision to perform them. If your friend jumps out from behind a corner and yells "Boo!" you will be startled and you might scream or leap back. You didn't decide to do that, and you may not have wanted to give your friend a reason to laugh at your expense, but it is a reflex involving skeletal muscle contractions. Other motor responses become automatic (in other words, unconscious) as a person learns motor skills (referred to as "habit learning" or "procedural memory").

The **autonomic nervous system (ANS)** is responsible for involuntary control of the body, usually for the sake of homeostasis (regulation of the internal environment). Sensory input for autonomic functions can be from sensory structures tuned to external or internal environmental stimuli. The motor output extends to smooth and cardiac muscle as well as glandular tissue. The role of the autonomic system is to regulate the organ systems of the body, which usually means to control homeostasis. Sweat glands, for example, are controlled by the autonomic system. When you are hot,

sweating helps cool your body down. That is a homeostatic mechanism. But when you are nervous, you might start sweating also. That is not homeostatic, it is the physiological response to an emotional state.

There is another division of the nervous system that describes functional responses. The **enteric nervous system (ENS)** is responsible for controlling the smooth muscle and glandular tissue in your digestive system. It is a large part of the PNS, and is not dependent on the CNS. It is sometimes valid, however, to consider the enteric system to be a part of the autonomic system because the neural structures that make up the enteric system are a component of the autonomic output that regulates digestion. There are some differences between the two, but for our purposes here there will be a good bit of overlap. See Figure 16.10 for examples of where these divisions of the nervous system can be found.

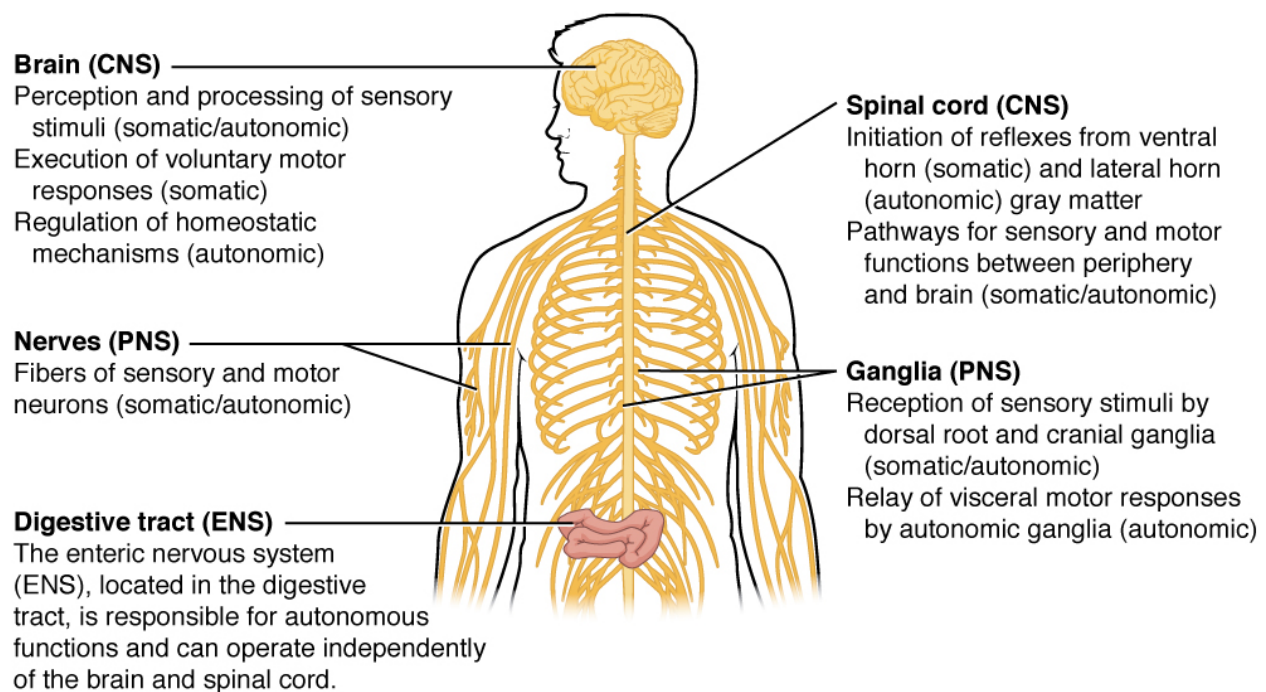


Figure 16.10 Somatic, Autonomic, and Enteric Structures of the Nervous System. Somatic structures include the spinal nerves, both motor and sensory fibers, as well as the sensory ganglia (posterior root ganglia and cranial nerve ganglia). Autonomic structures are found in the nerves also, but include the sympathetic and parasympathetic ganglia. The enteric nervous system includes the nervous tissue within the organs of the digestive tract. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Functions of the Cerebral Cortex

The cerebrum is the seat of many of the higher mental functions, such as memory and learning, language, and conscious perception, which are the subjects of subtests of the **mental status** exam. The cerebral cortex is the thin layer of gray matter on the outside of the cerebrum. It is approximately a millimeter thick in most regions and highly folded to fit within the limited space of the cranial vault. These higher functions are distributed across various regions of the cortex, and specific locations can be said to be responsible for particular functions. There is a limited set of regions, for example, that are involved in language function, and they can be subdivided on the basis of the particular part of language function that each governs.

Cognitive Abilities

Assessment of cerebral functions is directed at cognitive abilities. The abilities assessed through the mental status exam can be separated into four groups: orientation and memory, language and speech, sensorium, and judgment and abstract reasoning.

Orientation and Memory

Orientation is the patient's awareness of his or her immediate circumstances. It is awareness of time, not in terms of the clock, but of the date and what is occurring around the patient. It is awareness of place, such that a patient should know where he or she is and why. It is also awareness of who the patient is—recognizing personal identity and being able to relate that to the examiner. The initial tests of orientation are based on the questions, “Do you know what the date is?” or “Do you know where you are?” or “What is your name?” Further understanding of a patient's awareness of orientation can come from questions that address remote memory, such as “Who is the President of the United States?”, or asking what happened on a specific date.

Memory is largely a function of the temporal lobe, along with structures beneath the cerebral cortex such as the hippocampus and the amygdala. The storage of memory requires these structures of the medial temporal lobe. A famous case of a man who had both medial temporal lobes removed to treat intractable epilepsy provided insight into the relationship between the structures of the brain and the function of memory.

The prefrontal cortex can also be tested for the ability to organize information. In one subtest of the mental status exam called set generation, the patient is asked to generate a list of words that all start with the same letter, but not to include proper nouns or names. The expectation is that a person can generate such a list of at least 10 words within 1 minute. Many people can likely do this much more quickly, but the standard separates the accepted normal from those with compromised prefrontal cortices.

Read this [article](#) to learn about a young man who texts his fiancée in a panic as he finds that he is having trouble remembering things. At the hospital, a neurologist administers the mental status exam, which is mostly normal except for the three-word recall test. The young man could not recall them even 30 seconds after hearing them and repeating them back to the doctor. An undiscovered mass in the mediastinum region was found to be Hodgkin's lymphoma, a type of cancer that affects the immune system and likely caused antibodies to attack the nervous system. The patient eventually regained his ability to remember, though the events in the hospital were always elusive. Considering that the effects on memory were temporary, but resulted in the loss of the specific events of the hospital stay, what regions of the brain were likely to have been affected by the antibodies and what type of memory does that represent?

Language and Speech

Language is, arguably, a very human aspect of neurological function. There are certainly strides being made in understanding communication in other species, but much of what makes the human experience seemingly unique is its basis in language. Any understanding of our species is necessarily reflective, as suggested by the question “What am I?” And the fundamental answer to this question is suggested by the famous quote by René Descartes: “Cogito Ergo Sum” (translated from Latin as “I think, therefore I am”). Formulating an understanding of yourself is largely describing who you are to yourself. It is a confusing topic to delve into, but language is certainly at the core of what it means to be self-aware.

The neurological exam has two specific subtests that address language. One measures the ability of the patient to understand language by asking them to follow a set of instructions to perform an action, such as “touch your right finger to your left elbow and then to your right knee.” Another subtest assesses the fluency and coherency of language by having the patient generate descriptions of objects or scenes depicted in drawings, and by reciting sentences or explaining a written passage.

An important example of multimodal integrative areas is associated with language function (see Figure 16.11). Adjacent to the auditory association cortex, at the end of the lateral sulcus just anterior to the visual cortex, is **Wernicke’s area**. In the lateral aspect of the frontal lobe, just anterior to the region of the motor cortex associated with the head and neck, is Broca’s area. Both regions were originally described on the basis of losses of speech and language, which is called **aphasia**. The aphasia associated with Broca’s area is known as an **expressive aphasia**, which means that speech production is compromised. This type of aphasia is often described as non-fluency because the ability to say some words leads to broken or halting speech. Grammar can also appear to be lost. The aphasia associated with Wernicke’s area is known as a **receptive aphasia**, which is not a loss of speech production, but a loss of understanding of content. Patients, after recovering from acute forms of this aphasia, report not being able to understand what is said to them or what they are saying themselves, but they often cannot keep from talking.

The two regions are connected by white matter tracts that run between the posterior temporal lobe and the lateral aspect of the frontal lobe. **Conduction aphasia** associated with damage to this connection refers to the problem of connecting the understanding of language to the production of speech. This is a very rare condition, but is likely to present as an inability to faithfully repeat spoken language.

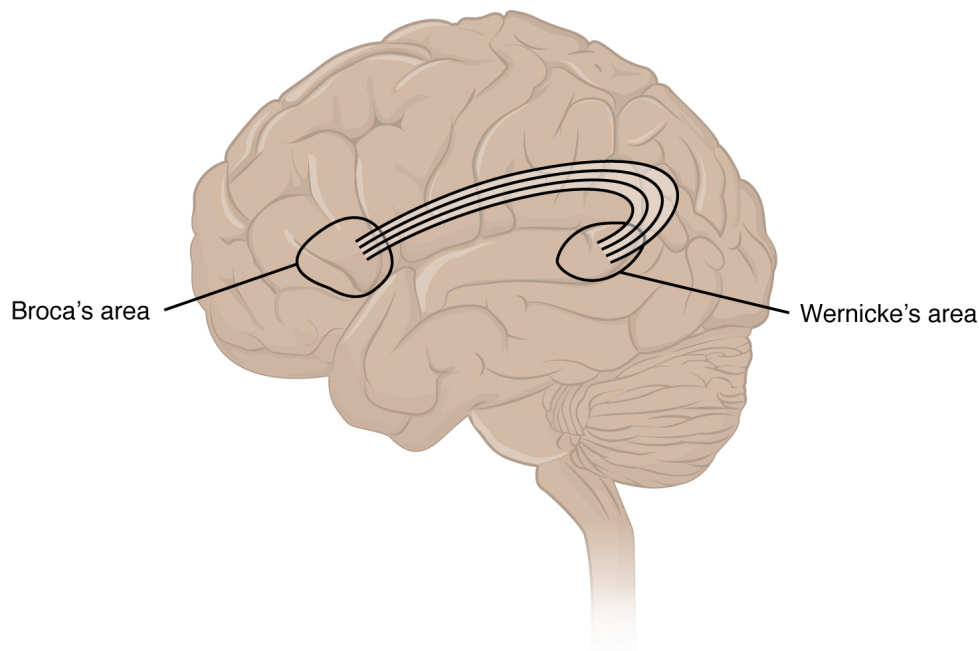


Figure 16.11 Broca’s and Wernicke’s Areas. Two important integration areas of the cerebral cortex associated with language function are Broca’s and Wernicke’s areas. The two areas are connected through the deep white matter running from the posterior temporal lobe to the frontal lobe. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Sensorium

Those parts of the brain involved in the reception and interpretation of sensory stimuli are referred to collectively as the sensorium. The cerebral cortex has several regions that are necessary for sensory perception. Several of the subtests can reveal activity associated with these sensory modalities, such as being able to hear a question or see a picture. Two subtests assess specific functions of these cortical areas.

The first is **praxis**, a practical exercise in which the patient performs a task completely on the basis of verbal description without any demonstration from the examiner. The second subtest for sensory perception is **gnosis**, which involves two tasks. The first task, known as **stereognosis**, involves the naming of objects strictly on the basis of the somatosensory information that comes from manipulating them. The patient keeps their eyes closed and is given a common object, such as a coin, that they have to identify. The patient should be able to indicate the particular type of coin, such as a dime versus a penny, or a nickel versus a quarter, on the basis of the sensory cues involved. For example, the size, thickness, or weight of the coin may be an indication, or to differentiate the pairs of coins suggested here, the smooth or corrugated edge of the coin will correspond to the particular denomination. The second task, **graphesthesia**, is to recognize numbers or letters written on the palm of the hand with a dull pointer, such as a pen cap.

Judgment and Abstract Reasoning

Planning and producing responses requires an ability to make sense of the world around us. Making judgments and reasoning in the abstract are necessary to produce movements as part of larger responses. For example, when your alarm goes off, do you hit the snooze button or jump out of bed? Is 10 extra minutes in bed worth the extra rush to get ready for your day? Will hitting the snooze button multiple times lead to feeling more rested or result in a panic as you run late? How you mentally process these questions can affect your whole day.

The prefrontal cortex is responsible for the functions responsible for planning and making decisions. In the mental status exam, the subtest that assesses judgment and reasoning is directed at three aspects of frontal lobe function. First, the examiner asks questions about problem solving, such as “If you see a house on fire, what would you do?” The patient is also asked to interpret common proverbs, such as “Don’t look a gift horse in the mouth.” Additionally, pairs of words are compared for similarities, such as apple and orange, or lamp and cabinet.

Everyday Connections

Left Brain, Right Brain

Popular media often refer to right-brained and left-brained people, as if the brain were two independent halves that work differently for different people. This is a popular misinterpretation of an important neurological phenomenon. As an extreme measure to deal with a debilitating condition, the corpus callosum may be sectioned to overcome intractable epilepsy. When the connections between the two cerebral hemispheres are cut, interesting effects can be observed.

The reason for this is that the language functions of the cerebral cortex are localized to the left hemisphere in 95 percent of the population. Additionally, the left hemisphere is connected to the right side of the body through the corticospinal tract and the ascending tracts of the spinal cord. Motor commands from the precentral gyrus control the opposite side of the body, whereas sensory information processed by the postcentral gyrus is received from the opposite

side of the body. For a verbal command to initiate movement of the right arm and hand, the left side of the brain needs to be connected by the corpus callosum. Language is processed in the left side of the brain and directly influences the left brain and right arm motor functions, but is sent to influence the right brain and left arm motor functions through the corpus callosum. Likewise, the left-handed sensory perception of what is in the left pocket travels across the corpus callosum from the right brain, so no verbal report on those contents would be possible if the hand happened to be in the pocket.

People who have had their corpus callosum cut can perform two independent tasks at the same time because the lines of communication between the right and left sides of his brain have been removed. Whereas a person with an intact corpus callosum cannot overcome the dominance of one hemisphere over the other, this patient can. If the left cerebral hemisphere is dominant in the majority of people, why would right-handedness be most common?

Common Nervous System Abbreviations



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-111>

Disease and Disorders

Neurodegenerative Diseases – Alzheimer’s Disease, Parkinson’s Disease, Amyotrophic Lateral Sclerosis (ALS) , Multiple sclerosis (MS)

A class of disorders that affect the nervous system are the neurodegenerative diseases: Alzheimer’s disease, Parkinson’s disease, Huntington’s disease, amyotrophic lateral sclerosis (ALS), Creutzfeldt–Jacob disease, multiple sclerosis (MS), and other disorders that are the result of nervous tissue degeneration. In diseases like Alzheimer’s, Parkinson’s, or ALS, neurons die; in diseases like MS, myelin is affected. Some of these disorders affect motor function, and others present with dementia. Some are the result of genetics, such as Huntington’s disease, or the result of autoimmunity, such as MS; others are not entirely understood, such as Alzheimer’s and Parkinson’s diseases.

Several diseases can result from the demyelination of axons. The causes of these diseases are not the same; some have genetic causes, some are caused by pathogens, and others are the result of autoimmune disorders. Though the causes are varied, the results are largely similar. The myelin insulation of axons is compromised, making electrical signaling slower (Betts, et al., 2021).

Multiple sclerosis (MS) is one such disease. It is an example of an autoimmune disease. The antibodies produced by lymphocytes (a type of white blood cell) mark myelin as something that should not be in the body. This causes inflammation and the destruction of the myelin in the central nervous system. As the insulation around the axons is destroyed by the disease, scarring becomes obvious (Betts, et al., 2021).

Guillain-Barre (pronounced gee-YAN bah-RAY) syndrome is an example of a demyelinating disease of the peripheral nervous system. It is also the result of an autoimmune reaction, but the inflammation is in peripheral nerves. Sensory

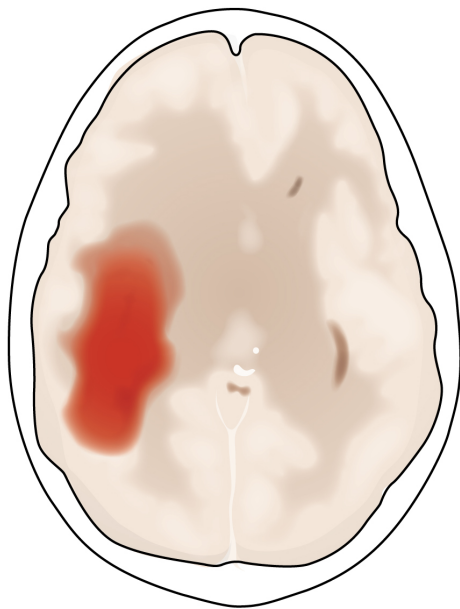
symptoms or motor deficits are common, and autonomic failures can lead to changes in the heart rhythm or a drop in blood pressure, especially when standing, which causes dizziness (Betts, et al., 2021).

Other Nerve Disorders

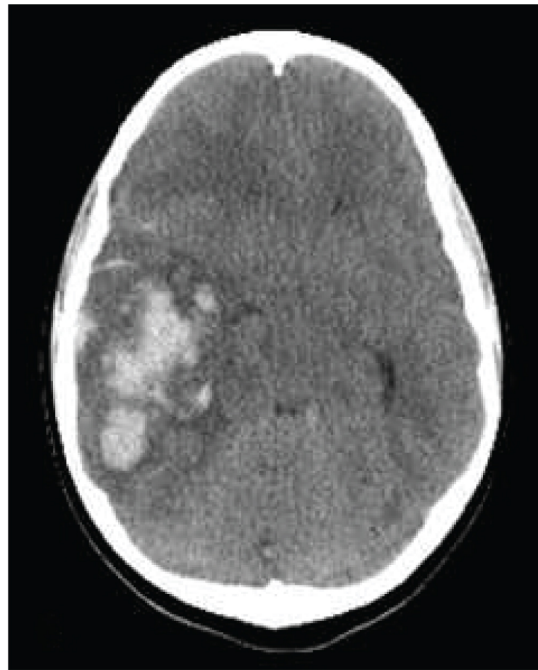
Infection, trauma, and congenital disorders can all lead to significant signs, as identified through the neurological exam. It is important to differentiate between an acute event, such as stroke, and a chronic or global condition such as blunt force trauma. Responses seen in the neurological exam can help. A loss of language function observed in all its aspects is more likely a global event as opposed to a discrete loss of one function, such as not being able to say certain types of words. A concern, however, is that a specific function—such as controlling the muscles of speech—may mask other language functions. The various subtests within the mental status exam can address these finer points and help clarify the underlying cause of the neurological loss (Betts, et al., 2021).

Stroke

Damage to the nervous system can be limited to individual structures or can be distributed across broad areas of the brain and spinal cord. Localized, limited injury to the nervous system is most often the result of circulatory problems. The loss of blood flow to part of the brain is known as a **stroke**, or a cerebrovascular accident (CVA). There are two main types of stroke, depending on how the blood supply is compromised: ischemic and hemorrhagic. An **ischemic stroke** is the loss of blood flow to an area because vessels are blocked or narrowed. This is often caused by an embolus, which may be a blood clot or fat deposit. Ischemia may also be the result of thickening of the blood vessel wall, or a drop in blood volume in the brain known as **hypovolemia**. A **hemorrhagic stroke** is bleeding into the brain because of a damaged blood vessel. Accumulated blood fills a region of the cranial vault and presses against the tissue in the brain (see Figure 16.12) (Betts, et al., 2021).



(a)



(b)

Figure 16.12 Hemorrhagic Stroke. (a) A hemorrhage into the tissue of the cerebrum results in a large accumulation of blood with an additional edema in the adjacent tissue. The hemorrhagic area causes the entire brain to be disfigured as suggested here by the lateral ventricles being squeezed into the opposite hemisphere. (b) A CT scan shows an intraparenchymal hemorrhage within the parietal lobe. (credit b: James Heilman). From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Cerebral Palsy

Cerebral Palsy (CP) is caused by an interruption to the normal development of a person's brain leading to weakness with muscles. Depending on the area of the brain that is affected, signs and symptoms will vary in the type and severity between individuals. Balance and coordination are often challenging due the inability to control muscles (Centers for Disease Control and Prevention, 2019). To learn more about cerebral palsy please visit the [Centers for Disease Control and Prevention's web page on cerebral palsy](https://www.cdc.gov/ncbddd/cp/).

Traumatic Brain Injury (TBI)

According to the Centers for Disease Control and Prevention, approximately 61,000 Americans die each year due to causes related to traumatic brain injuries. Brain injuries range from moderate to severe and include concussions. TBI can be caused by falls, automobile accidents, sports, assaults and strokes. Investment has been made to educate people on how to prevent TBIs with a focus on concussions from sports (Centers for Disease Control and Prevention, 2021).

Medical Terms in Context



An interactive H5P element has been excluded from this version of the text. You can view it online here:
<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-112>



An interactive H5P element has been excluded from this version of the text. You can view it online here:
<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-113>



An interactive H5P element has been excluded from this version of the text. You can view it online here:
<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-114>

Medical Specialties

Primary Specialist – Neurologist

Neurologists are medical doctors who complete an additional specialized training in the prevention, diagnosis, and treatment of disorders and conditions related to the brain, spinal cord, nerves and muscles (American Academy of Neurology, 2021). For more details visit the [American Academy of Neurology's webpage](#).

Procedures Related to the Nervous System

Lumbar Puncture (Spinal Tap)

A neurologist may order this procedure to test cerebrospinal fluid (CSF). This procedure is recommended if they believe symptoms are caused by a problem in the nervous system that can be detected in the cerebrospinal fluid. The procedure involves inserting a needle into the spine after numbing it and taking a sample of cerebrospinal fluid (Mayo Clinic, 2020).

Tensilon Test

This procedure can help a neurologist diagnose myasthenia gravis. In this test, the doctor injects with a medicine called

Tensilon. Then they observe how it affects muscle movements (Bergen, 2018). For more information visit [Healthline's Tensilon Test web page](#).

Electromyography (EMG)

An EMG measures electrical activity between your brain or spinal cord to a peripheral nerve. This nerve is found in your arms and legs, and is responsible for muscle control during times of movement and rest. EMGs can help your neurologist diagnose spinal cord disease as well as general muscle or nerve dysfunction (Moore & Cirino, 2018).

Electroencephalogram (EEG)

With electrodes applied to your scalp, an EEG measures electrical activity in the brain. It's used to help diagnose conditions of the brain, including inflammation, tumors, and injuries, as well as seizures and psychiatric disorders.

Test Yourself



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=181#h5p-115>

References

- American Academy of Neurology. (2021). *What is a neurologist?* <https://www.aan.com/tools-and-resources/medical-students/careers-in-neurology/what-is-a-neurologist/>
- Bergen, T. (2018). *Tensilon test*. Healthline. <https://www.healthline.com/health/tensilon-test>
- Centers for Disease Control and Prevention. (2018). *Mental health*. CDC. <https://www.cdc.gov/mentalhealth/learn/index.htm>
- Centers for Disease Control and Prevention. (2019). *TBI: Get the facts*. CDC. https://www.cdc.gov/traumaticbraininjury/get_the_facts.html
- Centers for Disease Control and Prevention. (2020). *Cerebral palsy (CP)*. CDC. <https://www.cdc.gov/dotw/cerebral-palsy/>
- Cherney, K. & De Pietro, M. (2019). *Neurologist*. Healthline. <https://www.healthline.com/find-care/articles/neurologists/neurologist>
- [CrashCourse]. (2015, February 23). *The nervous system, part 1: Crash course A&P #8* [Video]. YouTube. https://www.youtube.com/watch?v=qPix_X-9t7E

Mayo Clinic. (2020). Lumbar puncture (spinal tap). <https://www.mayoclinic.org/tests-procedures/lumbar-puncture/about/pac-20394631>

Merriam-Webster. (n.d.). Neurologist. In Merriam-Webster.com dictionary. <https://www.merriam-webster.com/dictionary/neurologist>

Moores, D., & Cirino, E. (2018). *Electromyography (EMG)*. Healthline. <https://www.healthline.com/health/electromyography>

Unless otherwise indicated, this chapter contains material adapted from *Anatomy and Physiology* (on [OpenStax](#)), by Betts, et al. and is used under a [CC BY 4.0 international license](#). Download and access this book for free at <https://openstax.org/books/anatomy-and-physiology/pages/1-introduction>.

17. Endocrine System

WTCS Learning Objectives

- Apply the rules of medical language to build, analyze, spell, pronounce, abbreviate, and define terms as they relate to the endocrine system
- Identify meanings of key word components of the endocrine system
- Categorize diagnostic, therapeutic, procedural or anatomic terms related to the endocrine system
- Use terms related to the endocrine system
- Use terms related to the diseases and disorders of the endocrine system

Endocrine System Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the Endocrine System.



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#h5p-116>

Introduction to Endocrine System



Figure 17.1 A Child Catches a Falling Leaf. Hormones of the endocrine system coordinate and control growth, metabolism, temperature regulation, the stress response, reproduction, and many other functions. (credit: "seenthroughmylense"/flickr.com). From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

You may never have thought of it this way, but when you send a text message to two friends to meet you for dinner at six, you're sending digital signals that (you hope) will affect their behavior—even though they are some distance away. Similarly, certain cells send chemical signals to other cells in the body that influence their behavior. This long-distance intercellular communication, coordination, and control is critical to maintain equilibrium (homeostasis). This intercellular activity is the fundamental function of the endocrine system.

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#oembed-1>

Media 17.1 [Endocrine System, Part 1 – Glands & Hormones: Crash Course A&P #23](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Endocrine System Medical Terms



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#h5p-117>

Anatomy (Structure) of the Endocrine System

Did You Know?

The pancreas acts as an endocrine and exocrine gland.

The endocrine system consists of cells, tissues, and organs that secrete hormones as a primary or secondary function. The **endocrine gland** is the major player in this system. The primary function of the endocrine gland is to secrete hormones directly into the surrounding fluid. The surrounding fluid (interstitial fluid) and the blood vessels then transport the hormones throughout the body. The endocrine system includes the pituitary, thyroid, parathyroid, adrenal, and pineal glands (see Figure 17.2). Some of these glands have both endocrine and non-endocrine functions. For example, the pancreas contains cells that function in digestion as well as cells that secrete the endocrine hormones like insulin and glucagon, which regulate blood glucose levels. The hypothalamus, thymus, heart, kidneys, stomach, small intestine, liver, skin, female ovaries, and male testes are other organs that contain cells with endocrine function. Moreover, fat (adipose) tissue has long been known to produce hormones, and recent research has revealed that even bone tissue has endocrine functions.

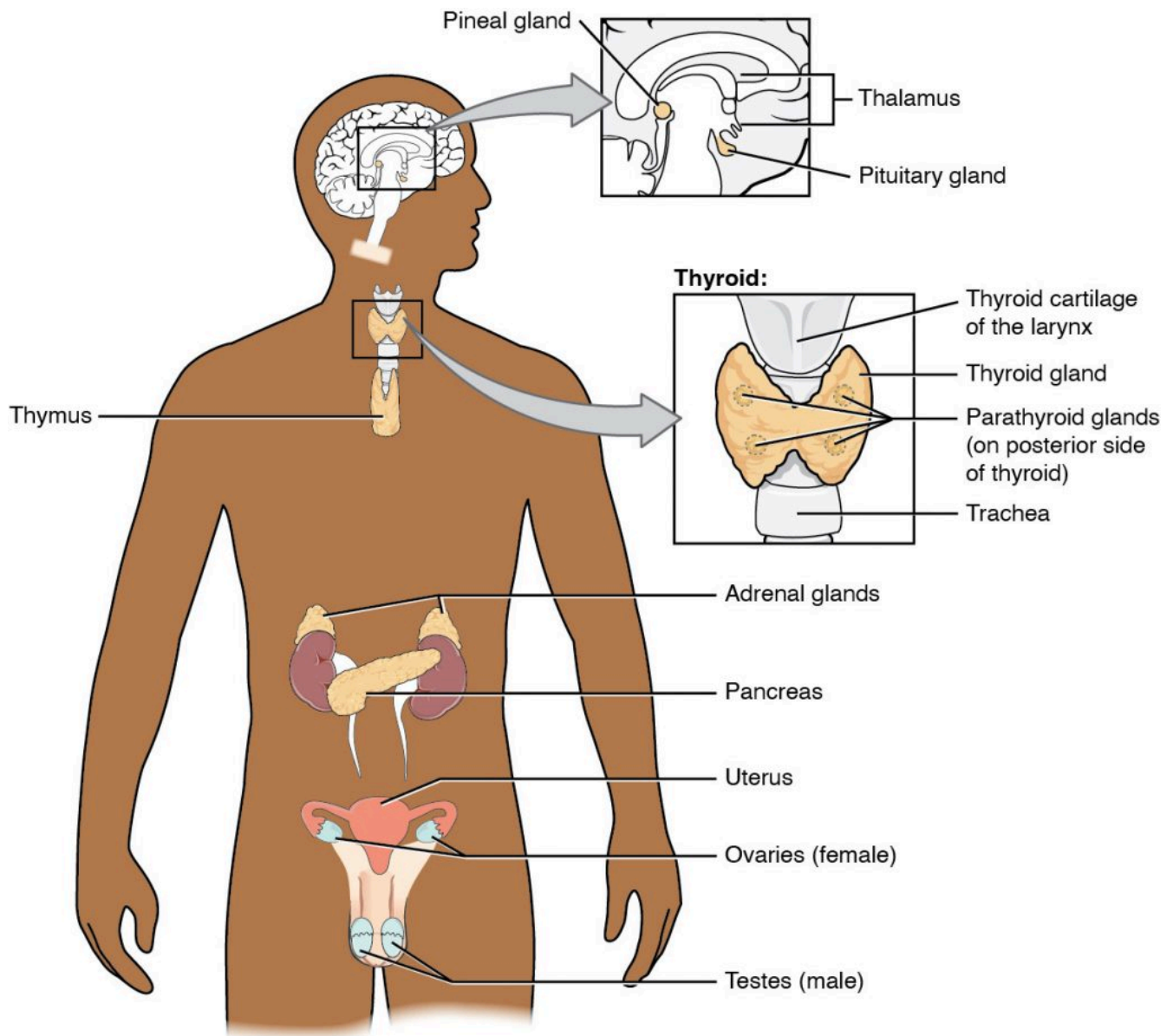


Figure 17.2 Endocrine System. Endocrine glands and cells are located throughout the body and play an important role in maintaining equilibrium (homeostasis). From Betts, et al., 2021. Licensed under CC BY 4.0.

The ductless endocrine glands are not to be confused with the body's **exocrine system**, whose glands release their secretions through ducts. Examples of exocrine glands include the sebaceous and sweat glands of the skin. As just noted, the pancreas also has an exocrine function: most of its cells secrete pancreatic juice through the pancreatic and accessory ducts to the lumen of the small intestine.

Anatomy Labeling Activity



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#h5p-118>

Physiology (Function) of the Endocrine System

Endocrine Signaling

The **endocrine system** uses one method of communication called chemical signaling. These chemical signals are sent by the endocrine organs. The endocrine organs secrete chemicals—called **hormones**—into the fluid outside of the tissue cells (extracellular fluid). Hormones are then transported primarily via the bloodstream throughout the body, where they bind to receptors on target cells, creating a particular response. For example, the hormones released when you are presented with a dangerous or a frightening situation, called the fight-or-flight response, occurs through the release of hormones from the adrenal gland, **epinephrine** and **norepinephrine**—within seconds. In contrast, it may take up to 48 hours for target cells to respond to certain reproductive hormones.

In addition, endocrine signaling is typically less specific than neural (nerve) signaling. The same hormone may also play a role in a variety of different physiological processes depending on the target cells involved. For example, the hormone oxytocin generates uterine contractions in women who are in labor. This hormone is also important in generating the milk release reflex during breastfeeding, and may be involved in the sexual response and in feelings of emotional attachment in both males and females.

Generally, the nervous system involves quick responses to rapid changes in the external environment, and the endocrine system is usually slower acting—taking care of the internal environment of the body, maintaining equilibrium (homeostasis), and in controlling reproduction (see Table 17.1). So how does the fight-or-flight response, that was mentioned earlier, happen so quickly if hormones are usually slower acting? It is because the two systems are connected. It is the fast action of the nervous system in response to the danger in the environment that stimulates the adrenal glands to secrete their hormones, epinephrine and norepinephrine. As a result, the nervous system can cause rapid endocrine responses to keep up with sudden changes in both the external and internal environments, when necessary.

Table 17.1: Endocrine and Nervous Systems. From Betts, et al., 2021. Licensed under CC BY 4.0.

Characteristic	Endocrine System	Nervous System
Signaling mechanism(s)	Chemical	Chemical/electrical
Primary chemical signal	Hormones	Neurotransmitters
Distance traveled	Long or short	Always short
Response time	Fast or slow	Always fast
Environment targeted	Internal	Internal and external

Hormones

Although a given hormone may travel throughout the body in the bloodstream, it will affect the activity only of its target cells; that is, cells with receptors for that particular hormone. Once the hormone binds to the receptor, a chain of events is initiated that leads to the target cell's response. Hormones play a critical role in the regulation of physiological processes because of the target cell responses they regulate. These responses contribute to human reproduction, growth and development of body tissues, metabolism, fluid, and electrolyte balance, sleep, and many other body functions. The major hormones of the human body and their effects are identified in Table 17.2.

Table 17.2: Endocrine Glands and Their Major Hormones. From Betts, et al., 2021. Licensed under CC BY 4.0.

Endocrine Gland	Associated Hormones	Chemical Class	Effect
Pituitary (anterior)	Growth hormone (GH)	Protein	Promotes growth of body tissues
Pituitary (anterior)	Prolactin (PRL)	Peptide	Promotes milk production
Pituitary (anterior)	Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid hormone release
Pituitary (anterior)	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates hormone release by adrenal cortex
Pituitary (anterior)	Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates gamete production
Pituitary (anterior)	Luteinizing hormone (LH)	Glycoprotein	Stimulates androgen production by gonads
Pituitary (posterior)	Antidiuretic hormone (ADH)	Peptide	Stimulates water reabsorption by kidneys
Pituitary (posterior)	Oxytocin	Peptide	Stimulates uterine contractions during childbirth
Thyroid	Thyroxine (T ₄), triiodothyronine (T ₃)	Amine	Stimulate basal metabolic rate
Thyroid	Calcitonin	Peptide	Reduces blood Ca ²⁺ levels
Parathyroid	Parathyroid hormone (PTH)	Peptide	Increases blood Ca ²⁺ levels
Adrenal (cortex)	Aldosterone	Steroid	Increases blood Na ⁺ levels
Adrenal (cortex)	Cortisol, corticosterone, cortisone	Steroid	Increase blood glucose levels
Adrenal (medulla)	Epinephrine, norepinephrine	Amine	Stimulate fight-or-flight response
Pineal	Melatonin	Amine	Regulates sleep cycles
Pancreas	Insulin	Protein	Reduces blood glucose levels
Pancreas	Glucagon	Protein	Increases blood glucose levels
Testes	Testosterone	Steroid	Stimulates development of male secondary sex characteristics and sperm production
Ovaries	Estrogens and progesterone	Steroid	Stimulate development of female secondary sex characteristics and prepare the body for childbirth

Types of Hormones

The hormones of the human body can be divided into two major groups on the basis of their chemical structure. Hormones derived from amino acids include amines, peptides, and proteins. Those derived from lipids include steroids. These chemical groups affect a hormone's distribution, the type of receptors it binds to, and other aspects of its function.

Amine Hormones

Hormones derived from the modification of amino acids are referred to as amine hormones. Amine hormones are synthesized from the amino acids tryptophan or tyrosine. An example of a hormone derived from tryptophan is melatonin, which is secreted by the pineal gland and helps regulate circadian rhythm.

Peptide and Protein Hormones

Whereas the amine hormones are derived from a single amino acid, peptide and protein hormones consist of multiple amino acids that link to form an amino acid chain. Examples of peptide hormones include antidiuretic hormone (ADH), a pituitary hormone important in fluid balance. Some examples of protein hormones include growth hormone, which is produced by the pituitary gland, and follicle-stimulating hormone (FSH). FSH helps stimulate the maturation of eggs in the ovaries and sperm in the testes.

Steroid Hormones

The primary hormones derived from lipids are steroids. Steroid hormones are derived from the lipid cholesterol. For example, the reproductive hormones testosterone and the estrogens—which are produced by the gonads (testes and ovaries)—are steroid hormones. The adrenal glands produce the steroid hormone aldosterone, which is involved in osmoregulation, and cortisol, which plays a role in metabolism.

Like cholesterol, steroid hormones are not soluble in water (they are hydrophobic). Because blood is water-based, lipid-derived hormones must travel to their target cell bound to a transport protein.

Did You Know?

Researchers say that one week of camping without electronics resets our biological body clock

Pathways of Hormone Action

The message a hormone sends is received by a **hormone receptor**, a protein located either inside the cell or within the cell membrane. The receptor will process the message by initiating other signaling events or cellular mechanisms that result in the target cell's response. Hormone receptors recognize molecules with specific shapes and side groups, and respond only to those hormones that are recognized. The same type of receptor may be located on cells in different body tissues, and trigger somewhat different responses. Thus, the response triggered by a hormone depends not only on the hormone, but also on the target cell.

Once the target cell receives the hormone signal, it can respond in a variety of ways. The response may include the stimulation of protein **synthesis**, activation or deactivation of enzymes, alteration in the **permeability** of the cell membrane, altered

rates of mitosis and cell growth, and stimulation of the secretion of products. Moreover, a single hormone may be capable of inducing different responses in a given cell.

and synchronizes our melatonin hormones with sunrise and sunset. (Shurkin, 2013).

Factors Affecting Target Cell Response

You will recall that target cells must have receptors specific to a given hormone if that hormone is to trigger a response. But several other factors influence the target cell response. For example, the presence of a significant level of a hormone circulating in the bloodstream can cause its target cells to decrease their number of receptors for that hormone. This process is called **downregulation**, and it allows cells to become less reactive to the excessive hormone levels. When the level of a hormone is chronically reduced, target cells engage in **upregulation** to increase their number of receptors. This process allows cells to be more sensitive to the hormone that is present. Cells can also alter the sensitivity of the receptors themselves to various hormones.

Two or more hormones can interact to affect the response of cells in a variety of ways. The three most common types of interaction are as follows:

- The permissive effect, in which the presence of one hormone enables another hormone to act. For example, thyroid hormones have complex permissive relationships with certain reproductive hormones. A dietary deficiency of iodine, a component of thyroid hormones, can therefore affect reproductive system development and functioning.
- The synergistic effect, in which two hormones with similar effects produce an amplified response. In some cases, two hormones are required for an adequate response. For example, two different reproductive hormones—FSH from the pituitary gland and estrogens from the ovaries—are required for the maturation of female ova (egg cells).
- The antagonistic effect, in which two hormones have opposing effects. A familiar example is the effect of two pancreatic hormones, insulin and glucagon. Insulin increases the liver's storage of glucose as glycogen, decreasing blood glucose, whereas glucagon stimulates the breakdown of glycogen stores, increasing blood glucose.

Concept Check

- Describe how a hormone receptor functions and reacts to messages received.

Regulation of Hormone Secretion

To prevent abnormal hormone levels and a potential disease state, hormone levels must be tightly controlled. The body maintains this control by balancing hormone production and degradation. Feedback loops govern the initiation and maintenance of most hormone secretion in response to various stimuli.

Role of Feedback Loops

The contribution of feedback loops to homeostasis will only be briefly reviewed here. Positive feedback loops are characterized by the release of additional hormone in response to an original hormone release. The release of oxytocin during childbirth is a positive feedback loop. The initial release of oxytocin begins to signal the uterine muscles to contract, which pushes the fetus toward the cervix, causing it to stretch. This, in turn, signals the pituitary gland to release more oxytocin, causing labor contractions to intensify. The release of oxytocin decreases after the birth of the child.

The more common method of hormone regulation is the negative feedback loop. Negative feedback is characterized by the inhibition of further secretion of a hormone in response to adequate levels of that hormone. This allows blood levels of the hormone to be regulated within a narrow range. An example of a negative feedback loop is the release of glucocorticoid hormones from the adrenal glands, as directed by the hypothalamus and pituitary gland. As glucocorticoid concentrations in the blood rise, the hypothalamus and pituitary gland reduce their signaling to the adrenal glands to prevent additional glucocorticoid secretion (see Figure 17.3).

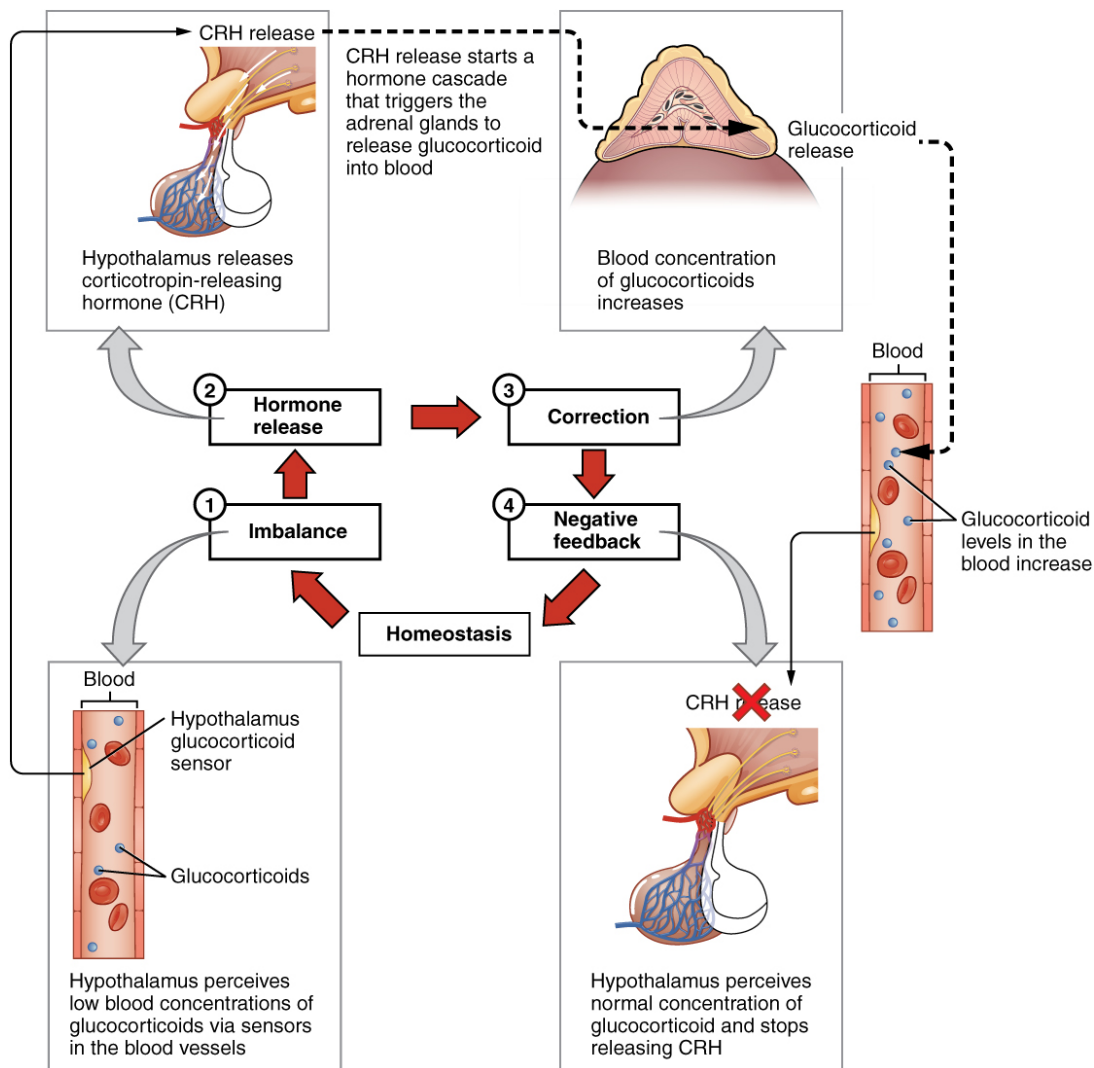


Figure 17.3 Negative Feedback Loop. The release of adrenal glucocorticoids is stimulated by the release of hormones from the hypothalamus and pituitary gland. This signaling is inhibited when glucocorticoid levels become elevated by causing negative signals to the pituitary gland and hypothalamus. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Anterior Pituitary Gland

Recall that the posterior pituitary does not synthesize hormones, but merely stores them. In contrast, the anterior pituitary does manufacture hormones. However, the secretion of hormones from the anterior pituitary is regulated by two classes of hormones. These hormones—secreted by the hypothalamus—are the releasing hormones that stimulate the secretion of hormones from the anterior pituitary and the inhibiting hormones that inhibit secretion.

Hypothalamic hormones are secreted by neurons, but enter the anterior pituitary through blood vessels.

The anterior pituitary produces seven hormones. These are the growth hormone (GH), thyroid-stimulating hormone (TSH), adrenocorticotropic hormone (ACTH), follicle-stimulating hormone (FSH), luteinizing hormone (LH), beta endorphin, and prolactin. Of the hormones of the anterior pituitary, TSH, ACTH, FSH, and LH are collectively referred to as tropic hormones (trope- = “turning”) because they turn on or off the function of other endocrine glands.

Growth Hormone

The endocrine system regulates the growth of the human body, protein synthesis, and cellular replication. A major hormone involved in this process is **growth hormone (GH)**, also called somatotropin—a protein hormone produced and secreted by the anterior pituitary gland. Its primary function is anabolic; it promotes protein synthesis and tissue building through direct and indirect mechanisms.

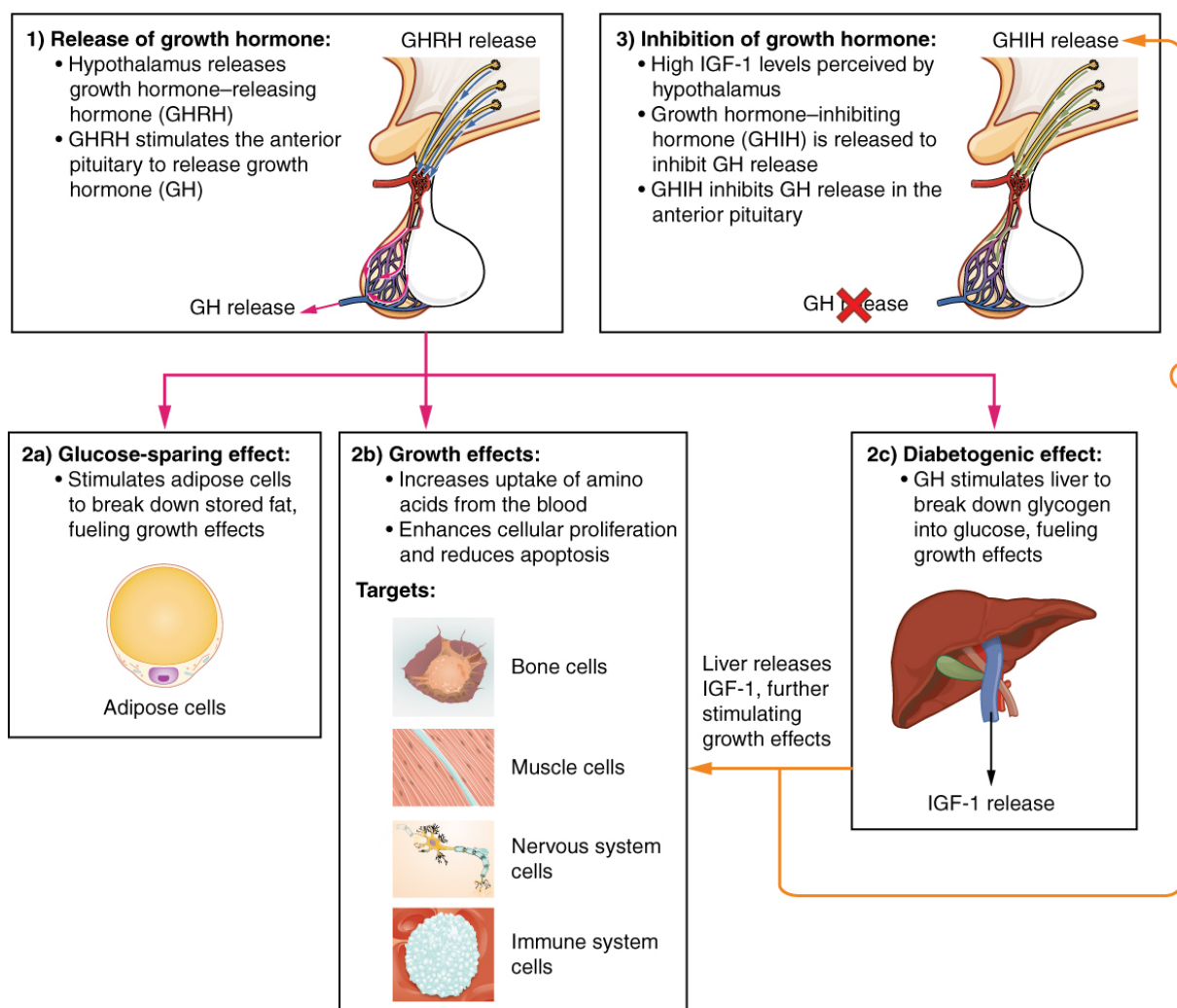


Figure 17.4 Hormonal Regulation of Growth. Growth hormone (GH) directly accelerates the rate of protein synthesis in skeletal muscle and bones. Insulin-like growth factor 1 (IGF-1) is activated by growth hormone and indirectly supports the formation of new proteins in muscle cells and bone. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

A glucose-sparing effect occurs when GH stimulates lipolysis, or the breakdown of adipose tissue, releasing fatty acids into the blood. As a result, many tissues switch from glucose to fatty acids as their main energy source, which means that less glucose is taken up from the bloodstream.

GH also initiates the diabetogenic effect in which GH stimulates the liver to break down glycogen to glucose, which is then deposited into the blood. The name “diabetogenic” is derived from the similarity in elevated blood glucose levels observed between individuals with untreated diabetes mellitus and individuals experiencing GH excess. Blood glucose levels rise as the result of a combination of glucose-sparing and diabetogenic effects.

Dysfunction of the endocrine system’s control of growth can result in several disorders. For example, **gigantism** is a disorder in children that is caused by the secretion of abnormally large amounts of GH, resulting in excessive growth. A similar condition in adults is **acromegaly**, a disorder that results in the growth of bones in the face, hands, and feet in response to excessive levels of GH in individuals who have stopped growing. Abnormally low levels of GH in children can cause growth impairment—a disorder called **pituitary dwarfism** (also known as growth hormone deficiency).

Posterior Pituitary Gland

The posterior pituitary is actually an extension of the neurons of the nuclei of the hypothalamus. The cell bodies of these regions rest in the hypothalamus.

The posterior pituitary gland does not produce hormones, but rather stores and secretes hormones produced by the hypothalamus. The paraventricular nuclei produce the hormone oxytocin, whereas the supraoptic nuclei produce ADH. These hormones travel along the axons into storage sites in the axon terminals of the posterior pituitary. In response to signals from the same hypothalamic neurons, the hormones are released from the axon terminals into the bloodstream.

Oxytocin

When fetal development is complete, the peptide-derived hormone **oxytocin** (tocia- = “childbirth”) stimulates uterine contractions and dilation of the cervix. Throughout most of pregnancy, oxytocin hormone receptors are not expressed at high levels in the uterus. Toward the end of pregnancy, the synthesis of oxytocin receptors in the uterus increases, and the smooth muscle cells of the uterus become more sensitive to its effects. Oxytocin is continually released throughout childbirth through a positive feedback mechanism. As noted earlier, oxytocin prompts uterine contractions that push the fetal head toward the cervix. In response, cervical stretching stimulates additional oxytocin to be synthesized by the hypothalamus and released from the pituitary. This increases the intensity and effectiveness of uterine contractions and prompts additional dilation of the cervix. The feedback loop continues until birth.

Although the mother’s high blood levels of oxytocin begin to decrease immediately following birth, oxytocin continues to play a role in maternal and newborn health. First, oxytocin is necessary for the milk ejection reflex (commonly referred to as “let-down”) in breastfeeding women. As the newborn begins suckling, sensory receptors in the nipples transmit signals to the hypothalamus. In response, oxytocin is secreted and released into the bloodstream. Within seconds, cells in the mother’s milk ducts contract, ejecting milk into the infant’s mouth. Secondly, in both males and females, oxytocin is thought to contribute to parent–newborn bonding, known as attachment. Oxytocin is also thought to be involved in feelings of love and closeness, as well as in the sexual response.

Did You Know?

Oxytocin is not only used during childbirth, but also breastfeeding.

Antidiuretic Hormone (ADH)

The solute concentration of the blood, or blood osmolarity, may change in response to the consumption of certain foods and fluids, as well as in response to disease, injury, medications, or other factors. Blood osmolarity is constantly monitored by **osmoreceptors**—specialized cells within the hypothalamus that are particularly sensitive to the concentration of sodium ions and other solutes.

In response to high blood osmolarity, which can occur during dehydration or following a very salty meal, the osmoreceptors signal the posterior pituitary to release **antidiuretic hormone (ADH)**. The target cells of ADH are located in the tubular cells of the kidneys. Its effect is to increase epithelial permeability to water, allowing increased water reabsorption. The more water reabsorbed from the filtrate, the greater the amount of water that is returned to the blood and the less that is excreted in the urine. A greater concentration of water results in a reduced concentration of solutes. ADH is also known as vasopressin because, in very high concentrations, it causes constriction of blood vessels, which

increases blood pressure by increasing peripheral resistance. The release of ADH is controlled by a negative feedback loop. As blood osmolarity decreases, the hypothalamic osmoreceptors sense the change and prompt a corresponding decrease in the secretion of ADH. As a result, less water is reabsorbed from the urine filtrate.

Interestingly, drugs can affect the secretion of ADH. For example, alcohol consumption inhibits the release of ADH, resulting in increased urine production that can eventually lead to dehydration and a hangover. A disease called diabetes insipidus is characterized by chronic underproduction of ADH that causes chronic dehydration. Because little ADH is produced and secreted, not enough water is reabsorbed by the kidneys. Although patients feel thirsty, and increase their fluid consumption, this doesn't effectively decrease the solute concentration in their blood because ADH levels are not high enough to trigger water reabsorption in the kidneys. Electrolyte imbalances can occur in severe cases of diabetes insipidus.

Thyroid-Stimulating Hormone

The activity of the thyroid gland is regulated by **thyroid-stimulating hormone (TSH)**, also called thyrotropin. TSH is released from the anterior pituitary in response to thyrotropin-releasing hormone (TRH) from the hypothalamus. As discussed shortly, it triggers the secretion of thyroid hormones by the thyroid gland. In a classic negative feedback loop, elevated levels of thyroid hormones in the bloodstream then trigger a drop in production of TRH and subsequently TSH.

Adrenocorticotropic Hormone

The **adrenocorticotropic hormone (ACTH)**, also called corticotropin, stimulates the adrenal cortex (the more superficial "bark" of the adrenal glands) to secrete corticosteroid hormones such as cortisol. The release of ACTH is regulated by the corticotropin-releasing hormone (CRH) from the hypothalamus in response to normal physiologic rhythms. A variety of stressors can also influence its release, and the role of ACTH in the stress response is discussed later in this chapter.

Follicle-Stimulating Hormone and Luteinizing Hormone

The endocrine glands secrete a variety of hormones that control the development and regulation of the reproductive system (these glands include the anterior pituitary, the adrenal cortex, and the gonads—the testes in males and the ovaries in females). Much of the development of the reproductive system occurs during puberty and is marked by the development of sex-specific characteristics in both male and female adolescents. Puberty is initiated by gonadotropin-releasing hormone (GnRH), a hormone produced and secreted by the hypothalamus. GnRH stimulates the anterior pituitary to secrete **gonadotropins**—hormones that regulate the function of the gonads. The levels of GnRH are regulated through a negative feedback loop; high levels of reproductive hormones inhibit the release of GnRH. Throughout life, gonadotropins regulate reproductive function and, in the case of women, the onset and cessation of reproductive capacity.

The gonadotropins include two glycoprotein hormones: **follicle-stimulating hormone (FSH)** stimulates the production and maturation of sex cells, or gametes, including ova in women and sperm in men. FSH also promotes follicular growth; these follicles then release estrogens in the female ovaries. **Luteinizing hormone (LH)** triggers ovulation in women, as well as the production of estrogens and progesterone by the ovaries. LH stimulates production of testosterone by the male testes.

Prolactin

As its name implies, **prolactin (PRL)** promotes lactation (milk production) in women. During pregnancy, it contributes to development of the mammary glands, and after birth, it stimulates the mammary glands to produce breast milk. However, the effects of prolactin depend heavily upon the permissive effects of estrogens, progesterone, and other hormones. And as noted earlier, the let-down of milk occurs in response to stimulation from oxytocin.

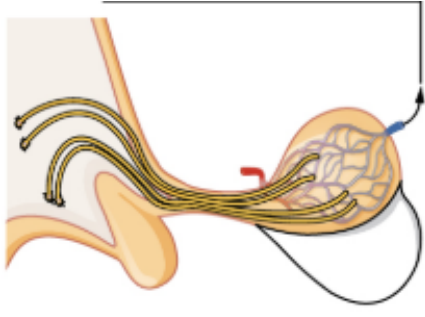
In a non-pregnant woman, prolactin secretion is inhibited by prolactin-inhibiting hormone (PIH), which is actually the **neurotransmitter** dopamine, and is released from neurons in the hypothalamus. Only during pregnancy do prolactin levels rise in response to prolactin-releasing hormone (PRH) from the hypothalamus.

Intermediate Pituitary: Melanocyte-Stimulating Hormone

The cells in the zone between the pituitary lobes secrete a hormone known as melanocyte-stimulating hormone (MSH) that is formed by cleavage of the pro-opiomelanocortin (POMC) precursor protein. Local production of MSH in the skin is responsible for melanin production in response to UV light exposure. The role of MSH made by the pituitary is more complicated. For instance, people with lighter skin generally have the same amount of MSH as people with darker skin. Nevertheless, this hormone is capable of darkening of the skin by inducing melanin production in the skin's melanocytes. Women also show increased MSH production during pregnancy; in combination with estrogens, it can lead to darker skin pigmentation, especially the skin of the areolas and labia minora. Table 17.3 is a summary of the pituitary hormones and their principal effects.

Table 17.3 Major Pituitary Hormones. Major pituitary hormones and their target organs. Adapted from Betts, et al., 2021. Licensed under CC BY 4.0.

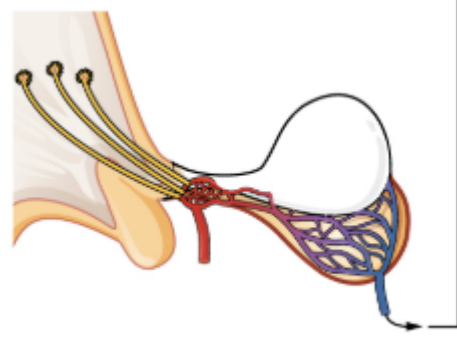
HORMONES			
Posterior Pituitary Hormones			
Releasing hormone (hypothalamus)	Pituitary Hormone	Target	Effects
ADH	Stores ADH	Kidneys, sweat glands, circulatory system	Water balance
-	OT	Female reproductive system	Triggers uterine contractions during childbirth



An image displaying the posterior pituitary gland

HORMONES			
Anterior Pituitary Hormones			
Releasing hormone (hypothalamus)	Pituitary Hormone	Target	Effects
GnRH	LH	Reproductive system	Stimulates production of sex hormones by gonads
GnRH	FSH	Reproductive system	stimulates production of sperm and eggs
TRH	TSH	Thyroid gland	Stimulates the release of thyroid hormone (TH), TH regulates metabolism
PRH (inhibited by PIH)	PRL	Mammary glands	Promotes milk production
GHRH (inhibited by GHIH)	GH	Liver, bone, muscles	Induces targets to produce insulin-like growth factors (IGF). IGFs stimulate body growth and higher metabolic rate.
CRH	ACTH	Adrenal glands	Induces targets to produce glucocorticoids, which regulate metabolism and stress response

IMAGE OF GLANDS



An image displaying the Anterior Pituitary Gland

Pineal Gland

A tiny endocrine gland whose functions are not entirely clear. The **pinealocyte** cells that make up the pineal gland are known to produce and secrete the amine hormone **melatonin**, which is derived from serotonin.

The secretion of melatonin varies according to the level of light received from the environment. When photons of light stimulate the retinas of the eyes, a nerve impulse is sent to a region of the hypothalamus which is important in regulating biological rhythms. When blood levels of melatonin fall they promote wakefulness. In contrast, as light levels decline—such as during the evening—melatonin production increases, boosting blood levels and causing drowsiness.

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#oembed-2>

Media 17.2 [2-Minute Neuroscience: Melatonin](#) [Youtube]. Copyright 2020 by [Neuroscientifically Challenged](#).

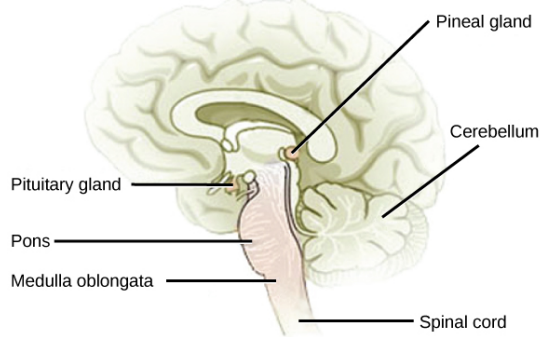
What should you avoid doing in the middle of your sleep cycle that would lower melatonin?

The secretion of melatonin may influence the body's circadian rhythms, the dark-light fluctuations that affect not only sleepiness and wakefulness, but also appetite and body temperature. Interestingly, children have higher melatonin levels than adults, which may prevent the release of gonadotropins from the anterior pituitary, thereby inhibiting the onset of puberty. Finally, an antioxidant role of melatonin is the subject of current research.

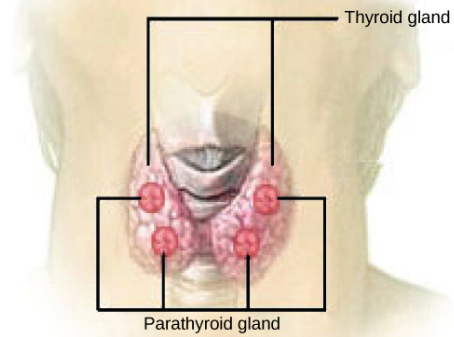
Jet lag occurs when a person travels across several time zones and feels sleepy during the day or wakeful at night. Traveling across multiple time zones significantly disturbs the light-dark cycle regulated by melatonin. It can take up to several days for melatonin synthesis to adjust to the light-dark patterns in the new environment, resulting in jet lag. Some air travelers take melatonin supplements to induce sleep.

Thyroid Gland

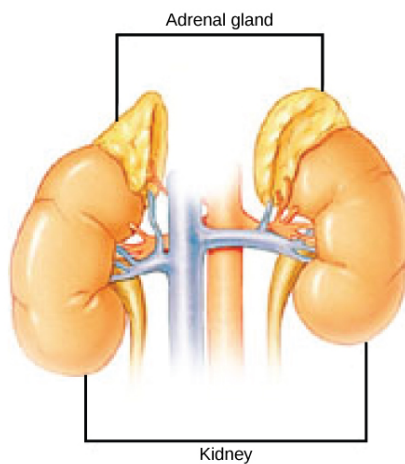
A butterfly-shaped organ, the **thyroid gland** is located anterior to the trachea, just inferior to the larynx (see Figure 17.5). The medial region, called the isthmus, is flanked by wing-shaped left and right lobes. Each of the thyroid lobes are embedded with parathyroid glands, primarily on their posterior surfaces.



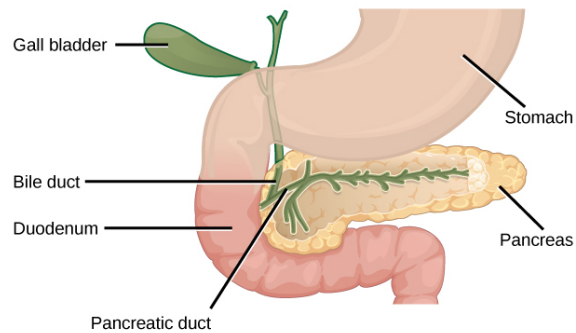
(a)



(b)



(c)



(d)

Figure 17.5 (a) The pituitary gland sits at the base of the brain, just above the brain stem. (b) The parathyroid glands are located on the posterior of the thyroid gland. (c) The adrenal glands are on top of the kidneys. (d) The pancreas is found between the stomach and the small intestine. (credit: modification of work by NCI, NIH)

Regulation of TH Synthesis

The release of T_3 and T_4 from the thyroid gland is regulated by thyroid-stimulating hormone (TSH). Low blood levels of T_3 and T_4 stimulate the release of thyrotropin-releasing hormone (TRH) from the hypothalamus, which triggers secretion of TSH from the anterior pituitary. In turn, TSH stimulates the thyroid gland to secrete T_3 and T_4 . The levels of TRH, TSH, T_3 , and T_4 are regulated by a negative feedback system in which increasing levels of T_3 and T_4 decrease the production and secretion of TSH. The thyroid hormones, T_3 and T_4 , are often referred to as metabolic hormones because their levels influence the body's basal metabolic rate, the amount of energy used by the body at rest.

The thyroid gland also secretes a hormone called **calcitonin**. Calcitonin is released in response to a rise in blood calcium levels.

Parathyroid Gland

The **parathyroid glands** are tiny, round structures usually found embedded in the posterior surface of the thyroid gland. A thick connective tissue capsule separates the glands from the thyroid tissue. Most people have four parathyroid glands, but occasionally there are more in tissues of the neck or chest. The primary functional cells of the parathyroid glands are the chief cells. These epithelial cells produce and secrete the **parathyroid hormone (PTH)**, the major hormone involved in the regulation of blood calcium levels.

Adrenal Gland

The **adrenal glands** are wedges of glandular and neuroendocrine tissue adhering to the top of the kidneys by a fibrous capsule (see Figure 17.6). The adrenal glands have a rich blood supply and experience one of the highest rates of blood flow in the body. They are served by several arteries branching off the aorta, including the suprarenal and renal arteries. Blood flows to each adrenal gland at the adrenal cortex and then drains into the adrenal medulla. Adrenal hormones are released into the circulation via the left and right suprarenal veins.

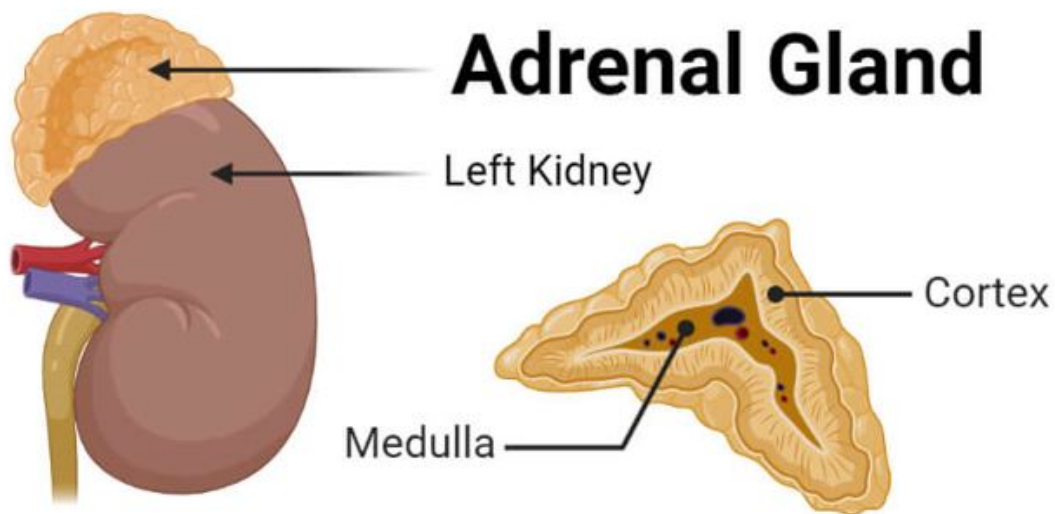


Figure 17.6 Adrenal Gland. There are two adrenal glands that sit atop each kidney and are composed of an outer cortex and an inner medulla. From [Microbenotes.com/adrenal-gland/](https://www.microbenotes.com/adrenal-gland/) and created with BioRender.com

The **adrenal cortex**, as a component of the hypothalamic-pituitary-adrenal (HPA) axis, secretes steroid hormones important for the regulation of the long-term stress response, blood pressure and blood volume, nutrient uptake and storage, fluid and electrolyte balance, and inflammation. The HPA axis involves the stimulation of hormone release of adrenocorticotropic hormone (ACTH) from the pituitary by the hypothalamus. ACTH then stimulates the adrenal cortex to produce the hormone cortisol. This pathway will be discussed in more detail below.

The **adrenal medulla** is neuroendocrine tissue composed of postganglionic sympathetic nervous system (SNS) neurons. It is really an extension of the autonomic nervous system, which regulates homeostasis in the body. The medulla is stimulated to secrete the amine hormones epinephrine and norepinephrine.

One of the major functions of the adrenal gland is to respond to stress. Stress can be either physical or psychological or both. Physical stresses include exposing the body to injury, walking outside in cold and wet conditions without a coat on, or malnutrition. Psychological stresses include the perception of a physical threat, a fight with a loved one, or just a bad day at school.

The body responds in different ways to short-term stress and long-term stress following a pattern known as the **general adaptation syndrome (GAS)**. Stage one of GAS is called the **alarm reaction**. This is short-term stress, the fight-or-flight response, mediated by the hormones epinephrine and norepinephrine from the adrenal medulla via the SAM pathway. Their function is to prepare the body for extreme physical exertion. Once this stress is relieved, the body quickly returns to normal. The section on the adrenal medulla covers this response in more detail.

If the stress is not soon relieved, the body adapts to the stress in the second stage called the **stage of resistance**. If a person is starving for example, the body may send signals to the gastrointestinal tract to maximize the absorption of nutrients from food.

If the stress continues for a longer term however, the body responds with symptoms quite different than the fight-or-flight response. During the **stage of exhaustion**, individuals may begin to suffer depression, the suppression of their immune response, severe fatigue, or even a fatal heart attack. These symptoms are mediated by the hormones of the adrenal cortex, especially cortisol, released as a result of signals from the HPA axis.

Adrenal hormones also have several non-stress-related functions, including the increase of blood sodium and glucose levels, which will be described in detail below.

Adrenal Cortex

The adrenal cortex consists of multiple layers of lipid-storing cells that occur in three structurally distinct regions. Each of these regions produces different hormones.

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: <https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#oembed-3>

Media 17.3 [Endocrine System, Part 2 – Hormone Cascades: Crash Course A&P #24](#) [Online video]. Copyright 2015 by [CrashCourse](#).

Concept Check

- Which hormone produced by the adrenal glands is responsible for the mobilization of energy stores?

The Adrenal Cortex

Aldosterone is important in the regulation of the concentration of sodium and potassium ions in urine, sweat, and saliva. For example, it is released in response to elevated blood K^+ , low blood Na^+ , low blood pressure, or low blood volume. In response, aldosterone increases the excretion of K^+ and the retention of Na^+ , which in turn increases blood volume and blood pressure. Its secretion is prompted when CRH from the hypothalamus triggers ACTH release from the anterior pituitary.

Aldosterone is also a key component of the renin-angiotensin-aldosterone system (RAAS) in which specialized cells of the kidneys secrete the enzyme renin in response to low blood volume or low blood pressure. Renin then catalyzes the conversion of the blood protein angiotensinogen, produced by the liver, to the hormone angiotensin I. Angiotensin I is converted in the lungs to angiotensin II by **angiotensin-converting enzyme** (ACE). Angiotensin II has three major functions:

1. Initiating vasoconstriction of the arterioles, decreasing blood flow
2. Stimulating kidney tubules to reabsorb $NaCl$ and water, increasing blood volume
3. Signaling the adrenal cortex to secrete aldosterone, the effects of which further contribute to fluid retention, restoring blood pressure and blood volume

For individuals with hypertension, or high blood pressure, drugs are available that block the production of angiotensin II. These drugs, known as ACE inhibitors, block the ACE enzyme from converting angiotensin I to angiotensin II, thus mitigating the latter's ability to increase blood pressure.

Glucocorticoid

The glucocorticoid hormones play a role in glucose metabolism. The most important of these is **cortisol**, some of which the liver converts to cortisone. A glucocorticoid produced in much smaller amounts is corticosterone. In response to long-term stressors, the hypothalamus secretes CRH, which in turn triggers the release of ACTH by the anterior pituitary. ACTH triggers the release of the glucocorticoids. Their overall effect is to inhibit tissue building while stimulating the breakdown of stored nutrients to maintain adequate fuel supplies. In conditions of long-term stress, for example, cortisol promotes the catabolism of glycogen to glucose, the catabolism of stored triglycerides into fatty acids and glycerol, and the catabolism of muscle proteins into amino acids. These raw materials can then be used to synthesize additional glucose and ketones for use as body fuels. The hippocampus, which is part of the temporal

lobe of the cerebral cortex and important in memory formation, is highly sensitive to stress levels because of its many glucocorticoid receptors.

You are probably familiar with prescription and over-the-counter medications containing glucocorticoids, such as cortisone injections into inflamed joints, prednisone tablets and steroid-based inhalers used to manage severe asthma, and hydrocortisone creams applied to relieve itchy skin rashes. These drugs reflect another role of cortisol—the downregulation of the immune system, which inhibits the inflammatory response.

Androgens

The deepest region of the adrenal cortex produces small amounts of a class of steroid sex hormones called androgens. During puberty and most of adulthood, androgens are produced in the gonads. The androgens produced in the zona reticularis supplement the gonadal androgens. They are produced in response to ACTH from the anterior pituitary and are converted in the tissues to testosterone or estrogens. In adult women, they may contribute to the sex drive, but their function in adult men is not well understood. In post-menopausal women, as the functions of the ovaries decline, the main source of estrogens becomes the androgens produced by the zona reticularis.

Adrenal Medulla

As noted earlier, the adrenal cortex releases glucocorticoids in response to long-term stress such as severe illness. In contrast, the adrenal medulla releases its hormones in response to acute, short-term stress mediated by the sympathetic nervous system (SNS).

The medullary tissue is composed of unique postganglionic SNS neurons called **chromaffin** cells, which are large and irregularly shaped, and produce the neurotransmitters **epinephrine** (also called adrenaline) and **norepinephrine** (or noradrenaline). Epinephrine is produced in greater quantities—approximately a 4 to 1 ratio with norepinephrine—and is the more powerful hormone. Because the chromaffin cells release epinephrine and norepinephrine into the systemic circulation, where they travel widely and exert effects on distant cells, they are considered hormones. Derived from the amino acid tyrosine, they are chemically classified as catecholamines.

The secretion of medullary epinephrine and norepinephrine is controlled by a neural pathway that originates from the hypothalamus in response to danger or stress. Both epinephrine and norepinephrine signal the liver and skeletal muscle cells to convert glycogen into glucose, resulting in increased blood glucose levels. These hormones increase the heart rate, pulse, and blood pressure to prepare the body to fight the perceived threat or flee from it. In addition, the pathway dilates the airways, raising blood oxygen levels. It also prompts vasodilation, further increasing the oxygenation of important organs such as the lungs, brain, heart, and skeletal muscle. At the same time, it triggers vasoconstriction to blood vessels serving less essential organs such as the gastrointestinal tract, kidneys, and skin, and downregulates some components of the immune system. Other effects include a dry mouth, loss of appetite, pupil dilation, and a loss of peripheral vision.

Pancreas

The **pancreas** is a long, slender organ, most of which is located posterior to the bottom half of the stomach (see Figure 17.7). Although it is primarily an exocrine gland, secreting a variety of digestive enzymes, the pancreas has an endocrine

function. Its **pancreatic islets**—clusters of cells formerly known as the islets of Langerhans—secrete the hormones glucagon, insulin, somatostatin, and pancreatic polypeptide (PP).

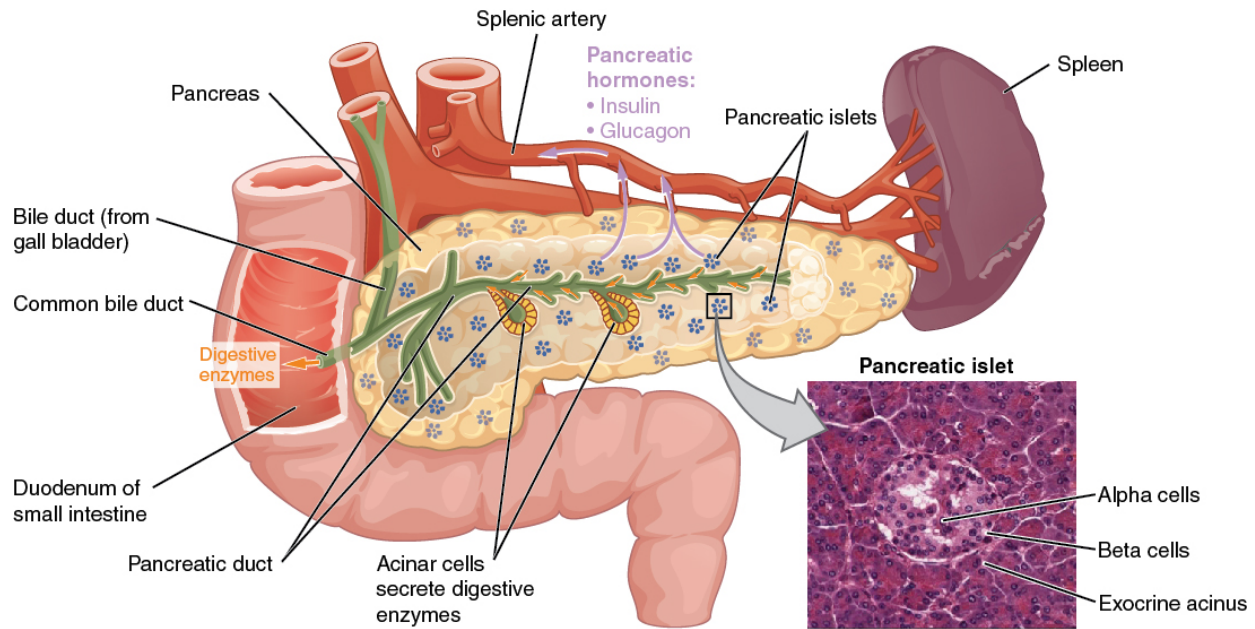


Figure 17.7 Pancreas. The pancreatic exocrine function involves the acinar cells secreting digestive enzymes that are transported into the small intestine by the pancreatic duct. Its endocrine function involves the secretion of insulin and glucagon within the pancreatic islets. These two hormones regulate the rate of glucose metabolism in the body (Micrograph provided by the Regents of University of Michigan Medical School © 2012). From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Cells and Secretions of the Pancreatic Islets

The pancreatic islets each contain four varieties of cells:

- The **alpha cell** produces the hormone glucagon and makes up approximately 20 percent of each islet. Glucagon plays an important role in blood glucose regulation; low blood glucose levels stimulate its release.
- The **beta cell** produces the hormone insulin and makes up approximately 75 percent of each islet. Elevated blood glucose levels stimulate the release of insulin.
- The **delta cell** accounts for four percent of the islet cells and secretes the peptide hormone somatostatin. Recall that somatostatin is also released by the hypothalamus (as GHIH), and the stomach and intestines also secrete it. An inhibiting hormone, pancreatic somatostatin inhibits the release of both glucagon and insulin.
- The **PP cell** accounts for about one percent of islet cells and secretes the pancreatic polypeptide hormone. It is thought to play a role in appetite, as well as in the regulation of pancreatic exocrine and endocrine secretions. Pancreatic polypeptide released following a meal may reduce further food consumption; however, it is also released in response to fasting.

Regulation of Blood Glucose Levels by Insulin and Glucagon

Glucose is required for cellular respiration and is the preferred fuel for all body cells. The body derives glucose from the

breakdown of the carbohydrate-containing foods and drinks we consume. Glucose not immediately taken up by cells for fuel can be stored by the liver and muscles as glycogen, or converted to triglycerides and stored in the adipose tissue. Hormones regulate both the storage and the utilization of glucose as required. Receptors located in the pancreas sense blood glucose levels, and subsequently the pancreatic cells secrete glucagon or insulin to maintain normal levels.

Gonadal Glands

The male testes and female ovaries—which produce the sex cells (sperm and ova) and secrete the gonadal hormones. The roles of the gonadotropins released from the anterior pituitary (FSH and LH) were discussed earlier.

The primary hormone produced by the male testes is **testosterone**, a steroid hormone important in the development of the male reproductive system, the maturation of sperm cells, and the development of male secondary sex characteristics such as a deepened voice, body hair, and increased muscle mass. Interestingly, testosterone is also produced in the female ovaries, but at a much reduced level. In addition, the testes produce the peptide hormone **inhibin**, which inhibits the secretion of FSH from the anterior pituitary gland. FSH stimulates spermatogenesis.

The primary hormones produced by the ovaries are **estrogens**, which include estradiol, estriol, and estrone. Estrogens play an important role in a larger number of physiological processes, including the development of the female reproductive system, regulation of the menstrual cycle, the development of female secondary sex characteristics such as increased adipose tissue and the development of breast tissue, and the maintenance of pregnancy. Another significant ovarian hormone is **progesterone**, which contributes to regulation of the menstrual cycle and is important in preparing the body for pregnancy as well as maintaining pregnancy. In addition, the granulosa cells of the ovarian follicles produce inhibin, which—as in males—inhibits the secretion of FSH. During the initial stages of pregnancy, an organ called the placenta develops within the uterus. The placenta supplies oxygen and nutrients to the fetus, excretes waste products, and produces and secretes estrogens and progesterone. The placenta produces human chorionic gonadotropin (hCG) as well. The hCG hormone promotes progesterone synthesis and reduces the mother's immune function to protect the fetus from immune rejection. It also secretes human placental lactogen (hPL), which plays a role in preparing the breasts for lactation, and relaxin, which is thought to help soften and widen the pubic symphysis in preparation for childbirth.

Common Endocrine System Abbreviations



An interactive H5P element has been excluded from this version of the text.

You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#h5p-119>

Concept Check

- Do you recall the term which describes high level of glucose in the blood?

- Do you recall the neurotransmitter responsible for assisting the response to danger or stress?
- Suggest what may happen if the adrenal cortex failed to secrete its hormones.

Diseases and Disorders

Acromegaly

A disorder in adults caused when abnormally high levels of GH trigger growth of bones in the face, hands, and feet.

Addison's disease

A rare disorder that causes low blood glucose levels and low blood sodium levels. The signs and symptoms of Addison's disease are vague and are typical of other disorders as well, making diagnosis difficult. They may include general weakness, abdominal pain, weight loss, nausea, vomiting, sweating, and cravings for salty food (Betts, et al., 2021).

Cushing's disease

A disorder characterized by high blood glucose levels and the accumulation of lipid deposits on the face and neck. It is caused by hypersecretion of cortisol. The most common source of Cushing's disease is a pituitary tumor that secretes cortisol or ACTH in abnormally high amounts (Betts, et al., 2021).

Gigantism

A disorder in children caused when abnormally high levels of GH prompt excessive growth in the body (Betts, et al., 2021).

Hirsutism

Hirsutism is a symptom of an excessive production of **androgens** causing hair growth in women where they typically do not have hair growth. While some medications may cause the increased androgen production it can also be linked to endocrine disorders such as Polycystic Ovary Syndrome (PCOS), Cushing syndrome and tumors in the ovaries or adrenal glands (Mayo Clinic Staff, 2020).

Hyperthyroidism

A condition marked by high levels of thyroid hormones that results in weight loss, profuse sweating, and increased heart rate (Betts, et al., 2021).

Hypothyroidism

A condition marked by low levels of thyroid hormones that results in weight gain, cold sensitivity, and reduced mental activity (Betts, et al., 2021).

Graves Disease

A condition marked by a disorder of the thyroid gland, resulting in hyperthyroidism (Betts, et al., 2021).

Diabetes Insipidus

A condition caused by a lack of or hyposecretion of the antidiuretic hormone (ADH). The condition can also be caused by the failure of the kidneys to respond to ADH (Betts, et al., 2021).

Diabetes (Mellitus)

A condition marked by a disorder of the pancreas, resulting in high levels of glucose in the blood (Betts, et al., 2021).

Medical Terms in Context



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#h5p-120>



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#h5p-121>

Medical Specialties and Procedures Related to the Endocrine System

Endocrinology is a specialization in the field of medicine that focuses on the treatment of endocrine system disorders. Endocrinologists—medical doctors who specialize in this field—are experts in treating diseases associated with hormonal systems, ranging from thyroid disease to diabetes. Endocrine surgeons treat endocrine disease through the removal of the affected endocrine gland or tissue. Some patients experience health problems as a result of the normal decline in hormones that can accompany aging. These patients can consult with an endocrinologist to weigh the risks and benefits of hormone replacement therapy intended to boost their natural levels of reproductive hormones. In addition to treating patients, endocrinologists may be involved in research to improve the understanding of endocrine system disorders and develop new treatments for these diseases (Betts, et al., 2021).

- A **thyroid specialist** is an endocrinologist whose sub specialty is focused on the treatment and disorders of the thyroid gland such as hypothyroidism (too low secretion) and hyperthyroidism (too high secretion).
- A **diabetes specialist** is an endocrinologist whose sub specialty is focused on the treatment of diabetic conditions.

Procedures

Thyroid Scan

This procedure is designed to check the status of the thyroid. In a thyroid scan, a radioactive compound is given and localized in the thyroid gland (Giorgi & Cherney, 2018). To learn more about a thyroid scan visit [HealthLine: Thyroid Scan](#).

Radioactive iodine uptake

Thyroid function evaluated by injecting radioactive iodine and then measuring how much is removed from the blood by the thyroid (MedlinePlus, 2020). To learn more about a radioactive iodine update test visit [Medline Plus: Radioactive Iodine Uptake](#).

Blood Serum Testing

Blood testing to determine the concentration and the presence of various endocrine hormones in the blood. These tests include the following levels: calcium, cortisol, electrolytes, FSH, GH, glucose, insulin, parathyroid hormones, T3, T4, testosterone, and TSH. All of these can be evaluated with blood serum tests (Betts, et al., 2021).

Endocrine Surgical Procedures

Most of the surgeries and procedures performed with the endocrine system involve removal of a gland or an incision

into the gland. Once an endocrine gland is surgically removed, due to a tumor or enlargement, hormone replacement treatment is required. Medication is required to artificially or synthetically replace the hormone produced by the gland and the function it regulates (Betts, et al., 2021).

Test Yourself



An interactive H5P element has been excluded from this version of the text. You can view it online here:

<https://nicoletcollege.pressbooks.pub/lcmedicalterminology/?p=198#h5p-122>

References

[CrashCourse]. (2015, June 22). *Endocrine system, part 1 – glands & hormones: Crash course A&P #23* [Video]. YouTube. <https://www.youtube.com/watch?v=eWHH9je2zG4>

[CrashCourse]. (2015, June 29). *Endocrine system, part 2 – hormone cascade: Crash course A&P #24* [Video]. YouTube. <https://www.youtube.com/watch?v=eWHH9je2zG4>

Giorgi, A., & Cherney, K. (2018). *Thyroid scan*. Healthline. <https://www.healthline.com/health/thyroid-scan>

MedlinePlus. (2020). *Radioactive iodine uptake*. US National Library of Medicine. <https://medlineplus.gov/ency/article/003689.htm>

Shurkin, J.N.(2013, August 2). *Trouble sleeping? Go camping: Artificial light sources can negatively affect circadian rhythms, scientists say*. Scientific American. <https://www.scientificamerican.com/article/trouble-sleeping-go-campi/>

Neuroscientifically Challenged. (2020, May 16). *2-Minute Neuroscience: Melatonin* [Video]. YouTube. <https://www.youtube.com/watch?v=SpaBMgZG9XQ>

Unless otherwise indicated, this chapter contains material adapted from *Anatomy and Physiology* (on [OpenStax](#)), by Betts, et al. and is used under a [CC BY 4.0 international license](#). Download and access this book for free at <https://openstax.org/books/anatomy-and-physiology/pages/1-introduction>.