SPEAKING THE LANGUAGE OF HEALTH: MEDICAL TERMINOLOGY FOR LIFE AND CAREER



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Speaking the Language of Health: Medical Terminology for Life and Career

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Acknowledgments

This open educational resource grew from a simple belief: the cost of a textbook should never stand between a student and the opportunity to learn. Our goal is to provide accessible, meaningful medical terminology education that builds confidence and supports students as they pursue their academic and professional goals.

Creating this resource has been a journey of reading, researching, adapting, and connecting ideas to the realities of healthcare. It is designed for students exploring medical language for the first time, as well as those preparing for careers in nursing and other healthcare professions. Throughout these pages, the emphasis is on understanding and applying medical terminology—helping students connect the words they learn to the people they will someday serve.

We are grateful to the educators and authors who share their work through open education, making resources like this possible. We also thank our students, whose questions, curiosity, and determination continually shape our teaching. Their experiences remind us that learning should be engaging, approachable, and connected to a meaningful purpose.

About the Authors

Dr. Lisa Harding, DNP, RN, CEN, has taught at Bakersfield College since fall 2008, serving as a full-time, tenured nursing professor. She earned her Bachelor of Science in Nursing from Walla Walla University, formerly Walla Walla College; her master's degree in nursing education from Holy Names University; and her Doctor of Nursing Practice from Grand Canyon University.

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Dr. Harding is passionate about helping students become knowledgeable, compassionate nurses who think critically, advocate for their patients, and support one another. Her teaching emphasizes active participation, practical application, and the confidence to ask questions and keep learning.

Outside of nursing and teaching, Lisa enjoys doing life with her best friend and husband, David. Whether serving together at church, visiting their daughter, heading out on their "Brading" adventures, or relaxing with a favorite television series, they treasure time together. Their rescue dog, Zannah Banana, adds another reason to smile.

To my husband, David: thank you for your love, encouragement, and support of the work I feel called to do.

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Dr. Elliott is a strong advocate for Open Educational Resources (OER) and has contributed to the development of several educational resources designed to make learning more accessible and affordable for students.

Outside of nursing and teaching, she enjoys a variety of creative hobbies, particularly those that involve working with her hands, as well as spending time outdoors and appreciating the natural world.

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1: Identifying Word Parts in Medical Terms

Welcome to ***Medical Terminology***. Medical terminology is a language that is used in health care settings. Medical terms are built from Greek and Latin word parts and in addition include acronyms, such as “laser” (light amplification by stimulated emission of radiation), eponyms, such as West Nile Virus (named after a geographical location where the virus was identified) or Alzheimer disease (named after the person who discovered it) and modern-day language terms, such as “nuclear medicine scanner”, which is derived from the English language.

Word Parts

Medical terms are built from four word parts. Those word parts are prefix, word root, suffix, and combining vowel. When a word root is combined with a combining vowel, the word part is referred to as a combining form.

Word Root

The word root contains the fundamental meaning of the word. It is the core part of the word. Each medical term contains at least one word root.

Examples:

- In the word: play/er (*play* is the word root)
- In the medical term: arthr/itis (*arthr* – meaning “joint” – is the word root)

Some words contain more than one word root. The order is generally dictated by common practice. As you practice throughout this course, you will learn more about how to determine the order of word roots.

Prefixes

Prefixes are located at the beginning of a medical term. The prefix alters the meaning of the medical term. It is important to spell and pronounce prefixes correctly.

Examples:

- In the word: re/play (“re” is the prefix)
- In the medical term: intra/ven/ous (“intra” is the prefix)

Many prefixes that you find in medical terms are common to English language prefixes. A good technique to help with memorization is the following:

- Start by reviewing the most common prefixes.
- Consider common English language words that begin with the same prefixes.
- Compare them to the examples of use in medical terms.

Prefixes often indicate:

- **Number:** such as bi-meaning two
- **Position:** such as sub-, meaning under
- **Direction:** such as intra-, meaning within
- **Time:** such as brady-, meaning slow
- **Negation:** such as a- and an-, meaning without

Suffixes

Suffixes are word parts that are located at the end of words. Suffixes can alter the meaning of medical terms. In order to properly spell and pronounce medical terms, it is helpful to learn the suffixes.

Examples:

- In the word: king/dom ("-dom" is the suffix)
- In the medical term: hepat/itis ("-itis" is the suffix)

When defining a medical term you often begin with the meaning of the suffix. For example: hepat/itis would be defined as "inflammation of the liver."

Suffixes often indicate:

- **Procedures**: such as -scopy, meaning visual examination
- **Conditions**: such as -itis, meaning inflammation
- **Diseases:** such as -oma, meaning tumor

Combining Vowel

The combining vowel is a word part – most often an o – that helps pronunciation.

The combining vowel is placed to connect two word roots or to connect a word root and a suffix. Do NOT place a combining vowel to connect a prefix and a word root. Not all medical terms will have combining vowels.

Table 1.1 Combining Vowel Guidelines

Guideline	Example
1. When connecting a word root and a suffix, a combining vowel is used if the suffix DOES NOT begin with a vowel	arthr/o/pathy
2. When connecting a word root and a suffix, a combining vowel is usually NOT USED if the suffix BEGINS with a vowel	hepat/ic
3. When connecting two word roots, a combining vowel is usually used even if vowels are present at the junction	oste/o/arthr/itis
4. When connecting a prefix and a word root, a combining vowel is NOT USED	sub/hepat/ic

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Categories of Medical Terms

All medical terms are divided into two basic categories:

1. terms built from word parts
2. terms NOT built from word parts

Table: 1.2 Categories of Medical Terms

Category	Origin	Example	Learning Method
Terms Built from Word Parts	Word parts of Greek and Latin origin combined to create literal translations	1. cytogenic 2. dysplasia	1. Analyzing terms 2. Defining terms 3. Building terms
Terms NOT built from Word Parts	1. Eponyms 2. Acronyms 3. Modern Language 4. Terms from Greek and Latin word parts that cannot be easily translated to find their meanings	1. Parkinson's Disease 2. AIDS (acquired immunodeficiency syndrome) 3. posttraumatic stress disorder 4. orthopedics	1. Recalling terms 2. Matching terms 3. Defining terms

Medical terms are also further divided into:

1. **Disease and Disorder** – These are terms that describe any harmful deviation from the normal structural or functional state of an organism, generally associated with certain signs and symptoms. It does not include physical injury. An example of a disease is bronchopneumonia, which is a diseased state of the bronchi and lungs.
2. **Diagnostic/Procedural** – These are terms related to the process of identifying a disease, condition, or injury from its signs and symptoms. An example of a diagnostic term is transrectal ultrasound, which is an ultrasound procedure used to diagnose prostate cancer.
3. **Therapeutic –** These are terms regarding treating or curing of diseases. An example of a therapeutic term is nebulizer, which is a device that creates a mist used to deliver medication for respiratory treatment.
4. **Anatomical** – These are terms used to describe specific areas and movement of the body as well as the relation of body parts to each other. An example of an anatomical term is medial, which describes the middle or direction toward the middle of the body.

Language Rules

Language rules are a good place to start when building a medical terminology foundation. Many medical terms are built from word parts and can be translated literally. At first, literal translations sound awkward. Once you build a medical vocabulary and become proficient at using it, the awkwardness will slip away. For example, suffixes will no longer be stated and will be assumed. The definition of *intravenous* then becomes *within the vein*.

Since you are at the beginning of building your medical terminology foundation stay literal when applicable. It should be noted that as with all language rules there are always exceptions and we refer to those as rebels.

By the end of this resource, you will have identified hundreds of word parts within medical terms. Here are some common medical

terms that many non-medically trained people may be familiar with.

Examples

Osteoarthritis
Oste/o/arthr/itis – Inflammation of bone and joint.
Oste/o is a combining form that means bone
arthr/o is a combining form that means joint
-itis is a suffix that means inflammation

Intravenous
Intra/ven/ous – Pertaining to within a vein.
Intra- is a prefix that means within
ven/o – is a combining form that means vein
-ous is a suffix that means pertaining to

When breaking down words place slashes between word parts and a slash on each side of a combining vowel. Notice how the term is defined by beginning with the meaning of the suffix, then shifts to the beginning of the term with the meaning of the word parts in the order they appear.

Pronunciation

Special marking above vowels indicate the proper pronunciation of the vowel. When you see a macron (or straight line) above the vowel, that means the vowel sound is long. A u-shaped symbol above a vowel indicates a short vowel sound. CAPITAL letters indicate where to place the emphasis when pronouncing a word. The table below provides examples, try pronouncing them aloud.

Table 1.3 Combining Vowels Tips

Guidelines	Examples
1. Words are distorted minimally to indicate the proper phonetic sound.	doctor (dŏk-tŏr)
2. The macron (line above the letter) indicated a long vowel sound.	prorate (prō-rāt) As in the: ā in play ē in be ī in wine ō in go ū in mule

Guidelines	Examples
3. A u-shaped mark above the vowel indicates a short sound.	medical (mĕd-ĭ-căl) As in the: **ă** in mad **ĕ** in bet **ĭ** in tip **ŏ** in mop **ŭ** in cup
4. Primary emphasis is indicated by capital letters.	debride (di-BRĒD) dehydration (dē-hī-DRĀ-shŏn)

Review

Table 1.4 Combining Vowels Tips

Combining Vowel Tip	Example
1. Use a combining vowel when connecting a word root to a suffix that begins with a consonant.	arthr/o/**p**athy
2. DO NOT use a combining vowel if the suffix begins with a vowel.	hepat/ic
3. Use a combining vowel when connection two word roots, even if vowels are present at the conjunction.	oste/o/arthr/itis
4. DO NOT use a combining vowel when connect a prefix and a word root.	sub/hepat/ic

Table 1.5 Word Parts and Combining Forms

Part	Definition	Example
Word Root	Core of the word	**hepat/**itis
Suffix	Attached to the end of a word root to alter its meaning	hepat/**itis**
Prefix	Attached to the beginning of the word root to alter its meaning	**sub/**hepatic
Combining Vowel	Typically an “o” used to assist pronunciation	hepat/**o**/magaly
Combining Form	Word root with a combining vowel	**hepat/o**

Table 1.6 Medical Terminology Learning Techniques

Technique	Instructions	Example
Analyze	1. Divide into word parts 2. Label the word parts 3. Underline and label each combining form	1. oste/o/arthr/o/pathy 2. oste =WR/ o= CV/ arthr = WR/ o = CV/ pathy = S 3**. oste/o**/**arthr/o**/pathy
Define	1. Define each word part in the term 2. Begin defining the suffix meaning and then move to the beginning of the term	1. oste = bone, arthr = joint, pathy= disease 2. **Disease** of the **bone** and **joint**
Build	1. Place word parts together to add terms 2. Add combining vowels	1. **Disease** of the **bone** and **joint =** oste/ /arthr/ /pathy 2. oste/**o**/arthr/**o**/pathy

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2: Medical Language Related to the Body as a Whole

Learning Objectives

- Use the anatomic reference system to identify the anatomic position of the body
- Use the anatomic reference system to identify the body planes
- Use the anatomic reference system to identify the body cavities
- Use the anatomic reference system to identify the directional terms
- Use the anatomic reference system to identify the divisions of the body
- Describe the structural organization of the body
- Apply the rules of medical language and terminology
- Identify meanings of key word components

As you memorize the language components of medical terminology it is important to support that learning within the context of anatomy and physiology. Proceeding through the body system chapters you will learn word parts, whole medical terms, and common abbreviations. It is important to put into context where in the body the medical term is referencing, and then consider how it works within the body.

Anatomy focuses on structure and **physiology** focuses on function. Much of the study of physiology centers on the body's tendency toward homeostasis .

Consider the structures of the body in terms of fundamental levels of organization that increase in complexity: subatomic particles, atoms, molecules, organelles, cells, tissues, organs, organ systems, organisms, and biosphere (Figure 2.1).

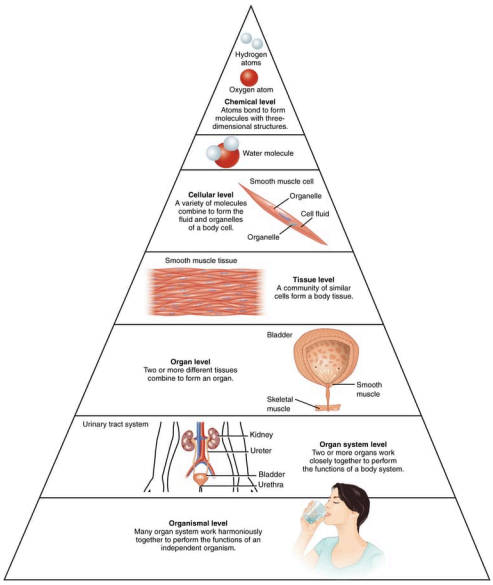


Figure 2.1 Levels of Structural Organization of the Human Body. The organization of the body often is discussed in terms of six distinct levels of increasing complexity, from the smallest chemical building blocks to a unique human organism. From Betts, et al., 2021. Licensed under CC BY 4.0.

The Levels of Organization

All matter in the universe is composed of one or more unique pure substances called **elements** , familiar examples are hydrogen, oxygen, carbon, nitrogen, calcium, and iron.

- The smallest unit of any of these pure substances (elements) is an **atom**.

    - Atoms are made up of subatomic particles such as the proton, electron, and neutron.
- Two or more atoms combine to form a **molecule**, such as the water molecules, proteins, and sugars found in living things.
    - **Molecules** are the chemical building blocks of all body structures.
- A **cell**is the smallest independently functioning unit of a living organism.
    - Even bacteria, which are extremely small, independently-living organisms, have a cellular structure. Each bacterium is a single cell. All living structures of human anatomy contain cells, and almost all functions of human physiology are performed in cells or are initiated by cells
    - A human cell typically consists of flexible membranes that enclose cytoplasm, a water-based cellular fluid, together with a variety of tiny functioning units called **organelles**. In humans, as in all organisms, cells perform all functions of life.
- A **tissue** is a group of many similar cells (though sometimes composed of a few related types) that work together to perform a specific function.
- An **organ**is an anatomically distinct structure of the body composed of two or more tissue types. Each organ performs one or more specific physiological functions.

An **organ system**is a group of organs that work together to perform major functions or meet the physiological needs of the body.

Did you know?

- Organs are very collaborative and work with multiple body systems.
- For example, the heart (cardiovascular system) and lungs (respiratory system) work together to deliver oxygen throughout the body and remove carbon dioxide from the body.

Consider the breakdown into eleven distinct organ systems in the human body (Figure 2.2 and Figure 2.3). Assigning organs to organ systems can be imprecise since organs that “belong” to one system can also have functions integral to another system. In fact, most organs contribute to more than one system.

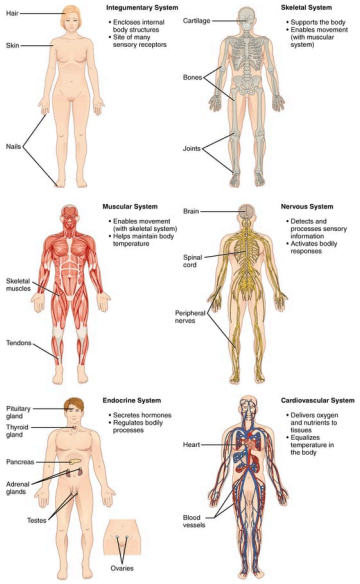


Figure 2.2. Organ Systems of the Human Body. Organs that work together are grouped into organ systems. From Betts, et al., 2021. Licensed under CC BY 4.0

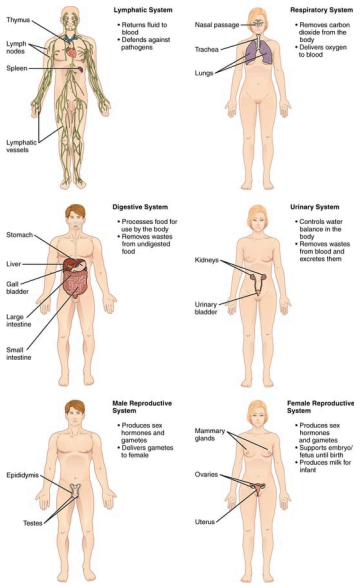


Figure 2.3. Organ Systems of the Human Body (continued). Organs that work together are grouped into organ systems. From Betts, et al., 2021. Licensed under CC BY 4.0

The **organism** level is the highest level of organization. An organism is a living being that has a cellular structure and that can independently perform all physiologic functions necessary for life. In multicellular organisms, including humans, all cells, tissues, organs, and organ systems of the body work together to maintain the life and health of the organism.

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Did you know?

Terminology is used for the purpose of precision and reduction of medical error.

Anatomical Position

Health care providers use terminology for the purpose of precision and to reduce medical errors. For example, is a scar “above the wrist” located on the forearm two or three inches away from the hand? Or is it at the base of the hand? Is it on the palm-side or back-side? By using precise anatomical terminology, we eliminate ambiguity. Anatomical terms derive from ancient Greek and Latin words.

To further increase precision, anatomists standardize the way in which they view the body. Just as maps are normally oriented with north at the top, the standard body “map,” or anatomical position, is that of the body standing upright, with the feet at shoulder width and parallel, toes forward. The upper limbs are held out to each side, and the palms of the hands face forward as illustrated.

Using this standard position reduces confusion. It does not matter how the body being described is oriented, the terms are used

as if it is in anatomical position. For example, a scar in the “anterior (front) carpal (wrist) region” would be present on the palm side of the wrist. The term “anterior” would be used even if the hand were palm down on a table.

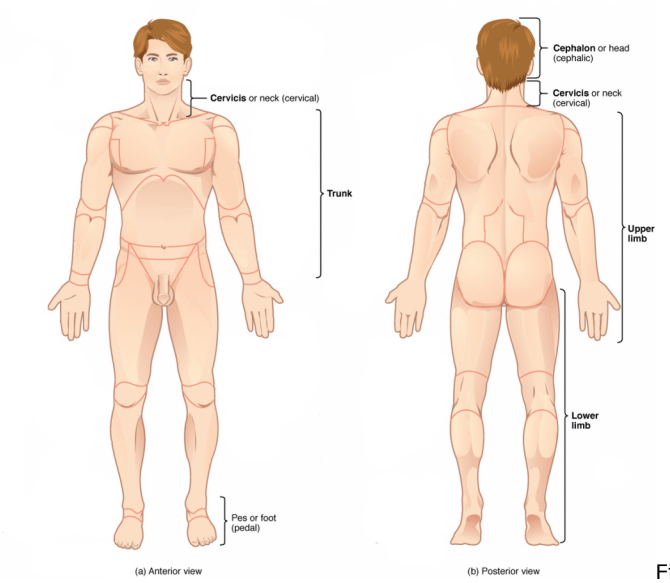


Figure 2.4. Regions of the Human Body. The human body is shown in anatomical position in an (a) anterior view and a (b) posterior view. The regions of the body are labeled in boldface. Remixed image from Betts, et al., 2021. Licensed under CC BY 4.0

A body that is lying down is described as either prone or supine. These terms are sometimes used in describing the position of the body during specific physical examinations or surgical procedures.

Regional Terms

The human body’s numerous regions have specific terms to help increase precision. Notice that the term “brachium” or “arm” is reserved for the “upper arm” and “antebrachium” or “forearm” is used rather than “lower arm.” Similarly, “femur” or “thigh” is correct, and “leg” or “crus” is reserved for the portion of the lower limb between the knee and the ankle. You will be able to describe the body’s regions using the terms from the anatomical position.

Directional Terms

Directional terms are essential for describing the relative locations of different body structures. For instance, an anatomist might describe one band of tissue as “inferior to” another or a physician might describe a tumor as “superficial to” a deeper body structure. Commit these terms to memory to avoid confusion when you are studying or describing the locations of particular body parts.

- **Anterior**(or **ventral**) describes the front or direction toward the front of the body. The toes are anterior to the foot.
- **Posterior** (or **dorsal**) describes the back or direction toward the back of the body. The popliteus is posterior to the patella.
- **Superior** (or **cranial**) describes a position above or higher than another part of the body proper. The orbits are superior to the oris.
- **Inferior** (or **caudal**) describes a position below or lower than another part of the body proper; near or toward the tail (in humans, the coccyx, or lowest part of the spinal column). The pelvis is inferior to the abdomen.
- **Lateral** describes the side or direction toward the side of the body. The thumb (pollex) is lateral to the digits.
- **Medial** describes the middle or direction toward the middle of the body. The hallux is the medial toe.
- **Proximal** describes a position in a limb that is nearer to the point of attachment or the trunk of the body. The brachium is proximal to the antebrachium.
- **Distal** describes a position in a limb that is farther from the point of attachment or the trunk of the body. The crus is distal to the femur.
- **Superficial** describes a position closer to the surface of the body. The skin is superficial to the bones.
- **Deep** describes a position farther from the surface of the body. The brain is deep to the skull.

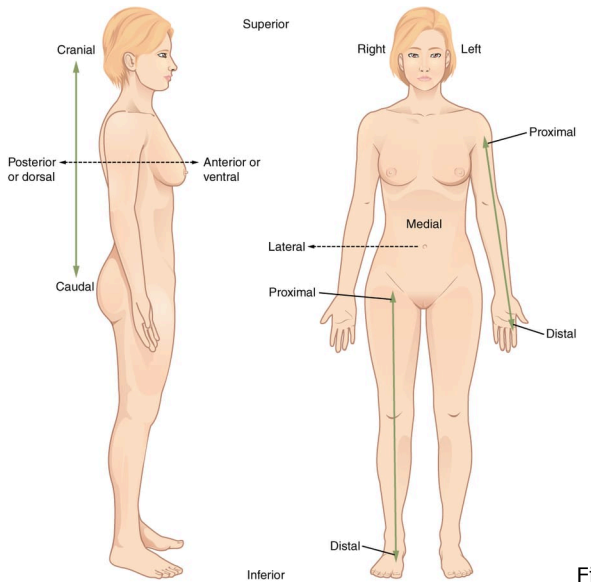


Figure 2.5. Directional Terms Applied to the Human Body. Paired directional terms are shown as applied to the human body. From Betts, et al., 2021. Licensed under CC BY 4.0.

Practice these directional terms.

Query 2.1

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Concept Check

- Find a partner and take turns choosing two body parts on your or your partner's body.
- Using directional terms, describe the location of those body parts relative to one another.

Body Planes

A section is a two-dimensional surface of a three-dimensional structure that has been cut. Modern medical imaging devices enable clinicians to obtain "virtual sections" of living bodies. We call these scans. Body sections and scans can be correctly interpreted, however, only if the viewer understands the plane along which the section was made. A plane is an imaginary two-dimensional surface that passes through the body. There are three planes commonly referred to in anatomy and medicine:

- The **sagittal plane** is the plane that divides the body or an organ vertically into right and left sides. If this vertical plane runs directly down the middle of the body, it is called the midsagittal or median plane. If it divides the body into unequal right and left sides, it is called a parasagittal plane or less commonly a longitudinal section.
- The **frontal plane** is the plane that divides the body or an organ into an anterior (front) portion and a posterior (rear) portion. The frontal plane is often referred to as a coronal plane. ("Corona" is Latin for "crown.")
- The **transverse plane** is the plane that divides the body or organ horizontally into upper and lower portions. Transverse planes produce images referred to as cross sections.

Can you locate the planes?

Query 2.2

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Body Cavities and Serous Membranes

The body maintains its internal organization by means of membranes, sheaths, and other structures that separate compartments. The **dorsal (posterior) cavity** and the **ventral (anterior) cavity** are the largest body compartments (Figure 2.6). These cavities contain and protect delicate internal organs, and the ventral cavity allows for significant changes in the size and shape of the organs as they perform their functions. The lungs, heart, stomach, and intestines, for example, can expand and contract without distorting other tissues or disrupting the activity of nearby organs.

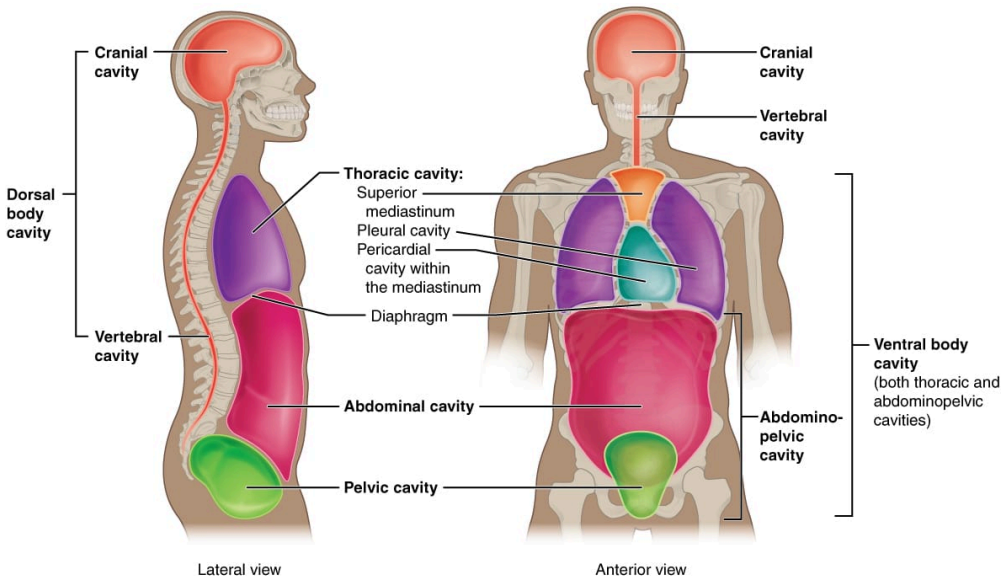


Figure 2.6. Dorsal and Ventral Body Cavities. The ventral cavity includes the thoracic and abdominopelvic cavities and their subdivisions. The dorsal cavity includes the cranial and spinal cavities. From Betts, et al., 2021. Licensed under CC BY 4.0.

Subdivisions of the Posterior (Dorsal) and Anterior (Ventral) Cavities

The posterior (dorsal) and anterior (ventral) cavities are each subdivided into smaller cavities:

The posterior (dorsal) cavity has two main subdivisions:

- In the posterior (dorsal) cavity, the **cranial cavity** houses the brain
  - Protected by the bones of the skulls and cerebrospinal fluid
- The **spinal cavity** (or vertebral cavity) encloses the spinal cord.
  - Protected by the vertebral column and cerebrospinal fluid

The anterior (ventral) cavity has two main subdivisions:

- The **thoracic cavity** is the more superior subdivision of the anterior cavity, and it is enclosed by the rib cage.
  - The thoracic cavity contains the lungs and the heart, which is located in the mediastinum.
  - The diaphragm forms the floor of the thoracic cavity and separates it from the more inferior abdominopelvic cavity.
- The **abdominopelvic cavity** is the largest cavity in the body.
  - No membrane physically divides the abdominopelvic cavity.
  - The abdominal cavity houses the digestive organs, the pelvic cavity, and the reproductive organs.

Practice locating cavities.

Query 2.3

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Abdominal Regions and Quadrants

To promote clear communication, for instance about the location of a patient's abdominal pain or a suspicious mass, health care providers typically divide up the cavity into either nine regions or four quadrants.

Practice locating the quadrants.

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Tissue Membranes

A **tissue membrane** is a thin layer or sheet of cells that covers the outside of the body (for example, skin), the organs (for example, pericardium), internal passageways that lead to the exterior of the body (for example, abdominal mesenteries), and the lining of the movable joint cavities. There are two basic types of tissue membranes: connective tissue and epithelial membranes (Figure 2.7).

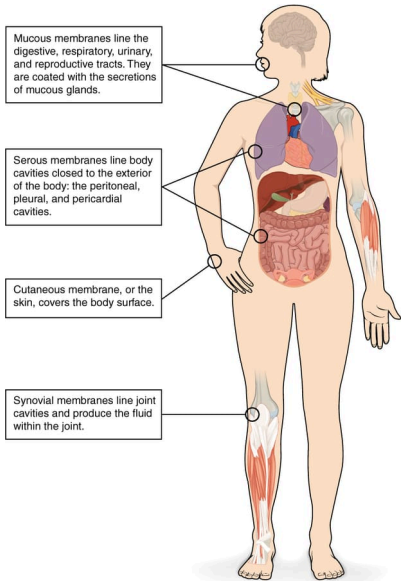


Figure 2.7. Tissue Membranes. The two broad categories of tissue membranes in the body are (1) connective tissue membranes, which include synovial membranes, and (2) epithelial membranes, which include mucous membranes, serous membranes, and the cutaneous membrane, in other words, the skin. From Betts, et al., 2021. Licensed under CC BY 4.0.

Did you know?

Synovial membranes line cavities which hold synovial fluid.

Synovial fluid lubricates the joints for movement.

Connective Tissue Membranes

- The **connective tissue membrane** is formed solely from connective tissue.
  - These membranes encapsulate organs, such as the kidneys, and line our movable joints.
- A **synovial membrane** is a type of connective tissue membrane that lines the cavity of a freely movable joint.
  - For example, synovial membranes surround the joints of the shoulder, elbow, and knee.

Epithelial Membranes

- The **epithelial membrane** is composed of epithelium attached to a layer of connective tissue.
  - For example, your skin.
- The **mucous membrane** is also a composite of connective and epithelial tissues.
  - Sometimes called mucosa, these epithelial membranes line the body cavities and hollow passageways that open to the external environment, and include the digestive, respiratory, excretory, and reproductive tracts.
  - Mucus, produced by the epithelial exocrine glands, covers the epithelial layer.
  - The underlying connective tissue, called the **lamina propria** (literally “own layer”), help support the fragile epithelial layer.
- The skin is an epithelial membrane also called the **cutaneous membrane**.
  - It is a stratified squamous epithelial membrane resting on top of connective tissue. The apical surface of this membrane is exposed to the external environment and is covered with dead, keratinized cells that help protect the body from desiccation and pathogens.

Membranes of the Anterior (Ventral) Body Cavity

- A **serous membrane** (also referred to as serosa) is an epithelial membrane composed of mesodermally derived epithelium called the mesothelium that is supported by connective tissue.
  - **Parietal layers:** line the walls of the body cavity.

- **Visceral layer:** covers the organs (the viscera).
- Between the parietal and visceral layers is a very thin, fluid-filled **serous space.**

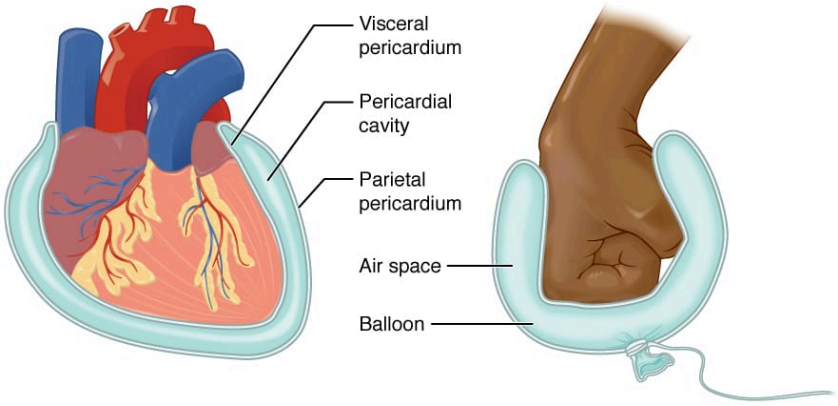


Figure 2.8. Serous Membrane. Serous membrane lines the pericardial cavity and reflects back to cover the heart—much the same way that an underinflated balloon would form two layers surrounding a fist. From Betts, et al., 2021. Licensed under CC BY 4.0.

There are three serous cavities and their associated membranes. Serous membranes provide additional protection to the viscera they enclose by reducing friction that could lead to inflammation of the organs.

- **Pleura**: surrounds the lungs in the pleural cavity and reduces friction between the lungs and the body wall.
- **Pericardium:** surrounds the heart in the pericardial cavity and reduces friction between the heart and the wall of the pericardium.
- **Peritoneum:** surrounds several organs in the abdominopelvic cavity. The peritoneal cavity reduces friction between the abdominal and pelvic organs and the body wall.

Test Yourself

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[CrashCourse]. (2015, January 6). *Introduction to anatomy & physiology: Crash course A&P #1* [Video]. YouTube. https://youtu.be/uBGI2BujkPQ

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3: Integumentary System

Learning Objectives

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

Integumentary System Word Parts

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

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Introduction to the Integumentary System

Did You Know?

The skin and accessory structures are the largest organ system in the human body.

The integumentary system refers to the skin and its accessory structures. In the adult human body, the skin makes up about 16 percent of body weight and covers an area of 16-21 ft^2.

In fact, the skin and accessory structures are the largest organ system in the human body. The skin protects your inner organs and it is in need of daily care and protection to maintain its health.

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Media 3.1. The science of skin – Emma Bryce [Video]. Copyright 2018 by Ted-Ed.

Practice integumentary system medical terms.

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Anatomy (Structures) of the Integumentary System

The skin and its accessory structures make up the integumentary system, which provides the body with overall protection. The skin is made of multiple layers of cells and tissues, which are held to underlying structures by connective tissue. The deeper layer of skin is well vascularized. It also has numerous sensory, and autonomic and sympathetic nerve fibers ensuring communication to and from the brain.

The skin is composed of two main layers:

1. The epidermis
2. The dermis
    1. Beneath the dermis lies the hypodermis

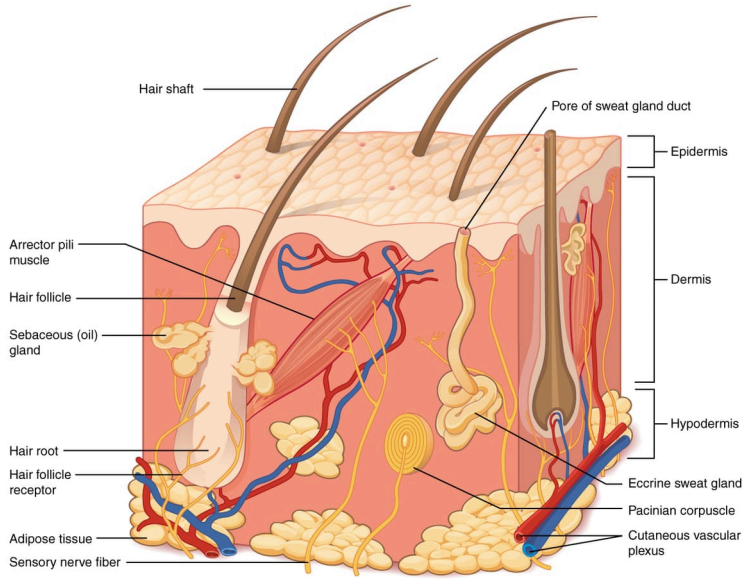


Figure 3.1 Layers of Skin. From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

- On the diagram above find the two layers of the skin; **epidermis** and **dermis**.
- The literal breakdown for **hypodermis** is below the dermis. On the diagram above where can you locate it?
- Can you find a **hair follicle**, **hair root** and **hair shaft**?
- Keep reading to find out what the **arrector pilli muscle** does when you are frightened.

Epidermis

The epidermis is composed of keratinized, stratified squamous epithelium. It is made of four or five layers of epithelial cells, depending on its location in the body. It is avascular.

The cells in all of the layers except the stratum basale are called keratinocytes. **Keratin** is an intracellular fibrous protein that gives hair, nails, and skin their hardness and water-resistant properties. The keratinocytes in the stratum corneum are dead and regularly slough away, being replaced by cells from the deeper layers.

Dermis

The dermis contains blood and lymph vessels, nerves, and other structures, such as hair follicles and sweat glands. The dermis is made of two layers (papillary layer and reticular layer) of connective tissue that compose an interconnected mesh of elastin and collagenous fibers, produced by fibroblasts (see Figure 3.2).

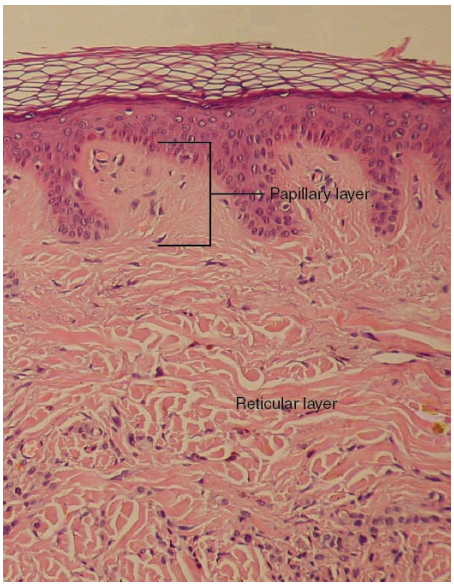


Figure 3.2 Layers of the Dermis. This stained slide shows the two components of the dermis—the papillary layer and the reticular layer. Both are made of connective tissue with fibers of collagen extending from one to the other, making the border between the two somewhat indistinct. The dermal papillae extending into the epidermis belong to the papillary layer, whereas the dense collagen fiber bundles below belong to the reticular layer. LM × 10. (credit: modification of work by "kilbad"/Wikimedia Commons). From Betts, et al., 2021. Licensed under CC BY 4.0.

Papillary Layer

The papillary layer is made of loose, areolar connective tissue, which means the collagen and elastin fibers of this layer form a loose mesh. This superficial layer of the dermis projects into the stratum basale of the epidermis to form finger-like dermal papillae (see Figure 3.2). Within the papillary layer are fibroblasts, a small number adipocytes, and an abundance of small blood vessels. In addition, the papillary layer contains phagocytes, that help fight bacteria or other infections that have breached the skin. This layer also contains lymphatic capillaries, nerve fibers, and Meissner corpuscles.

Reticular Layer

Underlying the papillary layer is the much thicker reticular layer, composed of dense, irregular connective tissue. This layer is well vascularized and has a rich sensory and sympathetic nerve supply. The reticular layer appears reticulated due to a tight meshwork of fibers. Elastin fibers provide some elasticity to the skin, enabling movement. Collagen fibers provide structure and tensile strength, with strands of collagen extending into both the papillary layer and the hypodermis. In addition, collagen binds water to keep the skin hydrated. Collagen injections and Retin-A creams help restore skin turgor by either introducing collagen externally or stimulating blood flow and repair of the dermis, respectively.

Hypodermis

The hypodermis serves to connect the skin to the underlying fascia of the bones and muscles. It is not strictly a part of the skin, although the border between the hypodermis and dermis can be difficult to distinguish. The hypodermis consists of well-vascularized, loose, areolar connective tissue and [pb_glossary id="1697"]adipose[/pb_glossary] tissue, which functions as a mode of fat storage and provides insulation and cushioning for the integument.

Practice labeling the layers of the skin.

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Physiology (Function) of the Integumentary System

The skin and accessory structures perform a variety of essential functions, such as protecting the body from invasion by microorganisms, chemicals, and other environmental factors; preventing dehydration; acting as a sensory organ; modulating body temperature and electrolyte balance; and synthesizing vitamin D. The underlying hypodermis has important roles in storing fats, forming a “cushion” over underlying structures, and providing insulation from cold temperatures.

Protection

The skin protects the body from wind, water, and UV sunlight. It acts as a protective barrier against water loss and it also is the first line of defense against abrasive activity such as grit, microbes, or harmful chemicals. Sweat excreted from sweat glands deters microbes from over-colonizing the skin surface.

Sensory Function

The skin acts as a sense organ because the epidermis, dermis, and the hypodermis contain specialized sensory nerve structures that detect touch, surface temperature, and pain. These receptors are more concentrated on the tips of the fingers, which are most sensitive to touch, especially the Meissner corpuscle, which responds to light touch, and the Pacinian corpuscle , which responds to vibration. Merkel cells, seen scattered in the stratum basale, are also touch receptors. In addition to these specialized receptors, there are sensory nerves connected to each hair follicle, pain and temperature receptors scattered throughout the skin, and motor nerves innervate the arrector pili muscles and glands. This rich innervation helps us sense our environment and react accordingly,

Thermoregulation

The integumentary system helps regulate body temperature through its tight association with the sympathetic nervous system. The sympathetic nervous system is continuously monitoring body temperature and initiating appropriate motor responses.

1. When the **body becomes warm** sweat glands, accessory structures to the skin, secrete water, salt, and other substances to cool the body.
    1. Even when the body does not appear to be noticeably sweating, approximately 500 mL of sweat are secreted a day.
2. If the **body becomes excessively warm** due to high temperatures, vigorous activity, or a combination of the two, sweat glands will be stimulated by the sympathetic nervous system to produce large amounts of sweat.
    1. When the sweat evaporates from the skin surface, the body is cooled as body heat is dissipated.
    2. In addition to sweating, arterioles in the dermis dilate so that excess heat carried by the blood can dissipate through

the skin and into the surrounding environment.
   3. This accounts for the skin redness that many people experience when exercising.
3. When **body temperatures drop**, the arterioles constrict to minimize heat loss, particularly in the ends of the digits and tip of the nose.
   1. This reduced circulation can result in the skin taking on a whitish hue.
   2. Although the temperature of the skin drops as a result, passive heat loss is prevented, and internal organs and structures remain warm.
   3. If the temperature of the skin drops too much (such as environmental temperatures below freezing), the conservation of body core heat can result frostbite .

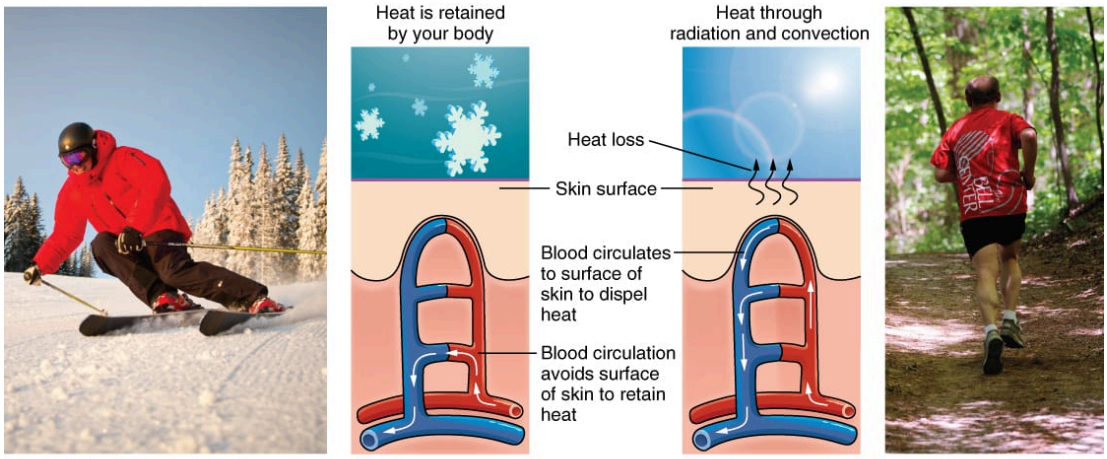


Figure 3.3 Thermoregulation. During strenuous physical activities, such as skiing (a) or running (c), the dermal blood vessels dilate and sweat secretion increases (b). These mechanisms prevent the body from overheating. In contrast, the dermal blood vessels constrict to minimize heat loss in response to low temperatures (b). (credit a: "Trysil"/flickr; credit c: Ralph Daily). From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

Can you describe the **thermoregulation** process between the integumentary system and the sympathetic system?

- When body temperature is too warm.
- When body temperature is too cold.

Vitamin D Synthesis

Did You Know?

Vitamin D is essential for general immunity against bacterial, viral and fungal infections.

The epidermal layer of human skin synthesizes Vitamin D when exposed to UV radiation. In the presence of sunlight, a form of Vitamin D_3 called cholecalciferol is synthesized from a derivative of the steroid cholesterol in the skin. The liver converts cholecalciferol to calcidiol, which is then converted to calcitriol (the active chemical form of the vitamin) in the kidneys.

- Vitamin D is essential for normal absorption of calcium and phosphorous, which are required for healthy bones.
- The absence of sun exposure can lead to a lack of vitamin D in the body, in children this can cause rickets. Vitamin D deficiency in elderly individuals may lead to osteomalacia.
- In present day society, Vitamin D is added as a supplement to many foods, including milk and orange juice, compensating

for the need for sun exposure. In addition to its essential role in bone health, Vitamin D is essential for general immunity against bacterial, viral, and fungal infections.

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Accessory Structures

Accessory structures of the skin include hair, nails, sweat glands, and sebaceous glands. These structures embryologically originate from the epidermis and can extend down through the dermis into the hypodermis.

Hair

Hair is a keratinous filament growing out of the epidermis. It is primarily made of dead, keratinized cells. Strands of hair originate in an epidermal penetration of the dermis called the hair follicle. The hair shaft is the part of the hair not anchored to the follicle, and much of this is exposed at the skin's surface. The rest of the hair, which is anchored in the follicle, lies below the surface of the skin and is referred to as the hair root. The hair root ends deep in the dermis at the hair bulb, and includes a layer of mitotically active basal cells called the hair matrix. The hair bulb surrounds the hair papilla, which is made of connective tissue and contains blood capillaries and nerve endings from the dermis (see Figure 3.4).

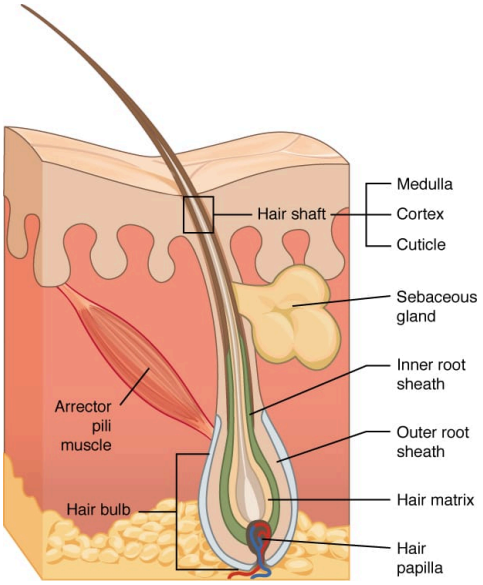


Figure 3.4 Hair. Hair follicles originate in the epidermis and have many different parts. From Betts, et al., 2021. Licensed under CC BY 4.0.

Hair Function

Did You Know?

When frightened, the arrector pili muscle is responsible for your hair standing on end. The same is true when a cat's fur is raised.

Hair serves a variety of functions, including protection, sensory input, thermoregulation, and communication. For example:

- Hair on the head **protects** the skull from the sun.
- Hair in the nose and ears, and around the eyes (eyelashes) **defends** the body by trapping and excluding dust particles that may contain allergens and microbes.
- Hair of the eyebrows **prevents** sweat and other particles from dripping into and bothering the eyes.

Hair also has a **sensory function** due to sensory innervation by a hair root plexus surrounding the base of each hair follicle. Hair is extremely sensitive to air movement or other disturbances in the environment, much more so than the skin surface. This feature is also useful for the **detection** of the presence of insects or other potentially damaging substances on the skin surface.

Each hair root is connected to a smooth muscle called the arrector pili that contracts in response to nerve signals from the sympathetic nervous system, making the external hair shaft "stand up." The primary purpose for this is to trap a layer of air to add insulation. This is visible in humans as goose bumps and even more obvious in animals, such as when a frightened cat raises its fur. Of course, this is much more obvious in organisms with a heavier coat than most humans, such as dogs and cats.

Hair Growth, Loss and Color

Hair grows and is eventually shed and replaced by new hair. Hair typically grows at the rate of 0.3 mm per day. On average, 50 hairs are lost and replaced per day. Hair loss occurs if there is more hair shed than what is replaced and can happen due to hormonal or dietary changes. Hair loss can also result from the aging process, or the influence of hormones. Similar to the skin, hair gets its color from the pigment melanin, produced by melanocytes in the hair papilla. Different hair color results from differences in the type of melanin. As a person ages, the melanin production decreases, and hair tends to lose its color and becomes gray and/or white.

Nails

The **nail bed** is a specialized structure of the epidermis that is found at the tips of our fingers and toes. The nail body is formed on the nail bed, and protects the tips of our fingers and toes as they are the farthest extremities and the parts of the body that experience the maximum mechanical stress (see Figure 3.5). The nail body forms a back-support for picking up small objects with the fingers. The nail body is composed of densely packed dead keratinocytes.

The epidermis in this part of the body has evolved a specialized structure upon which nails can form. The nail body forms at the nail root, which has a matrix of proliferating cells from the stratum basale that enables the nail to grow continuously. The lateral nail fold overlaps the nail on the sides, helping to anchor the nail body. The nail fold that meets the proximal end of the nail body forms the nail cuticle, also called the eponychium.

The nail bed is rich in blood vessels, making it appear pink, except at the base, where a thick layer of epithelium over the nail matrix forms a crescent-shaped region called the **lunula (the "little moon").** The area beneath the free edge of the nail, furthest from the cuticle, is called the hyponychium. It consists of a thickened layer of stratum corneum.

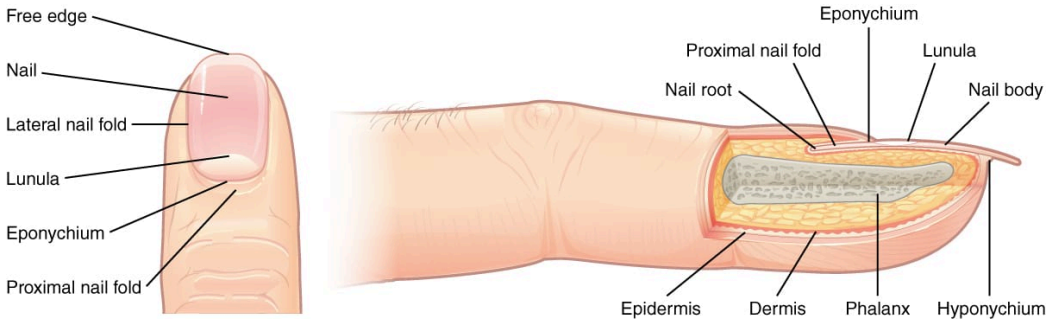


Figure 3.5 Nails. The nail is an accessory structure of the integumentary system. From Betts, et al., 2021. Licensed under CC BY 4.0.

Sweat Glands

Sudoriferous Glands

When the body becomes warm, sudoriferous glands produce sweat to cool the body. Sweat glands develop from epidermal projections into the dermis and are classified as merocrine glands; that is, the secretions are excreted by exocytosis through a duct without affecting the cells of the gland. There are two types of sweat glands, each secreting slightly different products.

An **eccrine sweat gland** is type of gland that produces a hypotonic sweat for thermoregulation as described previously. These glands are found all over the skin's surface, but are especially abundant on the palms of the hand, the soles of the feet, and the forehead (Figure 3.6). They are coiled glands lying deep in the dermis, with the duct rising up to a pore on the skin surface, where the sweat is released. This type of sweat, released by exocytosis, is hypotonic and composed mostly of water, with some salt, antibodies, traces of metabolic waste, and dermicidin, an antimicrobial peptide. **Eccrine glands** are a primary component of thermoregulation in humans and thus help to maintain homeostasis .

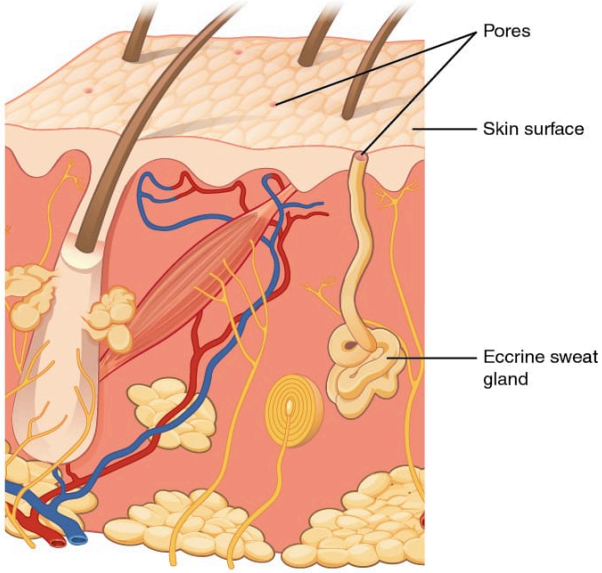


Figure 3.6 Eccrine Gland. Eccrine glands are coiled glands in the dermis that release sweat that is mostly water. From Betts, et al., 2021. Licensed under CC BY 4.0.

An **apocrine sweat gland** is usually associated with hair follicles in densely hairy areas, such as armpits and genital regions. Apocrine sweat glands are larger than eccrine sweat glands and lie deeper in the dermis, sometimes even reaching the hypodermis, with the duct normally emptying into the hair follicle. In addition to water and salts, apocrine sweat includes organic compounds that make the sweat thicker and subject to bacterial decomposition and subsequent smell. The release of this sweat is under both nervous and hormonal control, and plays a role in the poorly understood human pheromone response. Most commercial antiperspirants use an aluminum-based compound as their primary active ingredient to stop sweat. When the antiperspirant enters the sweat gland duct, the aluminum-based compounds precipitate due to a change in pH and form a

physical block in the duct, which prevents sweat from coming out of the pore.

Did You Know?

Aluminum-based compounds due to a change in pH form a physical block in the sweat gland duct. This prevents sweating.

Sebaceous Glands

A **sebaceous gland** is a type of oil gland that is found all over the body and helps to lubricate and waterproof the skin and hair. Most sebaceous glands are associated with hair follicles. They generate and excrete sebum, a mixture of lipids, onto the skin surface, thereby naturally lubricating the dry and dead layer of keratinized cells of the stratum corneum, keeping it pliable. The fatty acids of sebum also have antibacterial properties, and prevent water loss from the skin in low-humidity environments. The secretion of sebum is stimulated by hormones, many of which do not become active until puberty. Thus, sebaceous glands are relatively inactive during childhood.

Words not Easily Broken into Word Parts

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Common Integumentary System Abbreviations

Many terms and phrases related to the integumentary system are abbreviated. Learn these common abbreviations by expanding the list below.

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Changes Due to Aging

All systems in the body accumulate subtle and some not-so-subtle changes as a person ages. Among these changes are reductions in cell division, metabolic activity, blood circulation, hormonal levels, and muscle strength (see Figure 3.7). In the skin, these changes are reflected in decreased mitosis in the stratum basale, leading to a thinner epidermis. The dermis, which is responsible for the elasticity and resilience of the skin, exhibits a reduced ability to regenerate, which leads to slower wound healing. The hypodermis, with its fat stores, loses structure due to the reduction and redistribution of fat, which in turn contributes to the thinning and sagging of skin.



Figure 3.7 Aging. Generally, skin, especially on the face and hands, starts to display the first noticeable signs of aging, as it loses its elasticity over time. (credit: Janet Ramsden). From Betts, et al., 2021. Licensed under CC BY 4.0.

Did You Know?

A reduced sweating ability can cause some elderly to be intolerant to extreme heat.

The accessory structures also have lowered activity, generating thinner hair and nails, and reduced amounts of sebum and sweat. A reduced sweating ability can cause some elderly to be intolerant to extreme heat. Other cells in the skin, such as melanocytes and dendritic cells, also become less active, leading to a paler skin tone and lowered immunity. Wrinkling of the skin occurs due to breakdown of its structure, which results from decreased collagen and elastin production in the dermis, weakening of muscles lying under the skin, and the inability of the skin to retain adequate moisture.

Disease and Disorders

The integumentary system is susceptible to a variety of diseases, disorders, and injuries. These range from annoying but relatively benign bacterial or fungal infections that are categorized as disorders, to skin cancer and severe burns, which can be fatal. In this section, you will learn several of the most common skin conditions.

One of the most talked about diseases is skin cancer. Most cancers are identified by the organ or tissue in which the cancer originates. One common form of cancer is skin cancer.

In general, cancers result from an accumulation of DNA mutations. These mutations can result in cell populations that do not die when they should and uncontrolled cell proliferation that leads to tumors. Although many tumors are benign, some metastasize. Cancers are characterized by their ability to metastasize.

Sun Damage

It requires about 10 days after initial sun exposure for melanin synthesis to peak, which is why pale-skinned individuals tend to suffer sunburns of the epidermis initially. Dark-skinned individuals can also get sunburns, but are more protected than are pale-skinned individuals. Too much sun exposure can eventually lead to wrinkling due to the destruction of the cellular structure of the skin, and in severe cases, can cause sufficient DNA damage to result in skin cancer. When there is an irregular accumulation of melanocytes in the skin, freckles appear. Moles are larger masses of melanocytes, and although most are benign, they should be monitored for changes that might indicate the presence of cancer (see Figure 3.8).



Figure 3.8 Moles. Moles range from benign accumulations of melanocytes to melanomas. These structures populate the landscape of our skin. (credit: the National Cancer Institute). From Betts, et al., 2021. Licensed under CC BY 4.0.

Basal Cell Carcinoma (BCC)

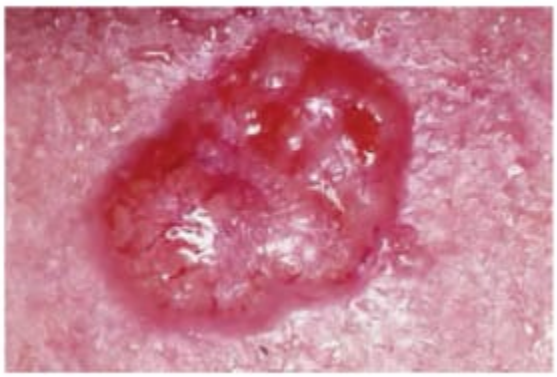


Figure 3.9 Basal Cell Carcinoma. Basal cell carcinoma can take several different forms. Similar to other forms of skin cancer, it is readily cured if caught early and treated. (credit: John Hendrix, MD). From Betts, et al., 2021. Licensed under CC BY 4.0.

Basal cell carcinoma is a form of cancer that affects the mitotically active stem cells in the stratum basale of the epidermis. It is the most common of all cancers that occur in the United States and is frequently found on the head, neck, arms, and back, which are are as that are most susceptible to long-term sun exposure. Although UV rays are the main culprit, exposure to other agents, such as radiation and arsenic, can also lead to this type of cancer. Wounds on the skin due to open sores, tattoos, burns, etc. may be predisposing factors. Basal cell carcinomas start in the stratum basale and usually spread along this boundary. At some point, they begin to grow toward the surface and become an uneven patch, bump, growth, or scar on the skin surface (see Figure 3.9). Like most cancers, basal cell carcinomas respond best to treatment when caught early. Treatment options include surgery, freezing (cryosurgery), and topical ointments.

Squamous Cell Carcinoma (SCC)

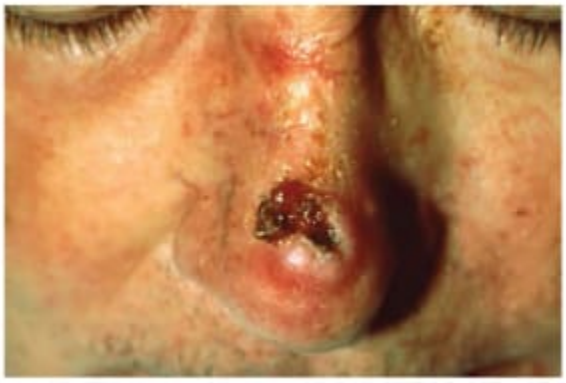


Figure 3.10 Squamous Cell Carcinoma Squamous cell carcinoma presents here as a lesion on a nose. (credit: the National Cancer Institute). From Betts, et al., 2021. Licensed under CC BY 4.0.

Squamous cell carcinoma is a cancer that affects the keratinocytes of the stratum spinosum and presents as lesions commonly found on the scalp, ears, and hands (see Figure 3.10). It is the second most common skin cancer. The American Cancer Society reports that two of 10 skin cancers are squamous cell carcinomas, and it is more aggressive than basal cell carcinoma. If not removed, these carcinomas can metastasize. Surgery and radiation are used to cure squamous cell carcinoma.

Melanoma

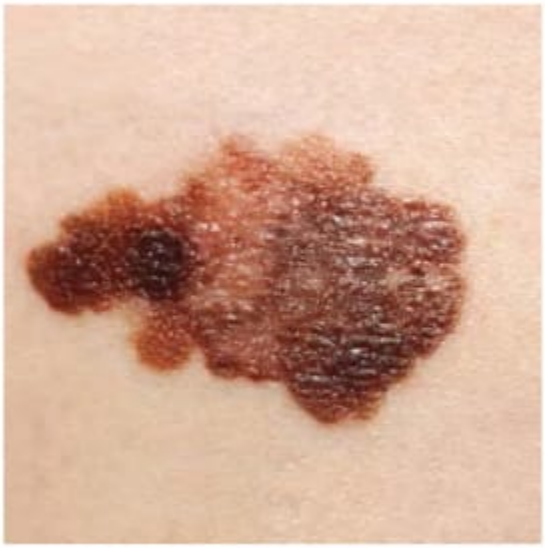


Figure 3.11 Melanoma. Melanomas typically present as large brown or black patches with uneven borders and a raised surface. (credit: the National Cancer Institute). From Betts, et al., 2021. Licensed under CC BY 4.0.

A melanoma is a cancer characterized by the uncontrolled growth of melanocytes, the pigment-producing cells in the epidermis. Typically, a melanoma develops from a mole. It is the most fatal of all skin cancers, as it is highly metastatic and can be difficult to detect before it has spread to other organs. Melanomas usually appear as asymmetrical brown and black patches with uneven borders and a raised surface (see Figure 3.11). Treatment typically involves surgical excision and immunotherapy.

ABCDE for Early Diagnosis

Doctors often give their patients the following ABCDE mnemonic to help with the diagnosis of early-stage melanoma (see Fig 3.12). If you observe a mole on your body displaying these signs, consult a doctor.

- **A**symmetry – the two sides are not symmetrical

- **B**orders – the edges are irregular in shape
- **C**olor – the color is varied shades of brown or black
- **D**iameter – it is larger than a pencil eraser
- **E**volving – its shape has changed

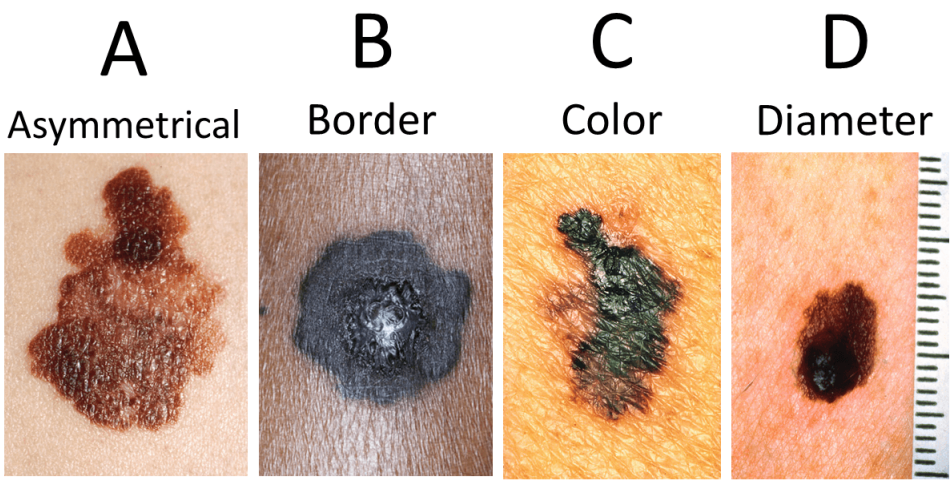


Fig 3.12 The ABC's of early diagnosis. Example of abnormal moles. (credit: the National Cancer Institute, moles C&D, n.d.). Mole A from Betts, et al., 2021. Licensed under CC BY 4.0.

Some specialists cite the following additional signs for the most serious form, nodular melanoma:

Elevated – it is raised on the skin surface
Firm – it feels hard to the touch
Growing – it is getting larger

Albinism

Albinism is a genetic disorder that affects (completely or partially) the coloring of skin, hair, and eyes. This is primarily due to the inability of melanocytes to produce melanin. Individuals with albinism tend to appear white or very pale due to the lack of melanin in their skin and hair. Recall that melanin helps protect the skin from the harmful effects of UV radiation. Individuals with albinism tend to need more protection from UV radiation, as they are more prone to sunburns and skin cancer. They also tend to be more sensitive to light and have vision problems due to the lack of pigmentation on the retinal wall (Betts, et al., 2021)

Treatment of this disorder usually involves addressing the symptoms, such as limiting UV light exposure to the skin and eyes. In **vitiligo**, the melanocytes in certain areas lose their ability to produce melanin, possibly due to an autoimmune reaction. This leads to a loss of color in patches (see Figure 3.13). Neither albinism nor vitiligo directly affects the lifespan of an individual (Betts, et al., 2021)



Figure 3.13 Vitiligo. Individuals with vitiligo experience depigmentation that results in lighter colored patches of skin. The condition is especially noticeable on darker skin. (credit: Klaus D. Peter). From Betts, et al., 2021. Licensed under CC BY 4.0.

Changes in Skin Coloration

Other changes in the appearance of skin coloration can be indicative of diseases associated with other body systems.

- Liver disease or liver cancer can cause the accumulation of bile and the yellow pigment bilirubin, leading to xanthoderma or jaundice.
- Tumors of the pituitary gland can result in the secretion of large amounts of melanocyte-stimulating hormone (MSH), which results in a **darkening** of the skin.
- Addison's disease can stimulate the release of excess amounts of adrenocorticotropic hormone (ACTH), which can give the skin a **deep bronze** color
- A sudden drop in oxygenation can affect skin color, causing the skin to initially turn **ashen** (white).
- A prolonged reduction in oxygen levels, dark red deoxyhemoglobin becomes dominant in the blood, making the skin appear **blue**, a condition referred to as cyanosis. This happens when the oxygen supply is restricted, as when someone is experiencing difficulty in breathing because of asthma or a heart attack. However, in these cases the effect on skin color has nothing do with the skin's pigmentation (Betts, et al., 2021)

Skin Disorders

Two common skin disorders are **eczema** and **acne**. Eczema is an inflammatory condition and occurs in individuals of all ages. Acne involves the clogging of pores, which can lead to infection and inflammation, and is often seen in adolescents. Other disorders, include seborrheic dermatitis (on the scalp), psoriasis, fungal infections, cold sores, impetigo, scabies, hives, and warts (Betts, et al., 2021).

Eczema



Figure 3.14 Eczema. Eczema is a common skin disorder that presents as a red, flaky rash. (credit: "Jambula"/Wikimedia Commons). From Betts, et al., 2021. Licensed under CC BY 4.0.

Eczema is an allergic reaction that manifests as dry, itchy patches of skin that resemble rashes (see Figure 3.14). It may be accompanied by swelling of the skin, flaking, and in severe cases, bleeding. Symptoms are usually managed with moisturizers, corticosteroid creams, and immunosuppressants (Betts, et al., 2021).

Acne

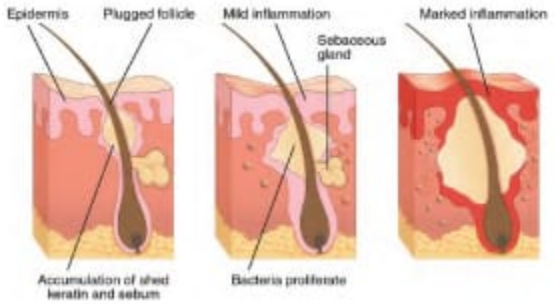


Figure 3.15. Acne. Acne is a result of over-productive sebaceous glands, which leads to formation of blackheads and inflammation of the skin. From Betts, et al., 2021. Licensed under CC BY 4.0.

Acne is a skin disturbance that typically occurs on areas of the skin that are rich in sebaceous glands (face and back). It is most common along with the onset of puberty due to associated hormonal changes, but can also occur in infants and continue into adulthood. Hormones, such as androgens, stimulate the release of sebum. An overproduction and accumulation of sebum along with keratin can block hair follicles. This plug is initially white. The sebum, when oxidized by exposure to air, turns black. Acne results from infection by acne-causing bacteria (*Propionibacterium* and *Staphylococcus*), which can lead to redness and potential scarring due to the natural wound healing process (see Figure 3.15) (Betts, et al., 2021).

Ringworm

Tinea or dermatophytosis is often referred to as ringworm. Ringworm presents as a circular rash that is itchy and red and can be found on various parts of the body. It is referred to by the location that it is found:

- Tinea Pedis – feet or commonly referred to as athlete's feet
- Tinea Capitis – scalp
- Tinea barbae – beard
- Tinea manuum – hands
- Tinea unguium – Toenails and fingernails also called onychomycosis
- Tinea corporis – Body parts such as arms and legs (Center for Disease Control and Prevention, 2018a)

To learn more about ringworm, visit the Center for Disease Control and Prevention's web page on fungal infections.

Psoriasis

Psoriasis is a chronic autoimmune disorder that results in patches of thick red skin with the appearance of silvery scales. These patches can be found on elbows, knees, scalp, low back, face, feet, fingernails, toenails and even the mouth. Psoriasis can be confused with other skin disease so a dermatologist is the best physician to diagnosis psoriasis. Treatments may include creams, ointments, ultraviolet light therapy and medication (Center for Disease Control and Prevention, 2018). To learn more, visit the Center for Disease Control and Prevention's web page on psoriasis.

Injuries

Because the skin is the part of our bodies that meets the world most directly, it is especially vulnerable to injury. Injuries include **burns, wounds**, as well as **scars** and **calluses**. They can be caused by sharp objects, heat, or excessive pressure or friction to the skin (Betts, et al., 2021).

Skin injuries set off a healing process that occurs in several overlapping stages.

- The first step to repairing damaged skin is the **formation of a blood clot** that helps stop the flow of blood and scabs over with time. Many different types of cells are involved in wound repair, especially if the surface area that needs repair is extensive.
- Before the basal stem cells of the stratum basale can **recreate the epidermis,** fibroblasts mobilize and divide rapidly to **repair the damaged tissue** by collagen deposition, forming granulation tissue.
- Blood capillaries follow the fibroblasts and help **increase blood circulation and oxygen** supply to the area.
- Immune cells, such as macrophages, roam the area and **engulf any foreign matter** to reduce the chance of infection (Betts, et al., 2021).

Burns

A burn results when the skin is damaged by intense heat, radiation, electricity, or chemicals. The damage results in the death of skin cells, which can lead to a massive loss of fluid. Dehydration, electrolyte imbalance, and renal and circulatory failure follow, which can be fatal. Burn patients are treated with intravenous fluids to offset dehydration, as well as intravenous nutrients that enable the body to repair tissues and replace lost proteins. Another serious threat to the lives of burn patients is infection. Burned skin is extremely susceptible to bacteria and other pathogens, due to the loss of protection by intact layers of skin (Betts, et al., 2021).

Burn Classification

Burns are sometimes measured in terms of the size of the total surface area affected. This is referred to as the *rule of nines*, which associates specific anatomical areas with a percentage that is a factor of nine (see Figure 3.16) (Betts, et al., 2021).

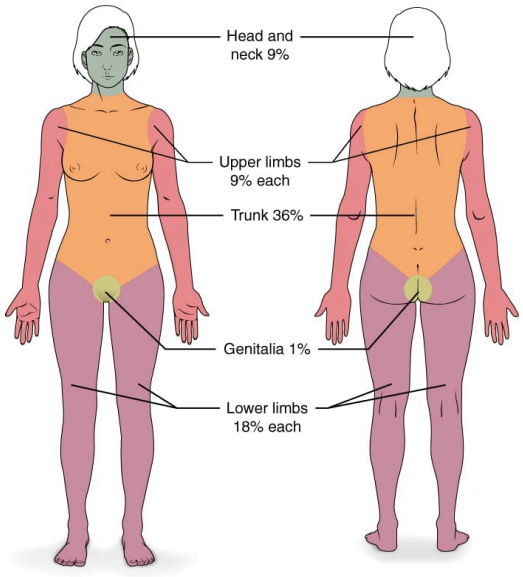


Figure 3.16 Calculating the Size of a Burn. The size of a burn will guide decisions made about the need for specialized treatment. Specific parts of the body are associated with a percentage of body area. From Betts, et al., 2021. Licensed under CC BY 4.0.

Burns are also classified by the **degree of their severity**.

- A **first-degree** burn is a superficial burn that affects only the epidermis. Although the skin may be painful and swollen, these burns typically heal on their own within a few days. Mild sunburn fits into the category of a first-degree burn.
- A **second-degree** burn goes deeper and affects both the epidermis and a portion of the dermis. These burns result in swelling and a painful blistering of the skin. It is important to keep the burn site clean and sterile to prevent infection. If this is done, the burn will heal within several weeks.
- A **third-degree** burn fully extends into the epidermis and dermis, destroying the tissue and affecting the nerve endings and sensory function. These are serious burns that may appear white, red, or black; they require medical attention and will heal slowly without it.
- A **fourth-degree** burn is even more severe, affecting the underlying muscle and bone.

Oddly, third and fourth-degree burns are usually not as painful because the nerve endings themselves are damaged. Full-thickness burns cannot be repaired by the body, because the local tissues used for repair are damaged and require debridement, or amputation in severe cases, followed by grafting of the skin from an unaffected part of the body, or from skin grown in tissue culture for grafting purposes. Skin grafts are required when the damage from trauma or infection cannot be closed with sutures or staples (Betts et al., 2021).

Scars and Keloids

Most cuts or wounds, with the exception of ones that only scratch the epidermis, lead to scar formation. Scarring occurs in cases in which there is repair of skin damage, but the skin fails to regenerate the original skin structure. Fibroblasts generate scar tissue in the form of collagen, and the bulk of repair is due to the basket-weave pattern generated by collagen fibers and does not result in regeneration of the typical cellular structure of skin. Instead, the tissue is fibrous in nature and does not allow for the regeneration of accessory structures, such as hair follicles, sweat glands, or sebaceous glands (Betts, et al., 2021).

Sometimes, there is an overproduction of scar tissue, because the process of collagen formation does not stop when the wound is healed; this results in a keloid (see Figure 3.17). In contrast, scars that result from acne and chickenpox have a sunken appearance and are called atrophic scars (Betts, et al., 2021).



Figure 3.17 Post surgical keloid on abdomen. From Htirgan. Licensed under CC BY-SA 3.0.

Scarring of skin after wound healing is a natural process and does not need to be treated further. Application of mineral oil and lotions may reduce the formation of scar tissue. However, modern cosmetic procedures, such as dermabrasion, laser treatments, and filler injections have been invented as remedies for severe scarring. All of these procedures try to reorganize the structure of the epidermis and underlying collagen tissue to make it look more natural (Betts, et al., 2021).

Bedsores and Stretch Marks

Skin and its underlying tissue can be affected by excessive pressure. One example of this is called a bedsore. Bedsores, also called decubitis ulcers, are caused by constant, long-term, unrelieved pressure on certain body parts that are bony, reducing blood flow to the area and leading to necrosis . Bedsores are most common in elderly patients who have debilitating conditions that cause them to be immobile. Most hospitals and long-term care facilities have the practice of turning the patients every few hours to prevent the incidence of bedsores. If left untreated bedsores can be fatal if they become infected (Betts, et al., 2021)

The skin can also be affected by pressure associated with rapid growth. A stretch mark results when the dermis is stretched beyond its limits of elasticity, as the skin stretches to accommodate the excess pressure. Stretch marks usually accompany rapid weight gain during puberty and pregnancy. They initially have a reddish hue, but lighten over time. Other than for cosmetic reasons, treatment of stretch marks is not required. They occur most commonly over the hips and abdomen (Betts, et al., 2021). For detailed images of types of bedsores, see Minnesota Hospital Association's Pressure Ulcer Staging Cards.

Calluses

When you wear shoes that do not fit well and are a constant source of abrasion on your toes, you tend to form a callus at the point of contact. This occurs because the basal stem cells in the stratum basale are triggered to divide more often to increase the thickness of the skin at the point of abrasion to protect the rest of the body from further damage. This is an example of a minor or local injury, and the skin manages to react and treat the problem independent of the rest of the body. Calluses can also form on your fingers if they are subject to constant mechanical stress, such as long periods of writing, playing string instruments, or video games. A corn is a specialized form of callus. Corns form from abrasions on the skin that result from an elliptical-type motion (Betts, et al., 2021).

Medical Terms in Context

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Medical Specialties and Procedures Related to the Integumentary System

A dermatologist is a medical doctor with specialized training in treating diseases, disorders and injuries related to the integumentary system and its accessory structures. There are many dermatologic subspecialties such as cosmetic dermatology, dermatopathology and pediatric dermatology. To learn more visit the 'What is a Dermatologist?' page of the American Academy of Dermatology Association website.

Dermatologists can be specially trained to perform a procedure called Mohs surgery. Mohs surgery excises skin cancers in thin layers until all cancer is removed from the tissue (Mayo Clinic Staff, 2017). For more details about each step of the process visit the Skin Cancer Foundation's site on Mohs Surgery.

Test Yourself

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4: Respiratory System

Learning Objectives

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

Respiratory System Word Parts

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

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Introduction to the Respiratory System

Did You Know?

If you hold your breath for longer than 3 minutes your autonomic nervous system will take control.

How long you can hold your breath as you continue reading... How long can you do it? Chances are you are feeling uncomfortable already. A typical human cannot survive without breathing for more than three minutes, and even if you wanted to hold your breath longer, your autonomic nervous system would take control. Although oxygen is critical for cells, it is the accumulation of carbon dioxide that primarily drives your need to breathe.

The major structures of the respiratory system function primarily to provide oxygen to body tissues for cellular respiration, remove the waste product carbon dioxide, and help to maintain acid-base balance. Portions of the respiratory system are also used for non-vital functions, such as sensing odors, speech production, and for straining, such as coughing.

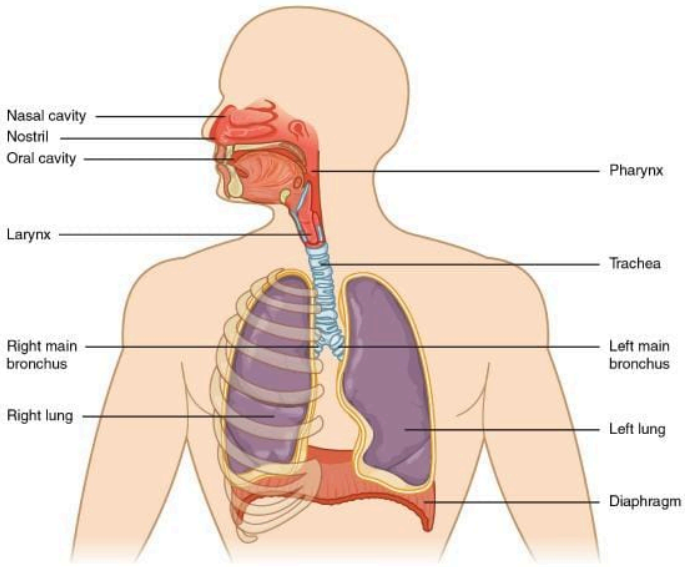


Figure 4.1 Major Respiratory Structures. The major respiratory structures span the nasal cavity to the diaphragm. From Betts, et al., 2021. Licensed under CC BY 4.0.

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Respiratory System Medical Terms

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Anatomy (Structures) of the Respiratory System

The Nose and its Adjacent Structures

The major entrance and exit for the respiratory system is through the **nose**. When discussing the nose, it is helpful to divide it into two major sections:

- external nose
- internal nose

The **nares** open into the nasal cavity, which is separated into left and right sections by the nasal septum (Figure 4.2). The **nasal septum** is formed anteriorly by a portion of the septal cartilage and posteriorly by the perpendicular plate of the ethmoid bone and the thin vomer bones.

Each lateral wall of the nasal cavity has three bony projections the inferior conchae are separate bones and the superior and middle conchae are portions of the ethmoid bone. **Conchae** increase the surface area of the nasal cavity, disrupt the flow of air as it enters the nose, causing air to bounce along the epithelium, where it is cleaned and warmed. The conchae and meatuses trap water during exhalation preventing dehydration.

The floor of the nasal cavity is composed of thehard palate and the soft palate. Air exits the nasal cavities via the internal nares and moves into the pharynx.

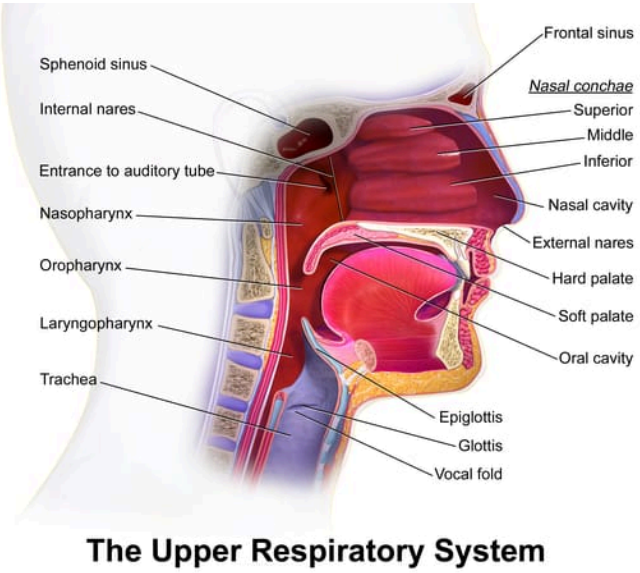


Figure 4.2 Upper Respiratory System. From Wikimedia 2019. Licensed under CC BY 3.0.

Paranasal sinuses serve to warm and humidify incoming air. They are lined with a mucosa which produces mucus. Paranasal sinuses are named for their associated bone:

- frontal sinus
- maxillary sinus
- sphenoidal sinus
- ethmoidal sinus

The nares and anterior portion of the nasal cavities are lined with mucous membranes, containing sebaceous glands and hair follicles that serve to prevent the passage of large debris, such as dirt, through the nasal cavity. An olfactory epithelium used to detect odors is found deeper in the nasal cavity.

Did You Know?

Cold air slows the movement of cilia that may result in the accumulation of mucus leading to rhinorrhea during cold weather.

The cilia of the respiratory epithelium help to remove mucus and debris with a constant beating motion, sweeping materials towards the throat to be swallowed. This moist epithelium functions to warm and humidify incoming air.

Pharynx

The pharynx is divided into three major regions: the **nasopharynx**, the **oropharynx**, and the **laryngopharynx** (see Figure 4.3).

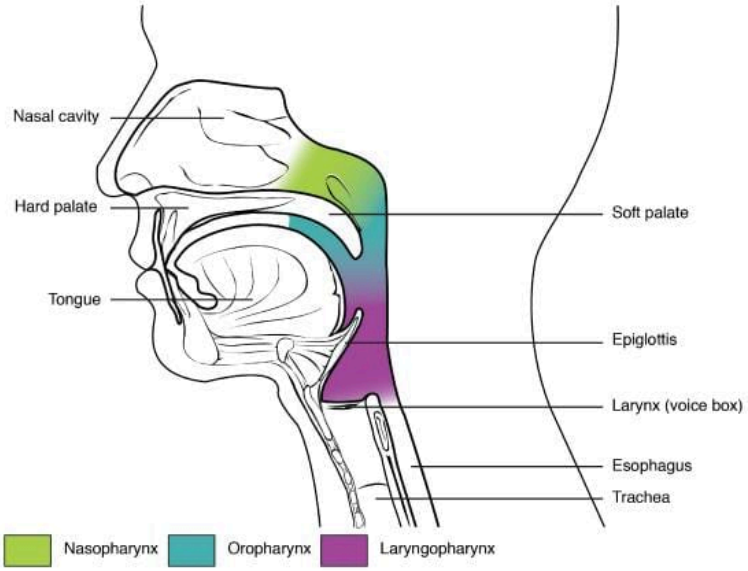


Figure 4.3 Divisions of the Pharynx. The pharynx is divided into three regions: the nasopharynx, the oropharynx, and the laryngopharynx. From Betts, et al., 2021. Licensed under CC BY 4.0.

At the top of the **nasopharynx** are the pharyngeal tonsils. The function of the pharyngeal tonsil is not well understood, but it contains a rich supply of lymphocytes and is covered with ciliated epithelium that traps and destroys invading pathogens that enter during inhalation. The pharyngeal tonsils are large in children, but tend to regress with age and may even disappear. The uvula and soft palate move like a pendulum during swallowing, swinging upward to close off the nasopharynx to prevent ingested materials from entering the nasal cavity. Auditory (Eustachian) tubes that connect to each middle ear cavity open into the nasopharynx. This connection is why colds often lead to ear infections.

The **oropharynx** is bordered superiorly by the nasopharynx and anteriorly by the oral cavity. The oropharynx contains two distinct sets of tonsils:

- The palatine tonsils.
  - A palatine tonsil is one of a pair of structures located laterally in the oropharynx
- The lingual tonsils.
  - The lingual tonsil is located at the base of the tongue.

Similar to the pharyngeal tonsil, the palatine and lingual tonsils are composed of lymphoid tissue, and trap and destroy pathogens entering the body through the oral or nasal cavities.

The **laryngopharynx** is inferior to the oropharynx and posterior to the larynx. It continues the route for ingested material and air until its inferior end, where the digestive and respiratory systems diverge. The stratified squamous epithelium of the oropharynx is continuous with the laryngopharynx. Anteriorly, the laryngopharynx opens into the larynx, whereas posteriorly, it enters the esophagus.

Larynx

The structure of the larynx is formed by several pieces of cartilage (see Figure 4.4). Three large cartilage pieces form the major structure of the larynx.

- Thyroid cartilage (anterior)
- Epiglottis (superior)
- Cricoid cartilage (inferior)

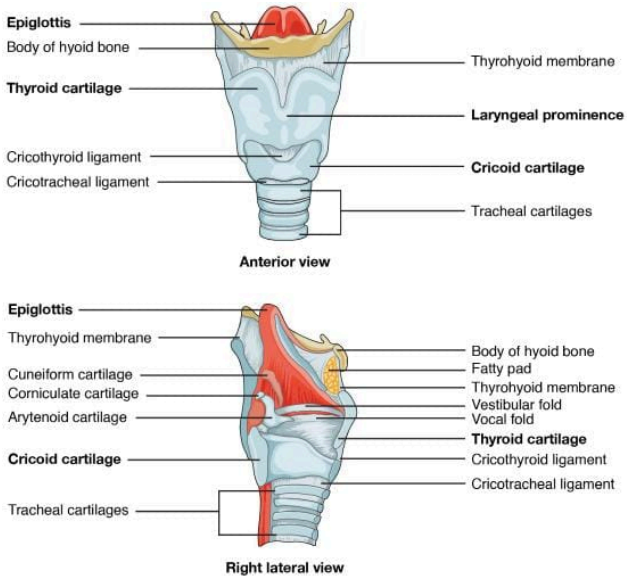


Figure 4.4 Larynx. The larynx extends from the laryngopharynx and the hyoid bone to the trachea. From Betts, et al., 2021. Licensed under CC BY 4.0.

When the epiglottis is in the “closed” position, the unattached end of the epiglottis rests on the glottis.

The act of swallowing causes the pharynx and larynx to lift upward, allowing the pharynx to expand and the epiglottis of the larynx to swing downward, closing the opening to the trachea. These movements produce a larger area for food to pass through, while preventing food and beverages from entering the trachea.

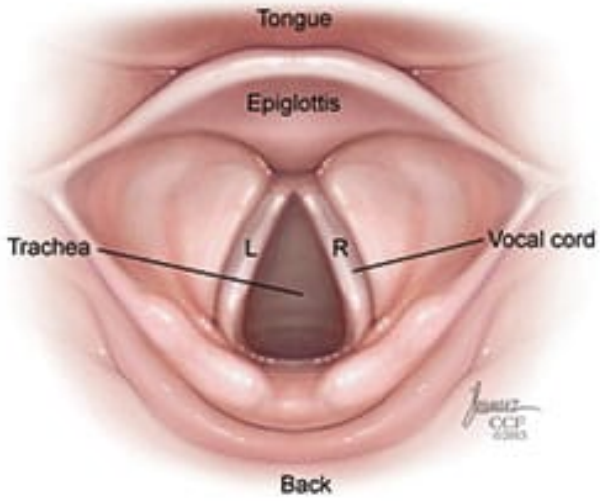


Figure 4.5 Healthy Vocal Cords. From ClevelandClinic.org

Similar to the nasal cavity and nasopharynx, this specialized epithelium produces mucus to trap debris and pathogens as they enter the trachea. The cilia beat the mucus upward towards the laryngopharynx, where it can be swallowed down the esophagus.

Trachea

The trachea is formed by 16 to 20 stacked, C-shaped pieces of hyaline cartilage that are connected by dense connective tissue (see Figure 4.6). The trachealis muscle and elastic connective tissue together form the fibroelastic membrane. The fibroelastic membrane allows the trachea to stretch and expand slightly during inhalation and exhalation, whereas the rings of cartilage

provide structural support and prevent the trachea from collapsing. The trachealis muscle can be contracted to force air through the trachea during exhalation. The trachea is lined with pseudostratified ciliated columnar epithelium, which is continuous with the larynx. The esophagus borders the trachea posteriorly.

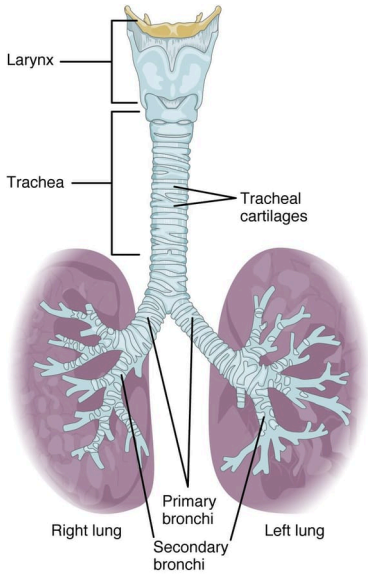


Figure 4.6 Trachea. The tracheal tube is formed by stacked, C-shaped pieces of hyaline cartilage. From Betts, et al., 2021. Licensed under CC BY 4.0.

Bronchial Tree

The trachea branches into the right and left primary bronchi at the carina. The carina is a raised structure that contains specialized nervous tissue that induces violent coughing if a foreign body, such as food, is present. Rings of cartilage, similar to those of the trachea, support the structure of the bronchi and prevent their collapse. The primary bronchi enter the lungs at the hilum. The bronchi continue to branch into bronchial a tree. A bronchial tree (or respiratory tree) is the collective term used for these multiple-branched bronchi. The main function of the bronchi, like other conducting zone structures, is to provide a passageway for air to move into and out of each lung. The mucous membrane traps debris and pathogens.

The bronchiole branches from the tertiary bronchi. Bronchioles, which are about 1 mm in diameter, further branch until they become the tiny terminal bronchioles, which lead to the structures of gas exchange. There are more than 1000 terminal bronchioles in each lung. The muscular walls of the bronchioles do not contain cartilage like those of the bronchi. This muscular wall can change the size of the tubing to increase or decrease airflow through the tube.

Respiratory Zone

In contrast to the conducting zone, the respiratory zone includes structures that are directly involved in gas exchange. The respiratory zone begins where the terminal bronchioles join a respiratory bronchiole, the smallest type of bronchiole (see Figure 4.7), which then leads to an alveolar duct, opening into a cluster of alveoli.

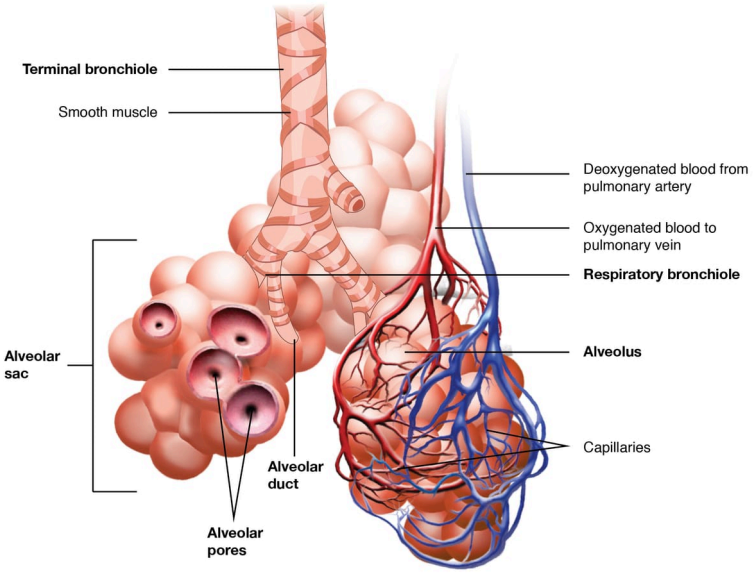


Figure 4.7 Respiratory Zone. Bronchioles lead to alveolar sacs in the respiratory zone, where gas exchange occurs. From Betts, et al., 2021. Licensed under CC BY 4.0.

Alveoli

An alveolar duct opens into a cluster of alveoli. An alveolus is one of the many small, grape-like sacs that are attached to the alveolar ducts. An alveolar sac is a cluster of many individual alveoli that are responsible for gas exchange. An alveolus is approximately 0.2 millimeters in diameter with elastic walls that allow the alveolus to stretch during air intake, which greatly increases the surface area available for gas exchange. Alveoli are connected to their neighbors by alveolar pores, which help maintain equal air pressure throughout the alveoli and lung (see Fig. 4.7).

Concept Check

- What are the components of the **bronchial** tree?
- What is the purpose of **cilia**?
- Where does **gas** exchange take place?

Gross Anatomy of the Lungs

The lungs are pyramid-shaped, paired organs that are connected to the trachea by the right and left bronchi; on the inferior surface, the lungs are bordered by the diaphragm. The lungs are enclosed by the pleurae, which are attached to the mediastinum. The right lung is shorter and wider than the left lung, and the left lung occupies a smaller volume than the right. The cardiac notch allows space for the heart (see Figure 4.8). The apex of the lung is the superior region, whereas the base is the opposite region near the diaphragm. The costal surface of the lung borders the ribs. The mediastinal surface faces the mid line.

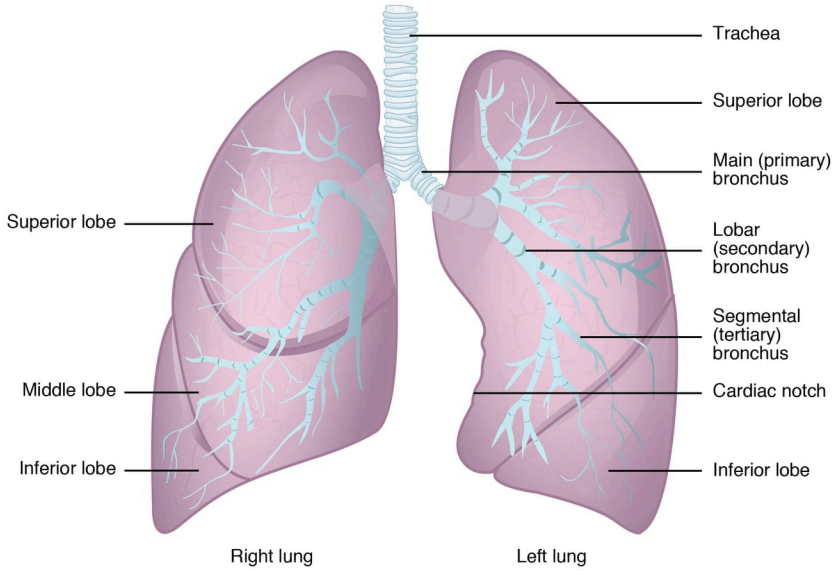


Figure 4.8 Gross Anatomy of the Lungs. From Betts, et al., 2021. Licensed under CC BY 4.0.

Each lung is composed of smaller units called lobes. Fissures separate these lobes from each other. The right lung consists of three lobes: the superior, middle, and inferior lobes. The left lung consists of two lobes: the superior and inferior lobes. A pulmonary lobule is a subdivision formed as the bronchi branch into bronchioles. Each lobule receives its own large bronchiole that has multiple branches. An interlobular septum is a wall, composed of connective tissue, which separates lobules from one another.

Can you correctly label the respiratory system structures?

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Physiology (Function) of the Respiratory System

Blood Supply

The major function of the lungs is to perform gas exchange, which requires blood from the pulmonary circulation.

- This blood supply contains deoxygenated blood and travels to the lungs where erythrocytes pick up oxygen to be transported to tissues throughout the body.
- The pulmonary artery carries deoxygenated, arterial blood to the alveoli.
- The pulmonary artery branches multiple times as it follows the bronchi, and each branch becomes progressively smaller in diameter.
- One arteriole and an accompanying venule supply and drain one pulmonary lobule. As they near the alveoli, the pulmonary arteries become the pulmonary capillary network.
- The pulmonary capillary network consists of tiny vessels with very thin walls that lack smooth muscle fibers.
- The capillaries branch and follow the bronchioles and structure of the alveoli. It is at this point that the capillary wall meets the alveolar wall, creating the respiratory membrane.

- Once the blood is oxygenated, it drains from the alveoli by way of multiple pulmonary veins, which exit the lungs through the hilum.

Nervous Innervation

The blood supply of the lungs plays an important role in gas exchange and serves as a transport system for gases throughout the body. Innervation by the both the parasympathetic and sympathetic nervous systems provides an important level of control through dilation and constriction of the airway.

- The parasympathetic system causes bronchoconstriction.
- The sympathetic nervous system stimulates bronchodilation.

Reflexes such as coughing, and the ability of the lungs to regulate oxygen and carbon dioxide levels, also result from autonomic nervous system control.

Pleura of the Lungs

Each lung is enclosed within a cavity that is surrounded by the pleura. The pleura (plural = pleurae) is a serous membrane that surrounds the lung. The right and left pleurae, which enclose the right and left lungs, respectively, are separated by the mediastinum.

The pleurae consist of two layers:

1. The **visceral pleura** is the layer that is superficial to the lungs, and extends into and lines the lung fissures (see Figure 4.9).
2. The **parietal pleura** is the outer layer that connects to the thoracic wall, the mediastinum, and the diaphragm.

The visceral and parietal pleurae connect to each other at the hilum. The pleural cavity is the space between the visceral and parietal layers.

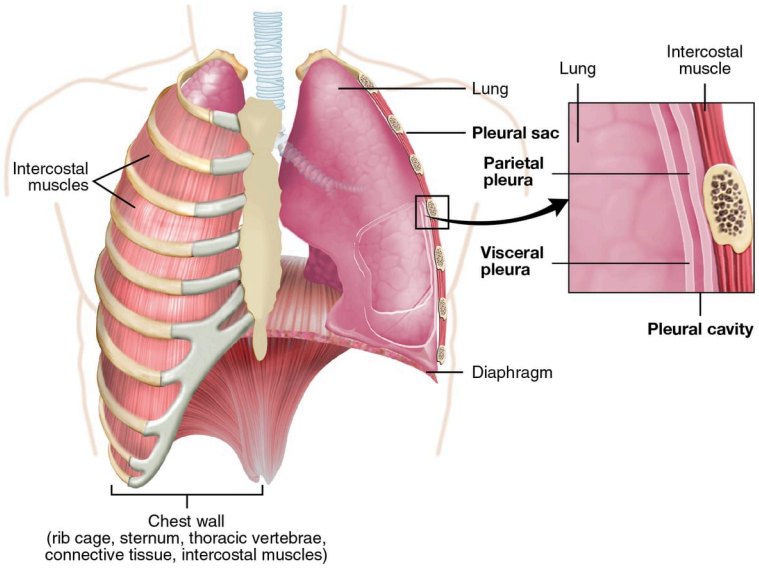


Figure 4.9 Parietal and Visceral Pleurae of the Lungs. From Betts, et al., 2021. Licensed under CC BY 4.0.

The pleurae perform two major functions:

1. **Produce pleural fluid** that that lubricates surfaces, reduces friction to prevent trauma during breathing, and creates surface tension that helps maintain the position of the lungs against the thoracic wall. This adhesive characteristic of the pleural fluid causes the lungs to enlarge when the thoracic wall expands during ventilation, allowing the lungs to fill with air.
2. The pleurae also **create a division** between major organs that prevents interference due to the movement of the organs, while preventing the spread of infection.

Pulmonary Ventilation

The difference in pressures drives pulmonary ventilation because air flows down a pressure gradient, that is, air flows from an area of higher pressure to an area of lower pressure.

- Air flows into the lungs largely due to a difference in pressure; atmospheric pressure is greater than intra-alveolar pressure, and intra-alveolar pressure is greater than intrapleural pressure.
- Air flows out of the lungs during expiration based on the same principle; pressure within the lungs becomes greater than the atmospheric pressure.

Pulmonary ventilation comprises two major steps: inspiration and expiration (see video below). A respiratory cycle is one sequence of inspiration and expiration.

Two muscle groups are used during **normal inspiration** the diaphragm and the external intercostal muscles. Additional muscles can be used if a bigger breath is required.

- The diaphragm contracts, it moves inferiorly toward the abdominal cavity, creating a larger thoracic cavity and more space for the lungs.
- The external intercostal muscles contract and moves the ribs upward and outward, causing the rib cage to expand, which increases the volume of the thoracic cavity.

Due to the adhesive force of the pleural fluid, the expansion of the thoracic cavity forces the lungs to stretch and expand as well. This increase in volume leads to a decrease in intra-alveolar pressure, creating a pressure lower than atmospheric pressure. As a result, a pressure gradient is created that drives air into the lungs.

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Media 4.2. 3D Medical Mechanics of Breathing [Online video]. Copyright 2014 by AIDA Educational Committee.

The process of **normal expiration** is passive, meaning that energy is not required to push air out of the lungs.

- The elasticity of the lung tissue causes the lung to recoil, as the diaphragm and intercostal muscles relax following inspiration.
- The thoracic cavity and lungs decrease in volume, causing an increase in interpulmonary pressure. The interpulmonary pressure rises above atmospheric pressure, creating a pressure gradient that causes air to leave the lungs.

There are different types, or modes, of breathing that require a slightly different process to allow inspiration and expiration:

- **Quiet breathing**, also known as eupnea, is a mode of breathing that occurs at rest and does not require the cognitive thought of the individual. During quiet breathing, the diaphragm and external intercostals must contract.
- **Diaphragmatic breathing**, also known as deep breathing, requires the diaphragm to contract. As the diaphragm relaxes, air passively leaves the lungs.
- **Costalbreathing**, also known as a shallow breath, requires contraction of the intercostal muscles. As the intercostal muscles relax, air passively leaves the lungs.
- **Forced breathing**, also known as hyperpnea, is a mode of breathing that can occur during exercise or actions that require the active manipulation of breathing, such as singing.
    - During forced breathing, inspiration and expiration both occur due to muscle contractions. In addition to the contraction of the diaphragm and intercostal muscles, other accessory muscles must also contract.
        - During **forced inspiration**, muscles of the neck contract and lift the thoracic wall, increasing lung volume.
        - During **forced expiration**, accessory muscles of the abdomen contract, forcing abdominal organs upward against

the diaphragm. This helps to push the diaphragm further into the thorax, pushing more air out. In addition, accessory muscles help to compress the rib cage, which also reduces the volume of the thoracic cavity.

Concept Check

- Breathing normally, place your hand on your stomach take in one full **respiratory** cycle.
  - What type of breathing are you doing?
- Keeping your hand on your stomach, take in one large breath and exhale.
  - What type of breathing are you doing?
- Complete 10 jumping jacks, once completed, place your hand on your stomach and take in one full respiratory cycle.
  - What type of breathing are you doing?

Respiratory Rate and Control of Ventilation

Did You Know?

Respiratory rate is the total number of breaths that occur each minute.

Breathing usually occurs without thought, although at times you can consciously control it, such as when you swim under water, sing a song, or blow bubbles. The respiratory rate is the total number of breaths that occur each minute. Respiratory rate can be an important indicator of disease, as the rate may increase or decrease during an illness or in a disease condition. The respiratory rate is controlled by the respiratory center located within the medulla oblongata in the brain, which responds primarily to changes in carbon dioxide, oxygen, and pH levels in the blood.

The normal respiratory rate of a child decreases from birth to adolescence:

- A child under 1 year of age has a normal respiratory rate between 30 and 60 breaths per minute.
- By the time a child is about 10 years old, the normal rate is closer to 18 to 30.
- By adolescence, the normal respiratory rate is similar to that of adults, 12 to 18 breaths per minute.

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Medical Terms not Easily Broken into Word Parts

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Common Respiratory Abbreviations

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Diseases and Disorders

A variety of diseases can affect the respiratory system, such as asthma, emphysema, chronic obstruction pulmonary disorder (COPD), and lung cancer. All of these conditions affect the gas exchange process and result in labored breathing and other difficulties. (Betts, et al., 2021).

The Effects of Second-Hand Tobacco Smoke

The burning of a tobacco cigarette creates multiple chemical compounds that are released through mainstream smokeand through sidestream smoke. **Second-hand smoke**, which is a combination of sidestream smoke and the mainstream smoke that is exhaled by the smoker, has been demonstrated by numerous scientific studies to cause disease. At least **40 chemicals in sidestream smoke** have been identified that negatively impact human health, leading to the development of cancer or other conditions, such as immune system dysfunction, liver toxicity, cardiac arrhythmias, pulmonary edema, and neurological dysfunction. Tobacco and second-hand smoke are considered to be carcinogenic. Exposure to second-hand smoke can cause lung cancer in individuals who are not tobacco users themselves.

- It is estimated that the risk of developing lung cancer is increased by up to **30 percent in nonsmokers** who live with an individual who smokes in the house, as compared to nonsmokers who are not regularly exposed to second-hand smoke.
- **Children who live with an individual who smokes** inside the home have a larger number of lower respiratory infections, which are associated with hospitalizations, and higher risk of sudden infant death syndrome (SIDS). Second-hand smoke in the home has also been linked to a greater number of ear infections in children, as well as worsening symptoms of asthma (Betts, et al., 2021).

Chronic Obstructive Pulmonary Disease (COPD)

COPD is a term used to represent a number of respiratory diseases including chronic bronchitis and emphysema. COPD is a chronic condition with most symptoms appearing in people in their middle 50s. Symptoms include shortness of breath, cough, and sputum production. Symptoms during flare ups or times of exacerbation, may include green or brown mucous, increase in the viscosity or amount of mucus, chest pain, fever, swollen ankles, headaches, dizziness, and blue lips or fingers There is no cure for COPD. Shortness of breath may be controlled with bronchodilators. The best plan is to avoid triggers and getting sick.

Clients with COPD are advised to avoid people who are sick, get the flu shot and reduce their exposure to pollution and cigarette smoke. While there are several risk factors, most cases are associated with cigarette smoking (Centers for Disease Control and Prevention, 2021c). To learn more about COPD visit the Centers for Disease Control and Prevention's webpage on COPD.

Asthma

Asthma is a common chronic condition that affects all age groups. In 2019 there were over 25 million Americans diagnosed with asthma and a disproportionate number of children and youth (Centers for Disease Control and Prevention, 2021b). Asthma is a chronic disease characterized by inflammation, edema of the airway, and bronchospasms which can inhibit air from entering the lungs. Bronchospasms can lead to an "asthma attack." An attack may be triggered by environmental factors such as dust, pollen, pet hair, or dander, changes in the weather, mold, tobacco smoke, and respiratory infections, or by exercise and stress (Betts, et al., 2021).

Symptoms of an asthma attack involve coughing, shortness of breath, wheezing, and tightness of the chest. Symptoms of a severe asthma attack require immediate medical attention and may include dyspnea that results in cyanotic lips or face, confusion, drowsiness, a rapid pulse, sweating, and severe anxiety. The severity of the condition, frequency of attacks, and identified triggers influence the type of medication that an individual may require. Longer-term treatments are used for those with more severe asthma. Short-term, fast-acting drugs that are used to treat an asthma attack are typically administered via an inhaler. For young children or individuals who have difficulty using an inhaler, asthma medications can be administered via a nebulizer (Betts, et al., 2021).

Lung Cancer

Lung cancer is a leading cause of cancer death among both males and females in the United States (Centers for Disease Control and Prevention, 2021a). Symptoms often appear in the late stages with 50% being diagnosed at STAGE IV (American Cancer Society medical and editorial content team, 2021). Symptoms may include shortness of breath, wheezing, blood in the mucus, chronic chest infections, dysphagia, pleural effusion, and enlarged lymph nodes. There are two types of lung cancer, **small cell lung cancer (SCLC)** linked to cigarette smoking, grows quickly and metastasizes. **Non-small cell lung cancer (NSCLC)** is more common and grows slowly. Changes in lung cells may lead to benign tumors or malignant tumors. Cancers that start in other parts of the body may metastasize to the lungs. Risk factors include smoking, air pollution, family history exposure to second-hand smoke, exposure to radon gas, and exposure to carcinogens (American Cancer Society medical and editorial content team, 2019). Treatment will depend on the type of lung cancer and the stage at diagnosis. Treatments may include surgery, chemotherapy, targeted therapy, immunotherapy, and radiation therapy (American Cancer Society medical and editorial content team, 2019).

Sleep Apnea

Sleep apnea is a chronic disorder that occurs in children and adults. It is characterized by the cessation of breathing during sleep. These episodes may last for several seconds or several minutes, and may differ in the frequency with which they are experienced. Sleep apnea leads to poor sleep, symptoms include fatigue, evening napping, irritability, memory problems, morning headaches, and excessive snoring. A diagnosis of sleep apnea is usually done during a sleep study, where the patient is monitored in a sleep laboratory for several nights. Treatment of sleep apnea commonly includes the use of a device called a **continuous positive airway pressure (CPAP) machine** during sleep. The CPAP machine has a mask that covers the nose, or the nose and mouth, and forces air into the airway at regular intervals. This pressurized air can help to gently force the airway to remain open, allowing more normal ventilation to occur (Betts, et al., 2021).

Medical Terms in Context

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Medical Specialties and Procedures Related to the Respiratory System

Pulmonologist

Respiratory medicine is concerned with the diagnosis and treatment of diseases related to the respiratory system. Respiratory medicine requires in-depth knowledge of internal medicine. A physician who specializes in the respiratory system is called a pulmonologist. For more information, visit the American Lung Association's page on pulmonologists.

Respiratory Therapists (RTs)

Respiratory Therapists (RTs) are health care professionals that monitor, assess and treat people who are having problems breathing. RTs are licensed in the state in which they practice. In Wisconsin, licensure is renewed every two years (American Association for Respiratory Care, 2021a). RTs are trained in ventilation and airway management, cardiopulmonary resuscitation, oxygen and aerosol therapy. They care for patients during cardiac stress-testing, pulmonary function testing, smoking cessation, high-risk births, rehabilitation, and surgery. They treat patients with asthma, bronchitis, COPD, emphysema, heart disease, and pneumonia (American Association for Respiratory Care, 2021b). For more information, visit the American Association for Respiratory Care's What is a Respiratory Therapist? web page.

Thoracic Surgeon

A thoracic surgeon refers to a surgeon who has specialized in either thoracic (chest) surgery or cardiothoracic (heart and chest) surgery and care or perform surgery for patients with serious conditions of the chest (American Board of Thoracic Surgery, n.d.).

To learn more, visit the American Board of Thoracic Surgery web page.

Spirometry Testing

Spirometry testing is used to find out how well lungs are working by measuring air volume.

- **Respiratory volume**, describes the amount of air in a given space within the lungs, or which can be moved by the lung, and is dependent on a variety of factors.
- **Tidal volume**, refers to the amount of air that enters the lungs during quiet breathing, whereas inspiratory reserve volume is the amount of air that enters the lungs when a person inhales past the tidal volume.
- **Expiratory reserve volume**, is the extra amount of air that can leave with forceful expiration, following tidal expiration.
- **Residual volume,** is the amount of air that is left in the lungs after expelling the expiratory reserve volume.
- **Respiratory capacity,** is the combination of two or more volumes.
- **Anatomical dead space,** refers to the air within the respiratory structures that never participates in gas exchange, because it does not reach functional alveoli.
- **Respiratory rate,** is the number of breaths taken per minute, which may change during certain diseases or conditions.

Both respiratory rate and depth are controlled by the respiratory centers of the brain, which are stimulated by factors such as chemical and pH changes in the blood. These changes are sensed by central chemoreceptors, which are located in the brain, and peripheral chemoreceptors, which are located in the aortic arch and carotid arteries. A rise in carbon dioxide or a decline in oxygen levels in the blood stimulates an increase in respiratory rate and depth (Betts, et al., 2021).

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Test Yourself

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5: Urinary System

Learning Objectives

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

Urinary System Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the urinary system. Then use the flashcards below to practice.

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Introduction to the Urinary System

The urinary system has roles you may be well aware of. Cleansing the blood and ridding the body of wastes probably come to mind. However, there are additional, equally important functions, played by the system. Take, for example, regulation of pH, a function shared with the lungs and the buffers in the blood. Additionally, the regulation of blood pressure is a role shared with the heart and blood vessels. What about regulating the concentration of solutes in the blood? Did you know that the kidney is important in determining the concentration of red blood cells? Eighty-five percent of the erythropoietin (EPO) produced to stimulate red blood cell production is produced in the kidneys. The kidneys also help control blood pressure by producing the enzyme renin . Additionally, the kidneys perform the final synthesis step of vitamin D production, converting calcidiol to calcitriol, the active form of vitamin D. If the kidneys fail, these functions are compromised or lost altogether, with devastating effects on homeostasis.

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Urinary System Medical Terms

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Anatomy (Structures) of the Urinary System

Kidney(s)

The kidneys lie on either side of the spine in the retroperitoneal space between the parietal peritoneum and the posterior abdominal wall, well protected by muscle, fat, and ribs. They are roughly the size of your fist. The male kidney is typically a bit larger than the female kidney. The kidneys are well vascularized, receiving about twenty-five percent of the cardiac output at rest. Figure 5.1 displays the location of the kidneys.

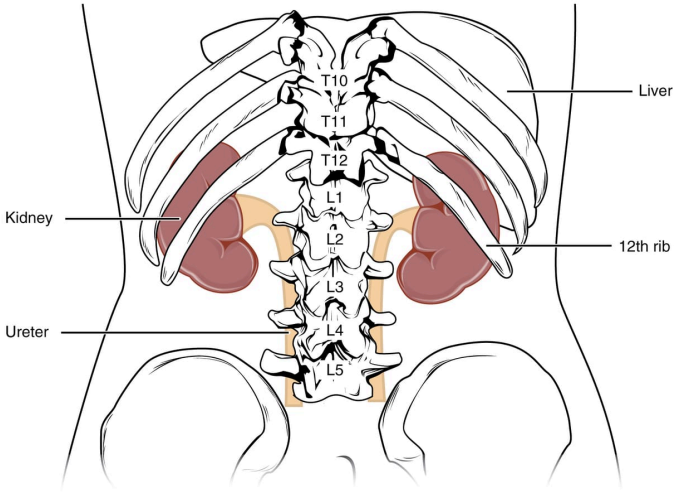


Figure 5.1 Kidneys. The kidneys are slightly protected by the ribs and are surrounded by fat for protection (not shown). From Betts, et al., 2021. Licensed under CC BY 4.0.

Did You Know?

The right kidney is smaller than the left. It also sits slightly lower to make room for the liver located on the right side of your body.

Kidneys' Internal Structure

A frontal section through the kidney reveals an outer region called the **renal cortex** and an inner region called the **medulla** (see Figure 5.2). The **renal columns** are connective tissue extensions that radiate downward from the cortex through the medulla to separate the most characteristic features of the medulla, the **renal pyramids** and **renal papillae**. The papillae are bundles of collecting ducts that transport urine made by nephrons to the **calyces** of the kidney for excretion. The renal columns also serve to divide the kidney into 6–8 lobes and provide a supportive framework for vessels that enter and exit the cortex. The pyramids and renal columns taken together constitute the kidney lobes.

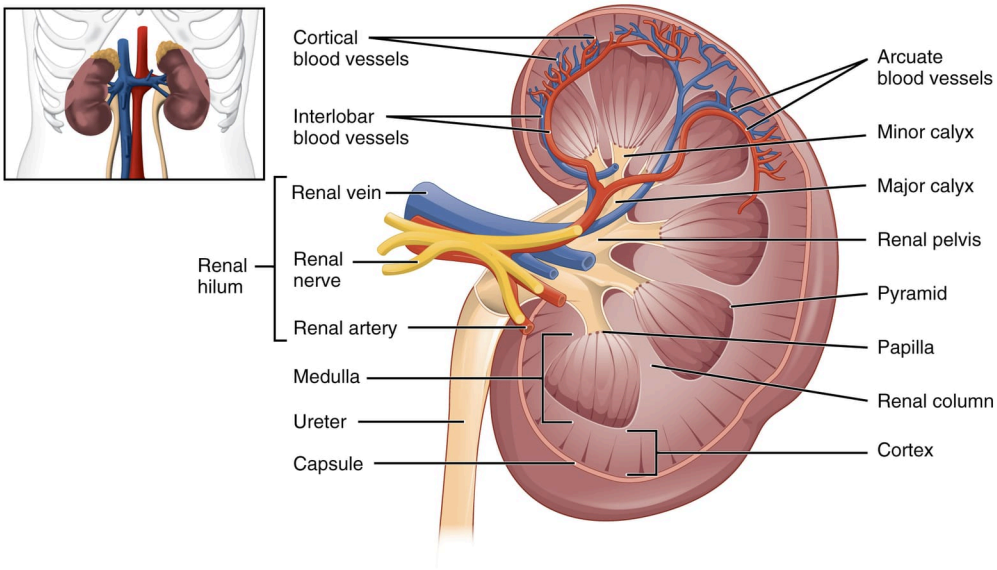


Figure 5.2 Left Kidney. From Betts, et al., 2021. Licensed under CC BY 4.0.

Renal Hilum

The **renal hilum** is the entry and exit site for structures servicing the kidneys: vessels, nerves, lymphatics, and ureters. The medial-facing hila are tucked into the sweeping convex outline of the cortex. Emerging from the hilum is the renal pelvis, which is formed from the major and minor **calyxes** in the kidney. The smooth muscle in the renal pelvis funnels urine via **peristalsis** into the ureter. The renal arteries form directly from the descending aorta, whereas the renal veins return cleansed blood directly to the inferior vena cava. The artery, vein, and renal pelvis are arranged in an anterior-to-posterior order.

Nephrons and Vessels

The renal artery first divides into segmental arteries, followed by further branching to form interlobar arteries that pass through the renal columns to reach the cortex (see Figure 5.3). The **interlobar** arteries, in turn, branch into **arcuate** arteries, cortical **radiate** arteries, and then into afferent arterioles. The afferent arterioles service about 1.3 million nephrons in each kidney.

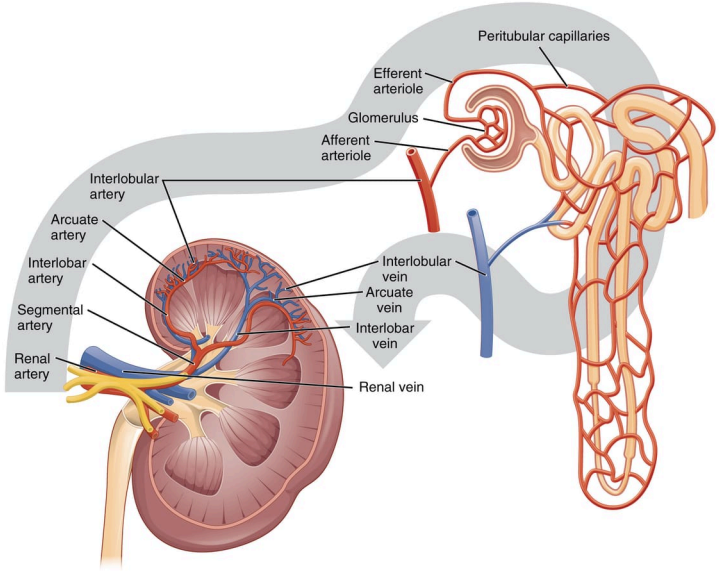


Figure 5.3 Blood Flow in the Kidney. From Betts, et al., 2021. Licensed under CC BY 4.0.

Nephrons are the “functional units” of the kidney; they cleanse the blood and balance the constituents of the circulation. The afferent arterioles form a tuft of high-pressure capillaries about 200 µm in diameter, the **glomerulus**. The rest of the nephron consists of a continuous sophisticated tubule whose proximal end surrounds the glomerulus in an intimate embrace—this is **Bowman’s capsule**. The glomerulus and Bowman’s capsule together form the **renal corpuscle**. As mentioned earlier, these glomerular capillaries filter the blood based on particle size. After passing through the renal corpuscle, the capillaries form a second arteriole, the **efferent arteriole** (see Figure 5.4). As the glomerular filtrate progresses through the nephron, these capillary networks recover most of the solutes and water, and return them to the circulation. Since a capillary bed (the glomerulus) drains into a vessel that in turn forms a second capillary bed, the definition of a portal system is met. This is the only portal system in which an arteriole is found between the first and second capillary beds. (Portal systems also link the hypothalamus to the anterior pituitary, and the blood vessels of the digestive viscera to the liver.

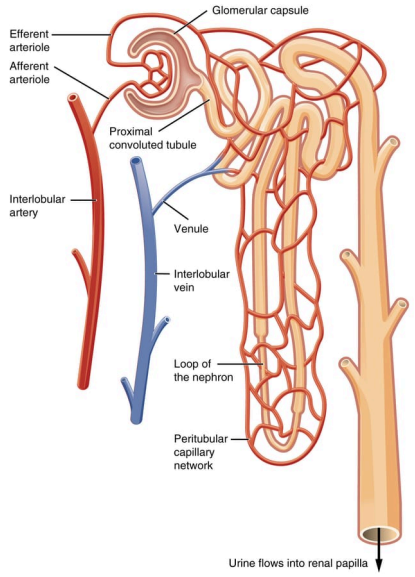


Figure 5.4. Blood Flow in the Nephron. The two capillary beds are clearly shown in this figure. The efferent arteriole is the connecting vessel between the glomerulus and the peritubular capillaries and vasa recta. From Betts, et al., 2021. Licensed under CC BY 4.0.

Ureter(s)

The kidneys and ureters are completely **retroperitoneal**, and the bladder has a **peritoneal** covering only over the dome. As urine is formed, it drains into the calyces of the kidney, which merge to form the funnel-shaped renal pelvis in the hilum of each kidney. The hilum narrows to become the **ureter** of each kidney. As urine passes through the ureter, it does not passively drain into the bladder but rather is propelled by waves of **peristalsis**. The ureters are approximately 30 cm long. The muscular layer of the ureter creates the peristaltic contractions to move the urine into the bladder without the aid of gravity.

Bladder

The urinary bladder collects urine from both ureters (see Figure 5.5). The bladder lies anterior to the uterus in females, posterior to the pubic bone and anterior to the rectum. During late pregnancy, its capacity is reduced due to compression by the enlarging uterus, resulting in increased frequency of urination. In males, the anatomy is similar, minus the uterus, and with the addition of the prostate inferior to the bladder. The bladder is partially retroperitoneal (outside the peritoneal cavity) with its peritoneal-covered “dome” projecting into the abdomen when the bladder is distended with urine.

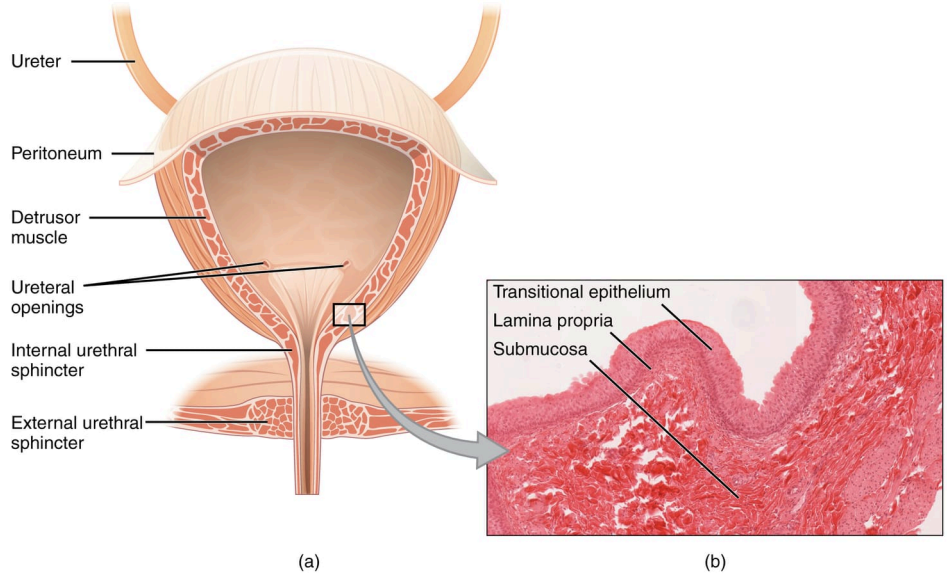


Figure 5.5 Bladder. (a) Anterior cross section of the bladder. (b) The detrusor muscle of the bladder (source: monkey tissue) LM × 448. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012). From Betts, et al., 2021. Licensed under CC BY 4.0.

Urethra

The urethra transports urine from the bladder to the outside of the body for disposal. The urethra is the only urologic organ that shows any significant anatomic difference between males and females; all other urine transport structures are identical (see Figure 5.6).

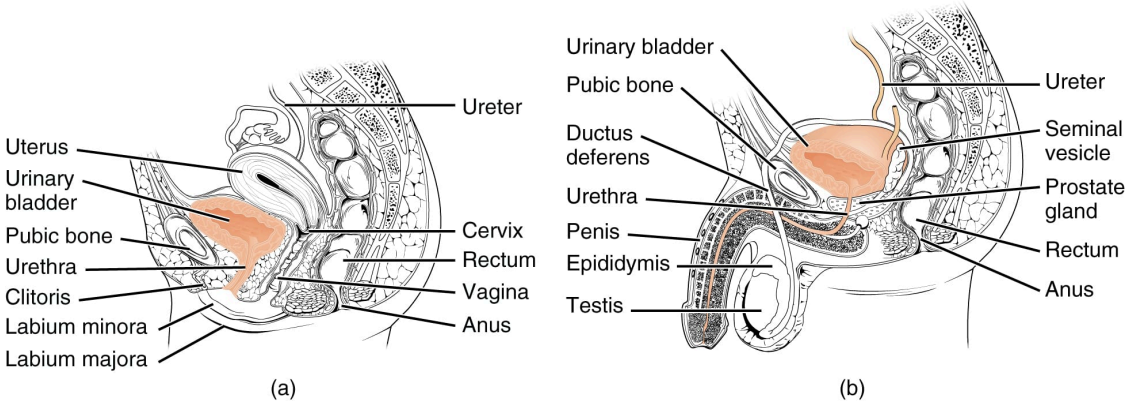


Figure 5.6. Female and Male Urethras. The urethra transports urine from the bladder to the outside of the body. This image shows (a) a female urethra and (b) a male urethra. From Betts, et al., 2021. Licensed under CC BY 4.0.

Voiding is regulated by an involuntary autonomic nervous system-controlled internal urinary sphincter, consisting of smooth muscle and voluntary skeletal muscle that forms the external urinary sphincter below it.

Did You Know?

A healthy adult bladder can store up to 455 ml (15 oz) of urine for between two to five hours.

Micturition Reflex

Micturition is a less-often used, but proper term for **urination** or **voiding**. It results from an interplay of involuntary and voluntary actions by the internal and external urethral sphincters. When bladder volume reaches about 150 ml (5 ounces), an urge to void is

sensed but is easily overridden. Voluntary control of urination relies on consciously preventing relaxation of the external urethral sphincter to maintain urinary continence. As the bladder fills, subsequent urges become harder to ignore. Ultimately, voluntary constraint fails with resulting incontinence, which will occur as bladder volume approaches 300 to 400 ml (10 to 13 oz).

- Normal micturition is a result of stretch **receptors** in the bladder wall that transmit nerve impulses to the sacral region of the spinal cord to generate a spinal reflex. The resulting parasympathetic neural outflow causes contraction of the detrusor muscle and relaxation of the involuntary internal urethral sphincter.
- At the same time, the spinal cord inhibits somatic motor neurons, resulting in the relaxation of the skeletal muscle of the external urethral **sphincter**.
- The micturition reflex is active in infants but with maturity, children learn to override the reflex by asserting external sphincter control, thereby delaying voiding (potty training). This reflex may be preserved even in the face of spinal cord injury that results in paraplegia or quadriplegia. However, relaxation of the external sphincter may not be possible in all cases, and therefore, periodic catheterization may be necessary for bladder emptying.

Concept Check

- Describe **two** organs or **structures** essential to the urinary system.
- Identify the **structure** within the kidneys which filters blood.
- Name a commonly used term for the **micturition reflex.**

Anatomy Labeling Activity

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Physiology (Function) of the Urinary System

- Remove waste products and medicines from the body
- Balance the body's fluids
- Balance a variety of electrolytes
- Release hormones to control blood pressure
- Release a hormone to control red blood cell production
- Help with bone health by controlling calcium and phosphorus

Having reviewed the anatomy of the urinary system now is the time to focus on physiology. You will discover that different parts of the **nephron** utilize specific processes to produce urine: **filtration**, **reabsorption**, and **secretion**. You will learn how each of these processes works and where they occur along the nephron and collecting ducts. The physiologic goal is to modify the composition of the plasma and, in doing so, produce the waste product urine.

Nephrons: The Functional Unit

Nephrons take a simple filtrate of the blood and modify it into urine. Many changes take place in the different parts of the nephron before urine is created for disposal. The term "forming urine" will be used hereafter to describe the **filtrate** as it is modified into true urine. The principal task of the nephron population is to balance the **plasma** to homeostatic set points and excrete potential toxins in the urine. They do this by accomplishing three principle functions—filtration, reabsorption, and secretion. They also have additional secondary functions that exert control in three areas: blood pressure (via the production of renin), red blood cell production (via the hormone EPO), and calcium absorption (via the conversion of calcidiol into calcitriol, the active form of

vitamin D).

Loop of Henle

The descending and ascending portions of the loop of Henle (sometimes referred to as the **nephron** loop) are, of course, just continuations of the same tubule. They run adjacent and parallel to each other after having made a hairpin turn at the deepest point of their descent. The descending loop of Henle consists of an initial short, thick portion and long, thin portion, whereas the ascending loop consists of an initial short, thin portion followed by a long, thick portion. The descending and ascending thin portions consist of simple squamous epithelium. Different portions of the loop have different **permeabilities** for solutes and water.

Collecting Ducts

The collecting ducts are continuous with the nephron but are not technically part of it. In fact, each duct collects filtrate from several nephrons for final modification. Collecting ducts merge as they descend deeper in the medulla to form about 30 terminal ducts, which empty at a papilla.

Glomerular Filtration Rate (GFR)

The volume of filtrate formed by both kidneys per minute is termed the **glomerular filtration rate** (GFR). The heart pumps about 5 L (169 fluid ounces) of blood per min under resting conditions. Approximately 20 percent or one liter enters the kidneys to be filtered. On average, this liter results in the production of about 125 mL/min filtrate produced in men (range of 90 to 140 mL/min) and 105 mL/min filtrate produced in women (range of 80 to 125 mL/min). This amount equates to a volume of about 180 L/day in men and 150 L/day in women. Ninety-nine percent of this filtrate is returned to the circulation by reabsorption so that only about 1–2 liters of urine are produced per day.

GFR is influenced by the hydrostatic pressure and colloid osmotic pressure on either side of the capillary membrane of the glomerulus. Recall that filtration occurs as pressure forces fluid and solutes through a **semipermeable** barrier with the solute movement constrained by particle size. Hydrostatic pressure is the pressure produced by a fluid against a surface. If you have fluid on both sides of a barrier, both fluids exert pressure in opposing directions. The net fluid movement will be in the direction of the lower pressure. Osmosis is the movement of solvent (water) across a membrane that is **impermeable** to a solute in the solution. This creates osmotic pressure which will exist until the solute concentration is the same on both sides of a semipermeable membrane. As long as the concentration differs, water will move. Glomerular filtration occurs when glomerular hydrostatic pressure exceeds the luminal **hydrostatic** pressure of Bowman's capsule. There is also an opposing force, the osmotic pressure, which is typically higher in the glomerular capillary.

A proper concentration of solutes in the blood is important in maintaining osmotic pressure both in the glomerulus and systemically. There are disorders in which too much protein passes through the filtration slits into the kidney filtrate. This excess protein in the filtrate leads to a deficiency of circulating **plasma** proteins. In turn, the presence of protein in the urine allows it to hold more water in the filtrate and results in an increase in urine volume. Because there is less circulating protein, principally albumin, the osmotic pressure of the blood falls. Less osmotic pressure pulling water into the capillaries tips the balance towards hydrostatic pressure, which tends to push it out of the capillaries. The net effect is that water is lost from the circulation to interstitial tissues and cells. This "plumps up" the tissues and cells, a condition termed systemic edema.

Reabsorption and Secretion

The renal corpuscle filters the blood to create a filtrate that differs from blood mainly in the absence of cells and large proteins. From this point to the ends of the collecting ducts, the filtrate or forming urine is undergoing modification through **secretion** and **reabsorption** before true urine is produced. Here, some substances are reabsorbed, whereas others are secreted. Note the use of the term "reabsorbed." All of these substances were "absorbed" in the digestive tract—99 percent of the water and most of the solutes filtered by the nephron must be reabsorbed. Water and substances that are reabsorbed are returned to the circulation by the peritubular and vasa recta capillaries.

Urinalysis

Urinalysis (urine analysis) often provides clues to renal disease. Normally, only traces of protein are found in urine, and when

higher amounts are found, damage to the glomeruli is the likely basis. Unusually large quantities of urine may point to diseases like diabetes mellitus or hypothalamic tumors that cause diabetes insipidus. The color of urine is determined mostly by the breakdown products of red blood cell destruction (see Figure 5.7). The “heme” of **hemoglobin** is converted by the liver into water-soluble forms that can be excreted into the **bile** and indirectly into the urine. This yellow pigment is urochrome. Urine color may also be affected by certain foods like beets, berries, and fava beans. A kidney stone or a cancer of the urinary system may produce sufficient bleeding to manifest as pink or even bright red urine. Diseases of the liver or obstructions of bile drainage from the liver impart a dark “tea” or “cola” hue to the urine. **Dehydration** produces darker, concentrated urine that may also possess the slight odor of **ammonia**. Most of the ammonia produced from protein breakdown is converted into **urea** by the liver, so ammonia is rarely detected in fresh urine. The strong ammonia odor you may detect in bathrooms or alleys is due to the breakdown of urea into ammonia by bacteria in the environment. About one in five people detect a distinctive odor in their urine after consuming asparagus; other foods such as onions, garlic, and fish can impart their own aromas. These food-caused odors are harmless.

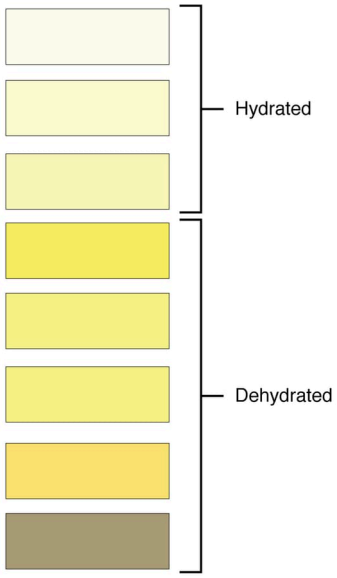


Figure 5.7 Urine Color. From Betts, et al., 2021. Licensed under CC BY 4.0.

Urine volume varies considerably. The normal range is one to two liters per day. The kidneys must produce a minimum urine volume of about 500 mL/day to rid the body of wastes. Output below this level may be caused by severe dehydration or renal disease and is termed **oliguria** . The virtual absence of urine production is termed **anuria** . Excessive urine production is **polyuria** , which may be due to diabetes mellitus or diabetes insipidus. In diabetes mellitus, blood glucose levels exceed the number of available sodium-glucose transporters in the kidney, and glucose appears in the urine. The osmotic nature of glucose attracts water, leading to its loss in the urine. In the case of diabetes insipidus, insufficient pituitary antidiuretic hormone (ADH) release or insufficient numbers of ADH receptors in the collecting ducts means that too few water channels are inserted into the cell membranes that line the collecting ducts of the kidney. Insufficient numbers of water channels (aquaporins) reduce water absorption, resulting in high volumes of very dilute urine.

Concept Check

- Contrast the following terms: **oliguria**, **anuria** and **polyuria**. What are the differences between these terms as they describe urinary output?
- Explain how urine **color** varies based on food consumed and/or **hydration** levels.

Endocrine Urinary Function

Several hormones have specific, important roles in regulating kidney function. They act to stimulate or inhibit blood flow. Some of these are endocrine, acting from a distance, whereas others are paracrine, acting locally.

Diuretics and Fluid Volume

A diuretic is a compound that increases urine volume. Three familiar drinks contain diuretic compounds: coffee, tea, and alcohol. The caffeine in coffee and tea works by promoting vasodilation in the nephron, which increases GFR. Alcohol increases GFR by inhibiting ADH release from the posterior pituitary, resulting in less water recovery by the collecting duct. In cases of high blood pressure, diuretics may be prescribed to reduce blood volume and, thereby, reduce blood pressure. The most frequently prescribed anti-hypertensive diuretic is **hydrochlorothiazide.**

Regulation of Nitrogen Wastes

Nitrogen wastes are produced by the breakdown of proteins during normal **metabolism**. Proteins are broken down into amino acids, which in turn are deaminated by having their nitrogen groups removed. Deamination converts the amino (NH_2) groups into ammonia (NH_3), ammonium ion (NH_4^+), urea, or uric acid (Figure 5.8). Ammonia is extremely toxic, so most of it is very rapidly converted into urea in the liver. Human urinary wastes typically contain primarily urea with small amounts of ammonium and very little uric acid.

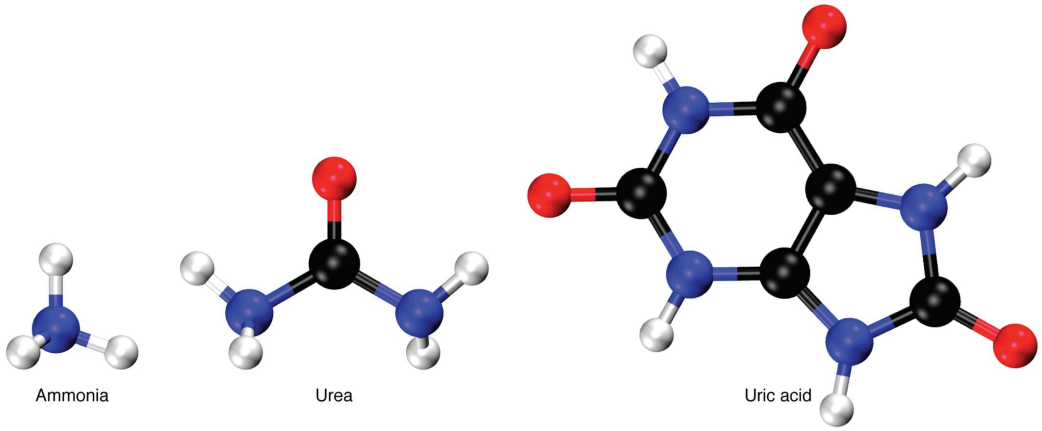


Figure 5.8 Nitrogen Wastes. From Betts, et al., 2021. Licensed under CC BY 4.0.

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Urinary System Medical Terms not Easily Broken into Word Parts

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Urinary System Abbreviations

Many terms and phrases related to the urinary system are abbreviated.
Learn these common abbreviations by expanding the list below.

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Diseases and Disorders

Glomerulonephritis

Glomerulonephritis refers to acute or chronic nephritis that involves inflammation of the capillaries of the renal glomeruli. It has various causes, and is noted especially by blood or protein in the urine and by edema. If untreated, it could lead to kidney failure.

Hydronephrosis

Hydronephrosis is a condition whereby the kidneys begin to swell because of the retention of urine. Several conditions can cause hydronephrosis, such as a kidney stone or blood clot. Treatment will vary, depending on the cause (Cleveland Clinic, 2019). To learn more about hydronephrosis the Cleveland Clinic's web page on hydronephrosis.

Polycystic Kidney Disease

Polycystic kidney disease (PKD) is a genetic disease where cysts grow inside the kidneys. The kidneys enlarge from the cystic collections and damage to the filtering structures of the kidneys can occur. As the disease progresses it may lead to chronic kidney disease (American Kidney Fund, 2020). To learn more, visit the Kidney Fund's PKD web page.

Renal Cell Cancer

Renal cell cancer is a cancer occurring in the kidney tubes where urine is produced or collected. This one of the most common cancers found within the kidneys. Removal of the cancerous lesions is the typical approach from a treatment perspective (Centers for Disease Control, 2020). To learn more, visit the CDC web page on Kidney Cancer.

Renal Failure

Renal failure occurs when kidneys suddenly or gradually become unable to filter waste products from blood. When kidneys stop filtering, high level of wastes may build. Two types exist acute kidney failure and chronic kidney failure (Mayo Clinic Staff, 2019a). To learn more about kidney failure visit the Mayo Clinic's page on Chronic Kidney Failure.

Cystitis

Cystitis is inflammation of the urinary bladder, often caused by an infection. A chronic form of this condition is known as interstitial cystitis. Symptoms of cystitis include bladder pressure, voiding frequently, and pain (Mayo Clinic Staff, 2019b). To learn more about cystitis visit the Mayo Clinic's page on Interstitial Cystitis.

Urinary Tract Infection

A urinary tract infection (UTI) is an infection caused by bacteria, or sometimes, fungi. The exact type of bacterial growth is determined by conducting urine for culture and sensitivity (C&S) testing. In rare cases a UTI may be caused by a virus (Lights & Boskey, 2019). For more information, visit Healthline's web page on Urinary Tract Infections.

Urinary Incontinence

Urinary incontinence is a loss of bladder control. Those afflicted with the condition will experience urine leakage from the bladder. Weak bladder muscles are a risk factor for developing this condition (Kim & O'Connell, 2017). To learn more about this condition visit Healthline's webpage Urologic Diseases.

Medical Terms in Context

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Medical Specialties and Procedures Related to the Urinary System

Urology is specialty that "excels in diagnosing and treating problems involving the male and female urinary tract and the male reproductive organs" (Mayo Clinic, 2021). Common clinical visits involve kidney stones, kidney failure and bladder dysfunction. To learn more about urology as a specialty visit the Why Urology? authored by the American Urological Association (2021).

Urologist

A urologist is a medical specialist involved in the diagnosis and treatment of urinary and male genitourinary system conditions, disorders, and diseases such as prostate disease, renal and bladder dysfunctions, and others (Watson, 2021).

Procedures and Testing

Urinalysis

A urinalysis is microscopic group of urine testing. This test detects and measures several substances in the urine such as products of normal and abnormal metabolism and bacteria (Lab Tests Online, 2020). To learn more about urinalysis visit Lab Tests Online's Urinalysis web page.

Urine for C&S

Urine for culture and sensitivity. Urine produced by the kidneys is analyzed by way of a urine culture test which can detect and identify bacteria in the urine, which may be causing a urinary tract infection (UTI). If harmful bacteria is found a sensitivity report is generated. This report lists antibiotics sensitive in the treatment of the bacteria present (Lab Tests Online, 2020a). To learn more about Urine for C&S, visit Lab Tests Online's Urine Culture web page.

24-Hour Urine Collection

This is a test whereby all urinary output is collected over a 24-hour period of time. The analysis of urinary output over this extended period of time provides a greater indication of normal or abnormal kidney function (Lab Tests Online, 2017). To learn more a, visit Lab Tests Online's *24-hour Urine Sample* article.

CT Scan of Kidney

Computed tomography is a diagnostic imaging procedure that uses a combination of x-rays and computer technology to produce a variety of images. It provides detailed images of the kidney looking for disease, cancer, obstructions and other kidney conditions (Johns Hopkins Medicine, n.d.) . To learn more about a CT scan of the kidney visit Johns Hopkins Medicine's page on Computed Tomography (CT or CAT) Scan of the Kidney.

Cystoscopy

A cystoscopy is a procedure allowing a physician to check for bladder or ureteral problems, such as bladder cancer. An endoscope, also known as a cystoscope, containing a camera at the end of it is used (Mayo Clinic, 2021). To learn more about cystoscopy visit the Mayo Clinic Cystoscopy Overview.

Dialysis is a treatment that removes waste products from the blood when the kidneys are not fully functioning. This type of therapy is available at home or in a hospital or clinic and there are two main types: peritoneal dialysis and hemodialysis (National Kidney Foundation, 2020). To learn more about dialysis visit the National Kidney Foundation webpage.

Intravenous Pyelogram

An intravenous pyelogram (IVP) is a specialized x-ray designed to produce views of the entire urinary tract. A dye is used to secure the enhanced imaging. The x-rays can also show how well the urinary tract is functioning and any identify any blockages (Mayo Clinic, 2020a). To learn more about IVP visit the Mayo Clinic IVP webpage.

Kidney Scan

A kidney scan is an imaging test which views the kidneys. It is considered a nuclear imaging test as it uses radioactive tracers to pick up hot or cold spots within the kidney. These variation are are considered abnormal.

Kidney Transplant

When kidneys fail or when a person is in end stage chronic kidney disease, a surgical procedure is performed in the form of a kidney transplant. This procedure involves harvesting a donor kidney which is transplanted into the recipient in need of a functioning kidney to support vital function of the urinary system.

Test Yourself

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6: Male Reproductive System

Learning Objectives

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

Male Reproductive System Word Parts

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

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Introduction to the Male Reproductive System

Gametes are the reproductive cells that combine to form a fetus. Organs called gonads produce the gametes, along with the hormones that regulate human reproduction. The male gametes are called sperm. Spermatogenesis occurs within the seminiferous tubules that make up most of the testis. The scrotum is a sac that holds the testes outside of the body cavity.

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Media 6.1. Reproductive System, Part 2 – Male Reproductive System: Crash Course A&P 41 [Online video]. Copyright 2015 by CrashCourse.

Male Reproductive Medical Terms

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Anatomy (Structures) of the Male Reproductive System

The structures of the male reproductive system include the testes, the epididymis, the penis, and the ducts and glands that produce and carry semen. Sperm exit the scrotum through the vas deferens. The spermatic cord is an enclosed sheath which includes the vas deferens, arteries, veins and nerves. The seminal vesicles and prostate gland add fluids to the sperm to create semen.

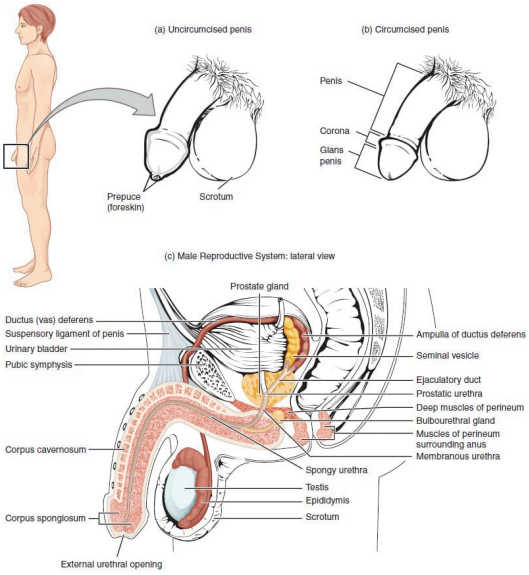


Figure 6.1. Male Reproductive System. From Betts, et al., 2021. Licensed under CC BY 4.0.

Physiology (Function) of the Male Reproductive System

Did You Know?

Sperm counts slowly decline after age 35, and some studies suggest that smoking can lower sperm counts irrespective of age.

Sperm

Sperm are smaller than most cells in the body; in fact, the volume of a sperm cell is 85,000 times less than that of the female gamete. Approximately 100 to 300 million sperm are produced each day, whereas women typically ovulate only one oocyte per month as is true for most cells in the body, the structure of sperm cells speaks to their function. Sperm have a distinctive head, mid-piece, and tail region.

Sperm Transport

To fertilize an egg, sperm must be moved from the seminiferous tubules in the testes, through the epididymis, and—later during ejaculation—along the length of the penis and out into the female reproductive tract. It takes an average of 12 days for sperm to move through the coils of the epididymis, with the shortest recorded transit time in humans being one day.

Epididymis

Sperm enter the head of the epididymis and are moved by the contraction of smooth muscles lining the epididymal tubes. As the sperm mature they acquire the ability to move under their own power. Once inside the female reproductive tract, they will use this ability to move independently toward the unfertilized egg. The more mature sperm are then stored in the tail of the epididymis until ejaculation occurs.

Ducts

During ejaculation, sperm exit the tail of the epididymis and are pushed by smooth muscle contraction to the vas deferens (also called the ductus deferens). The vas deferens is a thick, muscular tube that is bundled together inside the scrotum with connective tissue, blood vessels, and nerves into a structure called the **spermatic cord.** From each epididymis, each vas deferens extends through the inguinal canal in the abdominal wall and continues to a region called the ampulla. The sperm is mixed with fluid from the paired seminal vesicles and moves into its associated ejaculatory duct. The ejaculatory ducts transport the seminal fluid to the prostate gland.

Prostate Gland

The prostate gland secretes an alkaline, milky fluid to the passing seminal fluid (referred to as semen) to first coagulate and then decoagulate the semen following ejaculation. The temporary thickening of semen helps retain it within the female reproductive tract and once decoagulated the sperm can pass farther into the female reproductive tract.

Bulbourethral Glands

Bulbourethral glands release a thick, salty fluid that lubricates the end of the urethra and vagina, and helps to clean urine residues from the penile urethra.

Concept Check

- Write or draw out the components of the **pathway** that sperms takes from beginning until the end.
- Consider fertility challenges that may be experienced if a large number of defective sperm are produced.

Anatomy Labeling Activity

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Male Reproductive Terms not Easily Broken into Word Parts

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Common Male Reproductive System Abbreviations

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Diseases and Disorders

Erectile Disorder (ED)

Erectile dysfunction (ED) is a condition in which a male has difficulty either initiating or maintaining an erection. The combined prevalence of minimal, moderate, and complete ED is approximately 40% in men at age 40 and reaches nearly 70% by 70 years of age. In addition to aging, ED is associated with diabetes, vascular disease, psychiatric disorders, prostate disorders, the use of some drugs such as certain antidepressants, and problems with the testes resulting in low testosterone concentrations. These physical and emotional conditions can lead to disruptions in the vasodilation pathway and result in an inability to achieve an erection (Betts, et al., 2021).

Cancer

Prostate Cancer

According to the Centers for Disease Control and Prevention (CDC), prostate cancer is the second most common cancer occurring in men. However, some forms of prostate cancer grow very slowly and may not require treatment. Aggressive forms of prostate cancer, in contrast, involve metastasis to organs like the lungs and brain. There is no link between Benign Prostatic Hyperplasia and prostate cancer, but the symptoms are similar. Prostate cancer is detected by medical history, a blood test, and a digital rectal exam that allows physicians to palpate the prostate and check for unusual masses. If a mass is detected, the cancer diagnosis is confirmed by biopsy of the cells (Betts, et al., 2021).

Did You Know?

Family history is a common risk factor for testicular cancer.

Testicular Cancer

Testicular cancer begins in the testicle or testis. It is most often found in men age 15 to 35 years, although it can be diagnosed at any age (Mayo Clinic, 2020). Testicular cancer is rare and treatable when diagnosed early. Common symptoms are a painless lump in the testicle, swelling, a heavy feeling in the scrotum or abdomen, amongst others. Sometimes, testicular cancer is found during infertility testing. An orchiectomy is the most common procedure for diagnosing and treating testicular cancer (Mayo Clinic, 2020). To learn more about testicular cancer, diagnosis and treatments please go to the Mayo Clinic's page on testicular cancer.

Sexually Transmitted Infections (STIs)

The terms for sexually transmitted infections (STI) and sexuality transmitted diseases (STD) are often used interchangeably. Sexuality transmitted disease (STD) implies the disease was acquired through sexual transmission. A disease is a disorder of structure or function in a human, which produces specific signs or symptoms. A disease must be managed, as with the case of human immunodeficiency virus (which can also be acquired through the transmission of other bodily fluids; thus not solely sexual transmission). The treatment may include antiretrovirals or anti-virals (Urology Care Foundation, 2019).

Chlamydia (CT)

Chlamydia is one of the most common sexually transmitted infections (STIs) caused by bacteria that infect the cervix, urethra and other reproductive organs. Chlamydia is easy to treat and can be cured. Many people with chlamydia do not have any symptoms and unknowingly pass the infection to their sexual partner(s). If symptoms develop, they usually appear two to six weeks after sexual contact with an infected person. Males may have penial discharge and itching around the urethra. The urethra is the opening in the penis. Males may also experience dysuria, polyuria, urethral pain and urethritis (Centers for Disease Control and Prevention, 2021a).

Chlamydia spreads through unprotected oral, anal or vaginal sex with an infected person. Chlamydia can be spread to the eyes via the hands with direct contact of infected fluids. Until a patient finishes their treatment, they continue to have the infection and can continue to pass it to others. Chlamydia is treated with antibiotic pills. If the patient has epididymitis, they may need to be hospitalized and be treated with intravenous (IV) antibiotics. All sexual partners within the past 60 days should be examined, treated, and informed that having no symptoms does not mean there is no infection (Centers for Disease Control and Prevention, 2021a).

Gonorrhea (Gonococcus) – (GC)

Gonorrhea is a sexually transmitted infection (STI) caused by bacteria that infects the cervix, urethra and other reproductive organs. Infections can also infect the throat and anus. Gonorrhea can be treated and cured. Many people infected with gonorrhea have no symptoms and can unknowingly pass the infection on to their sexual partner(s). If symptoms develop, they may appear two to seven days after sexual contact with an infected person. Symptoms vary depending on which part of the body is infected. Males may have yellowish-white discharge from the penis. They may also have dysuria, polyuria , testicular pain and testitis. Gonorrhea infection from oral sex may lead to sore throat and swollen glands. Gonorrhea infection from anal sex may cause itchiness and discharge from the anus. Gonorrhea is spread through unprotected oral, vaginal or anal sex with an infected person. Until the patient finishes their treatment, they continue to have the infection and can pass it to others (Centers for Disease Control and Prevention, 2021b).

Gonorrhea is treated with oral antibiotics in combination with an intramuscular (IM) injection. It is important that one completes the treatment and abstain from unprotected sexual activity for at least seven days following treatment. If the patient develops epididymitis, the patient may need to go to a hospital and be treated with intravenous antibiotics.
All sexual partners within the past 60 days should be examined, treated and informed that having no symptoms does not mean there is no infection (Centers for Disease Control and Prevention, 2021b).

Reportable Diseases

Both chlamydia and gonorrhea are reportable diseases and the provider should report cases to local and state public health agencies as well as to the Centers for Disease Control and Prevention. Requirements and procedures vary by county and state. For more information see Medline's Reportable Diseases list.

Human Papillomavirus- HPV

HPV is another common sexually transmitted infection (STI). Both males and females can be infected with HPV. Around three quarters of sexually active individuals have been exposed to HPV during their lifetime. There are over 100 strains of HPV and some strains of HPV can cause visible genital warts. The warts are usually painless but may be itchy, uncomfortable and hard to treat. Some strains of HPV cause genital, anal, throat and cervical cancers. HPV spreads through sexual activity and skin-to-skin contact in the genital area with an infected person. Since some people are asymptomatic they don't know they have the virus and consequently pass the virus to their sexual partners. Treatments are available for genital warts but there is no cure for HPV (Centers for Disease Control and Prevention, 2021c). To learn more about HPV symptoms, treatments, and prognosis visit the CDC HPV Fact Sheet.

HPV Vaccine

A vaccine is available for 9 HPV strains. This vaccine, often known by the brand name Gardasil® 9, assists the immune system in protecting the body against infections and diseases caused by HPV (National Cancer Institute, 2019). To learn more about HPV vaccines, please visit the National Cancer Institute's HPV Vaccine Fact Sheet.

Herpes Simplex Virus (HSV)

Genital herpes is a sexually transmitted infection (STI) that is caused by a virus called herpes simplex virus (HSV). There are two types of herpes simplex viruses:

- Type 1- oral herpes or cold sores (HSV-1)
- Type 2- genital herpes (HSV-2).

These viruses are very similar and either type can cause genital herpes or cold sores. Symptoms might include dysuria, enlarged glands, myalgia, arthralgia and fever. Once a patient is infected with HSV, the virus remains in their body even after the symptoms are gone and can cause recurring outbreaks. When the virus becomes active again, the symptoms return but are usually less painful and heal faster. Recurring outbreaks vary from person-to-person, however they can be triggered by emotional or physical stress, exposure to sunlight, hormonal changes, poor nutrition, sexual intercourse, lack of sleep or a low immune system (Centers for Disease Control and Prevention, 2021d).

Herpes is spread through direct contact with the sores or blisters of an infected person. Contact (and transfer of the virus) can occur from genitals-to-genitals, mouth-to-genitals or mouth-to-mouth. Herpes can also be passed to the anal area. Herpes spreads easily during sexual contact while symptoms are present, or just before an outbreak of symptoms. An infected person may spread herpes even when they have *no* symptoms; this is called asymptomatic shedding. One can spread the herpes virus to other parts of their body after touching the sores; autoinoculation. The fingers, eyes and other body areas can accidentally become infected in this way. Hand washing after touching sores and blisters is recommended to prevent spreading the virus (Centers for Disease Control and Prevention, 2021d).

There is no cure for herpes. Antiviral pills help to reduce symptoms and speed the healing of blisters or sores and are prescribed by a doctor. Treatment of symptoms may be managed with medication for pain, bath salts, cold compresses and urinating in water may help to relieve discomfort. Keep the infected area clean and dry, wear cotton underwear and loose clothing to reduce discomfort. All sexual partner(s) should be informed. The only way to reduce the risk of transmission of herpes is to avoid direct contact with the sores and to use condoms. Condoms will reduce but not eliminate risk as the virus can be present and shed from the skin in the genital area (Centers for Disease Control and Prevention, 2021d).

To learn more about the symptoms, complications, treatments and prognosis of HSV please see the CDC Herpes Fact Sheet.

STI Medical Abbreviations

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Medical Terms in Context

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Medical Specialties and Procedures related to the Male Reproductive System

Vasectomy

Watch the Animated Dissection of Anatomy for Medicine's (A.D.A.M.) video to learn about a vasectomy. As described in this video, a vasectomy is a procedure in which a small section of the ductus (vas) deferens is removed from the scrotum. This cuts off the path taken by sperm through the ductus deferens. (as cited in Betts, et al., 2021).

No-Scalpel Vasectomy (NSV)

An alternative to a traditional vasectomy is the no-scalpel vasectomy (NSV). This is a minimally invasive procedure and an added benefit is that the recovery time is shorter. All vasectomies are completed by a urologist (Gentle Procedures Clinic, n.d.). To learn more about the NSV procedure, visit No-Scalpel Vasectomy Procedure Info by the Gentle Procedures Clinic in Toronto, Ontario.

Urology

Urology is a surgical sub specialty in which the surgeon has additional training in the treatments of diseases and disorders of the male and female urogenital systems (American Urological Association, 2021). To learn more about urology and the training involved to become a urologist visit the American Urological Association, Why Urology?

Test Yourself

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7: Female Reproductive System

Learning Objectives

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

Female Reproductive System Word Parts

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The female reproductive system produces gametes and reproductive hormones. In addition, the female reproductive system supports the developing fetus and delivers it to the outside world. The female reproductive system is located primarily inside the pelvic cavity. The female gonads are called ovaries and the gamete they produce is called an oocyte.

Watch this video:

YouTube Video

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Media 7.1. Reproductive System, Part 1 – Female Reproductive System: Crash Course A&P #40 [Online video]. Copyright 2015 by CrashCourse.

Female Reproductive System Medical Terms

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Anatomy (Structures) of the Female Reproductive System

External Female Genitals

The external female reproductive structures are referred to collectively as the **vulva** and they include:

- The **mons pubis** is a pad of fat that is located at the anterior, over the pubic bone. After puberty, it becomes covered in pubic hair.
- The **labia majora** (labia = "lips"; majora = "larger") are folds of hair-covered skin that begin just posterior to the mons pubis.
- The **labia minora** (labia = "lips"; minora = "smaller") is thinner and more pigmented and extends medially to the labia majora.
  - Although they naturally vary in shape and size from woman to woman, the labia minora serve to protect the female urethra and the entrance to the female reproductive tract.
  - The superior, anterior portions of the labia minora come together to encircle the **clitoris**(or glans clitoris), an organ that originates from the same cells as the glans penis and has abundant nerves that make it important in sexual sensation and orgasm. The **hymen**is a thin membrane that sometimes partially covers the entrance to the **vagina**.
- The vaginal opening is located between the opening of the urethra and the anus. It is flanked by outlets to the **Bartholin's glands** .

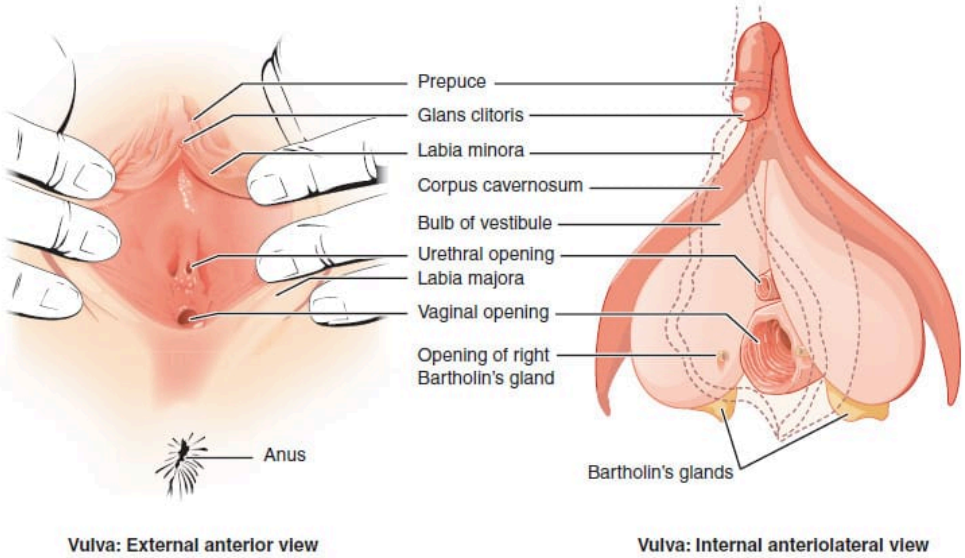


Figure 7.1. The Vulva. The external female genitalia are referred to collectively as the vulva. From Betts, et al., 2021. Licensed under CC BY 4.0.

Internal Female Reproductive Organs

Vagina

The **vagina** is a muscular canal (approximately 10 cm long) that is the entrance to the reproductive tract. It also serves as the exit from the uterus during menses and childbirth. The cervix is the opening to the uterus.

Together, the middle and inner layers allow the expansion of the vagina to accommodate intercourse and childbirth. The thin, perforated hymen can partially surround the opening to the vaginal orifice. The Bartholin's glands and the lesser vestibular glands (located near the clitoris) secrete mucus, which keeps the vestibular area moist .

The vagina has a normal population of microorganisms that help to **protect** against infection. There is both pathogenic bacteria, and yeast in the vagina. In a healthy woman, the most predominant type of vaginal bacteria is from the genus *Lactobacillus,* which secretes lactic acid. the lactic acid protects the vagina by maintaining an acidic pH (below 4.5).

Lactic acid, in combination with other vaginal secretions, makes the vagina a self-cleansing organ. However, douching can disrupt the normal balance of healthy microorganisms, and increase a woman's risk for infections and irritation. It is recommend that women do not douche and that they allow the vagina to maintain its normal healthy population of protective microbial flora.

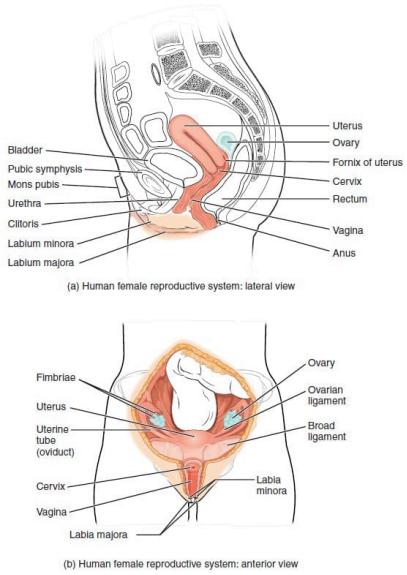


Figure 7.2 Female Reproductive System. The major organs of the female reproductive system are located inside the pelvic cavity. From Betts, et al., 2021. Licensed under CC BY 4.0.

Ovaries

The **ovaries** are the female gonads. There are two, one at each entrance to the fallopian tube. They are each about 2 to 3 cm in length, about the size of an almond. The ovaries are located within the pelvic cavity. The ovary itself is attached to the uterus via the ovarian ligament. This grouping of an oocyte and its supporting cells is called a **follicle.**

The Fallopian Tubes

The fallopian tubes are the conduit of the oocyte from the ovary to the uterus. Each of the two fallopian tubes is close to, but not directly connected to, the ovary. Instead fimbriae catch the oocyte like a baseball in a glove. The middle region of the tube, called the **ampulla**, is where fertilization often occurs.

The Uterus and Cervix

The **uterus** is the muscular organ that nourishes and supports the growing embryo. Its average size is approximately 5 cm wide

by 7 cm long and it has three sections.

- The portion of the uterus superior to (pertaining to above) the opening of the uterine tubes is called the **fundus**.
- The middle section of the uterus is called the **body of uterus** (or corpus).
- The **cervix** is the narrow inferior portion of the uterus that projects into the vagina.
  - The cervix produces mucus secretions that become thin and stringy under the influence of high systemic plasma estrogen concentrations, and these secretions can facilitate sperm movement through the reproductive tract.

The wall of the uterus is made up of three layers:

- **Perimetrium:** the most superficial layer and serous membrane.
- **Myometrium:** a thick layer of smooth muscle responsible for uterine contractions.
- **Endometrium:** the innermost layer containing a connective tissue lining covered by epithelial tissue that lines the lumen. It provides the site of implantation for a fertilized egg, and sheds during menstruation if no egg is fertilized.

Concept Check

- Write or draw out the components of the pathway that an **oocyte** takes from beginning to end.

Physiology (Function) of the Female Reproductive System-Ovulation

Following ovulation, the Fallopian tube receives the oocyte. Oocytes lack flagella, and therefore cannot move on their own.

- High concentrations of estrogen that occur around the time of ovulation induce contractions of the smooth muscle along the length of the Fallopian tube.
- These contractions occur every 4 to 8 seconds, causing the oocyte to flow towards the uterus, through the coordinated beating of the cilia that line the outside and lumen of the length of the Fallopian tube which pulls the oocyte into the interior of the tube.
- Once inside, the muscular contractions and beating cilia move the oocyte slowly toward the uterus.
- When fertilization does occur, sperm typically meet the egg while it is still moving through the ampulla.

Watch this video:

Watch this video on ovulation from MedLine Plus to observe ovulation and its initiation in response to the release of FSH and LH from the pituitary gland.
Media 7.2. Ovulation. From Betts, et al., 2021. Licensed under CC BY 4.0.

The Menstrual Cycle

The three phases of the menstrual cycle are:

1. The **menses phase** of the menstrual cycle is the phase during which reproductive hormone levels are low, the woman menstruates, and the lining is shed. The menses phase lasts between 2 – 7 days with an average of 5 days.
2. The **proliferative phase** is when menstrual flow ceases and the endometrium begins to proliferate . During this phase reproductive hormones are working in homeostasis to trigger ovulation on approximately day 14 of a typical 28-day menstrual cycle. Ovulation marks the end of the proliferative phase.
3. The **secretory phase** the endometrial lining prepares for implantation of a fertilized egg. If no pregnancy occurs within approximately 10- 12 days the endometrium will grow thinner and shed starting the first day of the next cycle.

Anatomy Labeling Activity

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Female Reproductive System Terms not Easily Broken into Word Parts

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Female Reproductive System Medical Abbreviations

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Diseases and Disorders of the Female Reproductive System

Cancer

Breast Cancer

Breast cancer starts in the cells that line the ducts or the lobule of the breast. Some warning signs include a new lump in the breast or axilla, thickening or swelling, irritation or dimpling of the breast skin, redness or flaky skin, pain, discharge, all in the breast or nipple area, and change in breast size. Risk factors include family history, obesity, hormonal treatment and changes in breast cancer-related genes (BRCA1 or BRCA2) (Centers for Disease Control and Prevention, n.d.; Cancer Care Ontario, n.d.).

Treatment options include chemotherapy, radiation and surgical interventions such as mastectomy, biopsy, incision and drainage and mammoplasty (Cancer Treatment Centers of America, n.d.). To learn more about breast cancer, view the Cancer Treatment Centers of America webpage.

Cervical Cancer

Cervical cancer is typically slow-growing cancer and is highly curable when found and treated early. Advanced cervical cancer may cause abnormal bleeding or discharge from the vagina such as bleeding after sex. It is diagnosed during a Papanicolaou test (or Pap smear) which looks for precancers, cell changes, on the cervix. The Pap test can find cervical cancer early, when treatment is most effective. The Pap test only screens for cervical cancer (Centers for Disease Control and Prevention, 2019).

The HPV (Human papillomavirus) test looks for HPV strains which is the virus that can cause precancerous cell changes. Almost all cervical cancers are caused by HPV. HPV is a common virus that is passed from one person to another during sexual contact. In Canada, there is the HPV vaccine. The age of administration varies between states. To learn more about cervical cancer please visit the Centers for Disease Control and Prevention's cervical cancer factsheet (PDF file).

Endometriosis

Endometriosis is an abnormal condition of the endometrium. Endometriosis occurs when this tissue grows and implants outside the uterus. The female hormone estrogen causes these implants to grow, bleed, and break down. They are implanted outside the uterus have no way to leave the body. They become painful, inflamed, and swollen. The inflammation causes scar tissue around nearby organs which can interfere with their normal functioning and cause pain (Mayo Clinic, 2019).

Endometriosis generally appears between the ages of 15 and 50. Signs and symptoms may include dysmenorrhea, lumbago, dyspareunia, menstrual irregularity and infertility. One-third of women diagnosed with endometriosis have no symptoms at all. Diagnosis may include laparoscopy and endometrial biopsy. Treatment may include medication, surgical interventions such as hysterectomy and oophorectomy. The cause of endometriosis is unknown (Mayo Clinic, 2019). To learn more about endometriosis visit the Mayo Clinic's *Endometriosis* profile.

PCOS

Polycystic Ovary Syndrome (PCOS) has no known etiology but researchers have linked it to excessive insulin production. Excessive insulin in the body can release extra male hormones in women. Since the ovaries produce high levels of androgens this causes the eggs to develop into cysts and instead of releasing during ovulation, the cysts build up and enlarge. The most common symptoms of PCOS include oligomenorrhea, amenorrhea, polymenorrhea, enlarged ovaries with multiple small painless cysts or follicles that form in the ovary, acrochordons, acanthosis nigricans, hirsuitism, thinning hair, acne, weight gain, anxiety, depression, hyperglycemia, and infertility (Mayo Clinic, 2020).

Treatments like medications such as birth control pills or antiandrogens can help balance the hormones in your body and relieve some of the symptoms (Mayo Clinic, 2020). To learn more about Polycystic Ovary Syndrome visit the Mayo Clinic's PCOS profile.

Sexually Transmitted Infections (STIs)

The terms for Sexually Transmitted Infections (STI) and Sexuality Transmitted Diseases (STD) are often used interchangeably. Sexuality Transmitted Diseases (STD) implies the disease was acquired through sexual transmission. A disease is a disorder of structure or function in a human, which produces specific signs or symptoms. A disease must be managed, as with the case of Human Immunodeficiency Virus (which can also be acquired to through the transmission of other bodily fluids; thus not solely sexual transmission). The treatment may include antiretrovirals or anti-virals (Urology Care Foundation, 2019).

Chlamydia (CT)

Chlamydia is one of the most common sexually transmitted infections (STIs) caused by bacteria that infect the cervix, urethra and other reproductive organs. Chlamydia is easy to treat and can be cured. Many people with chlamydia do not have any symptoms and unknowingly pass the infection to their sexual partner(s). If symptoms develop, they usually appear two to six weeks after sexual contact with an infected person. While females are most often asymptomatic they may experience cervicitis. Left untreated, chlamydia in females can lead to Pelvic Inflammatory Disease (PID) which can cause permanent damage to the reproductive organs and subsequent infertility (Centers for Disease Control and Prevention, 2021a).

Chlamydia spreads through unprotected oral, anal or vaginal sex with an infected person. Chlamydia can be spread to the eyes

via the hands with direct contact of infected fluids. Until a patient finishes their treatment, they continue to have the infection and can continue to pass it to others. Chlamydia is treated with antibiotic pills. If the patient has epididymitis, they may need to be hospitalized and be treated with intravenous (IV) antibiotics. All sexual partners within the past 60 days should be examined, treated, and informed that having no symptoms does not mean there is no infection (Centers for Disease Control and Prevention, 2021a).

Gonorrhea (Gonococcus) – (GC)

Gonorrhea is a sexually transmitted infection (STI) caused by bacteria that infects the cervix, urethra and other reproductive organs. Infections can also infect the throat and anus. Gonorrhea can be treated and cured. Many people infected with Gonorrhea have no symptoms and can unknowingly pass the infection on to their sexual partner(s). If symptoms develop, they may appear two to seven days after sexual contact with an infected person. Symptoms vary depending on which part of the body is infected. Females may experience abnormal vaginal bleeding, discharge, or dysuria. Left untreated, Gonorrhea in females may lead to pelvic inflammatory disease and fertility complications such as ectopic pregnancy. Gonorrhea infection from oral sex may lead to sore throat and swollen glands. Gonorrhea infection from anal sex may cause itchiness and discharge from the anus. Gonorrhea is spread through unprotected oral, vaginal or anal sex with an infected person. Until the patient finishes their treatment, they continue to have the infection and can pass it to others (Centers for Disease Control and Prevention, 2021b).

Gonorrhea is treated with oral antibiotics in combination with an intramuscular (IM) injection. It is important that one completes the treatment and abstain from unprotected sexual activity for at least seven days following treatment. All sexual partners within the past 60 days should be examined, treated and informed that having no symptoms does not mean there is no infection (Centers for Disease Control and Prevention, 2021b).

Reportable Diseases

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Herpes Simplex Virus (HSV)

Genital herpes is a sexually transmitted infection (STI) that is caused by a virus called herpes simplex virus (HSV). There are two types of herpes simplex viruses:

- Type 1- oral herpes or cold sores (HSV-1)
- Type 2- genital herpes (HSV-2).

These viruses are very similar and either type can cause genital herpes or cold sores. Symptoms might include dysuria, enlarged glands, myalgia, arthralgia and fever. Once a patient is infected with HSV, the virus remains in their body even after the symptoms are gone and can cause recurring outbreaks. Between the outbreaks, the virus stays in their body. When the virus becomes active

again, the symptoms return but are usually less painful and heal faster. Recurring outbreaks vary from person-to-person, however they can be triggered by emotional or physical stress, exposure to sunlight, hormonal changes, poor nutrition, sexual intercourse, lack of sleep or a low immune system (Centers for Disease Control and Prevention, 2021d).

Herpes is spread through direct contact with the sores or blisters of an infected person. Contact (and transfer of the virus) can occur from genitals-to-genitals, mouth-to-genitals or mouth-to-mouth. Herpes can also be passed to the anal area. Herpes spreads easily during sexual contact while symptoms are present, or just before an outbreak of symptoms. An infected person may spread herpes even when they have *no* symptoms; this is called asymptomatic shedding. One can spread the herpes virus to other parts of their body after touching the sores; autoinoculation. The fingers, eyes and other body areas can accidentally become infected in this way. Hand washing after touching sores and blisters is recommended to prevent spreading the virus (Centers for Disease Control and Prevention, 2021d).

There is no cure for herpes. Antiviral pills help to reduce symptoms and speed the healing of blisters or sores and are prescribed by a doctor. Treatment of symptoms may be managed with medication for pain, bath salts, cold compresses and urinating in water may help to relieve discomfort. Keep the infected area clean and dry, wear cotton underwear and loose clothing to reduce discomfort. All sexual partner(s) should be informed. The only way to reduce the risk of transmission of herpes is to avoid direct contact with the sores and to use condoms. Condoms will reduce but not eliminate risk as the virus can be present and shed from the skin in the genital area (Centers for Disease Control and Prevention, 2021d).

To learn more about the symptoms, complications, treatments and prognosis of HSV please see the CDC Herpes Fact Sheet.

Female Reproductive System Medical Abbreviations

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Medical Terms in Context

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Medical Specialties and Procedures related to the Female Reproductive System

Gynecology

A gynecologist is a specialist in the area of gynecology focusing on the diagnosis, treatment, management and prevention of diseases and disorders of the female reproductive system. Obstetrics is a specialty that provides care through pregnancy, labour, and puerperium. Further subspecialties in women's health include contraception, reproductive endocrinology, infertility, adolescent gynecology, endoscopy and gynecological oncology (American Board of Medical Specialties, n.d.). To learn more about obstetrics or gynecology please visit the specialty and subspecialty page of the American Board of Obstetrics and Gynecology.

Hysterectomy

A hysterectomy is done to stage or treat female reproductive cancers, treat precancerous conditions of the cervix and some non-cancerous conditions that have not responded to other forms of treatment. There are three types of hysterectomy:

- A **total hysterectomy** removes both the uterus and the cervix.
- A **subtotal hysterectomy** removes the uterus only.
- A **radical hysterectomy** removes uterus, cervix, part of the vagina, and ligaments.

Sometimes the ovaries and fallopian tubes are removed at the same time that a hysterectomy is done. A bilateral salpingo-oophorectomy (BSO) removes both ovaries and fallopian tubes. A unilateral salpingo-oophorectomy removes one ovary and one Fallopian tube (National Women's Health Network, 2015). To learn more about hysterectomy please follow visit the National Women's Health Network's page on hysterectomies.

Test Yourself

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8: Obstetrics

Learning Objectives

- Identify the common processes in obstetrics
- Describe the specialty of obstetrics
- Spell the medical terms used in obstetrics and use correct abbreviations
- Identify the medical specialties associated with obstetrics
- Explore common complications and procedures related to obstetrics

Obstetric Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize related to obstetrics.

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Introduction to Obstetrics

Obstetrics is a specialty that is concerned with the mother and fetus during pregnancy, childbirth and the immediate postpartum period. Obstetricians study obstetrics and gynecology and are referred to as OB/GYN Obstetrics and Gynecology.

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Fertilization

Fertilization occurs when a sperm and an oocyte (egg) combine. Because each of these reproductive cells is a haploid cell containing half of the genetic material needed to form a human being, their combination forms a diploid cell. This new single cell is called a zygote.

Most of the time, a woman releases a single egg during an ovulation cycle.

- In approximately 1 percent of ovulation cycles, two eggs are released and both are fertilized.
  - Two zygotes form, implant, and develop, resulting in the birth of **dizygotic (or fraternal) twins**. Because dizygotic twins develop from two eggs fertilized by two sperm, they are no more identical than siblings born at different times.
- Less common, one zygote can divide into two separate offspring during early development. This results in the birth of **monozygotic (or identical) twins**.

A full-term pregnancy lasts approximately 270 days (approximately 38.5 weeks) from conception to birth. Because it is easier to remember the first day of the last menstrual period (LMP) than to estimate the date of conception, obstetricians set the due date as 284 days (approximately 40.5 weeks) from the LMP. This assumes that conception occurred on day 14 of the woman's cycle, which is usually a good approximation. The 40 weeks of an average pregnancy are usually discussed in terms of three trimesters, each approximately 13 weeks. During the second and third trimesters, the pre-pregnancy uterus is about the size of a fist and grows dramatically to contain the fetus, causing a number of anatomical changes in the mother.

Stages of Childbirth

The process of childbirth can be divided into three stages (see Figure 8.1):

- cervical dilation
- expulsion of the newborn
- after birth

For vaginal birth to occur, the cervix must dilate fully to 10 cm in diameter, wide enough to deliver the newborn's head. The dilation stage is the longest stage of labor and typically takes 6-12 hours. However, it varies widely and may take minutes, hours, or days, depending in part on whether the mother has given birth before. In each subsequent labor, this stage tends to be shorter.

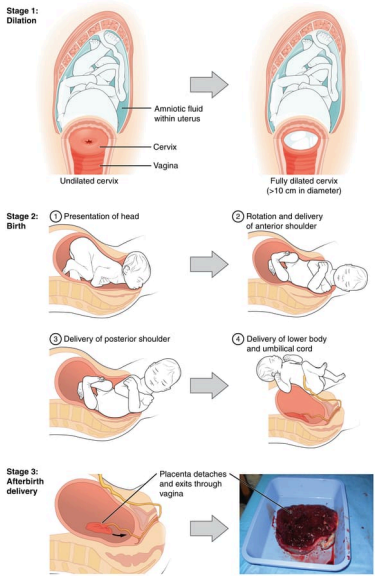


Figure 8.1 Stages of Childbirth. The stages of childbirth include Stage 1, early cervical dilation; Stage 2, full dilation and expulsion of the newborn; and Stage 3, delivery of the placenta and associated fetal membranes. (The position of the newborn's shoulder is described relative to the mother). From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

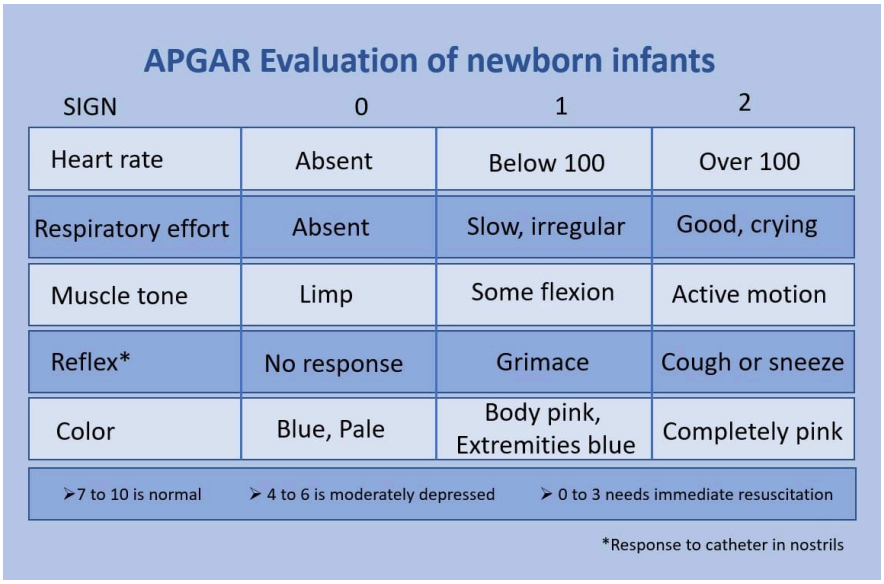
- How is a **due date** determined?
- Explain the difference between a **monozygotic pregnancy** and a **dizygotic pregnancy**.

Homeostasis in the Newborn: Apgar Score

In the minutes following birth, a newborn must undergo dramatic systemic changes to be able to survive outside the womb. An obstetrician, midwife, or nurse can estimate how well a newborn is doing by obtaining an **Apgar score** (Fig 8.2). The Apgar score was introduced in 1952 by the anesthesiologist Dr. Virginia Apgar as a method to assess the effects on the newborn of anesthesia given to the laboring mother. Healthcare providers now use it to assess the general well-being of the newborn, whether or not analgesics or anesthetics were used.

The technique for determining an Apgar score is quick and easy, painless for the newborn, and does not require any instruments except for a stethoscope. A convenient way to remember the five scoring criteria is to apply the mnemonic APGAR:

- **A**ppearance (skin color)
- **P**ulse (heart rate)
- **G**rimace (reflex)
- **A**ctivity (muscle tone)
- **R**espiration



APGAR Evaluation of newborn infants

SIGN	0	1	2
Heart rate	Absent	Below 100	Over 100
Respiratory effort	Absent	Slow, irregular	Good, crying
Muscle tone	Limp	Some flexion	Active motion
Reflex*	No response	Grimace	Cough or sneeze
Color	Blue, Pale	Body pink, Extremities blue	Completely pink

➢7 to 10 is normal ➢ 4 to 6 is moderately depressed ➢ 0 to 3 needs immediate resuscitation

*Response to catheter in nostrils

Fig 8.2 The five Apgar criteria, skin color, heart rate, reflex, muscle tone, and respiration, are assessed and each criterion is assigned a score of 0, 1, or 2. Scores are taken at 1 minute after birth and again at 5 minutes after birth. Each time scores are taken, the five scores are added together. High scores (out of a possible 10) indicate the baby has made the transition from the womb well, whereas lower scores indicate that the baby may be in distress.

Of the five Apgar criteria, heart rate and respiration are the most critical. Poor scores for either of these measurements may indicate the need for immediate medical attention to resuscitate or stabilize the newborn. In general, any score lower than 7 at the 5-minute mark indicates that medical assistance may be needed. A total score below 5 indicates an emergency situation. Normally, a newborn will get an intermediate score of 1 for some of the Apgar criteria and will progress to a 2 by the 5-minute assessment. Scores of 8 or above are normal.

Obstetrics Medical Terms not Easily Broken into Word Parts

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Obstetrics Abbreviations

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Medical Terms in Context

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Procedures Related to Obstetrics

In Vitro Fertilization (IVF)

IVF, which stands for in vitro fertilization, is an assisted reproductive technology. In vitro, which in Latin translates to in glass, refers to a procedure that takes place outside of the body. There are many different indications for IVF. For example, a woman may produce normal eggs, but the eggs cannot reach the uterus because the uterine tubes are blocked or otherwise compromised. A man may have a low sperm count, low sperm motility, sperm with an unusually high percentage of morphological abnormalities, or sperm that are incapable of penetrating the zona pellucida of an egg. Figure 8.3 illustrates the steps involved in IVF.



Figure 8.3 In Vitro. The ASRM Publications describes In vitro fertilization (IVF) as a method of assisted reproduction that involves combining an egg with sperm in a laboratory dish. If the egg fertilizes and begins cell division, the resulting embryo is transferred into the woman's uterus where it will hopefully implant in the uterine lining and further develop. After the various screening tests are conducted, and the woman has started the stimulation phase, here is a rundown of the next crucial steps. This shows how IVF (in vitro fertilization) generally works. Copyright ESCO Medical

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9: Cardiovascular System – Heart

Learning Objectives

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

Cardiovascular System – Heart Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the cardiovascular system – Heart.

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Introduction to the Heart

The heart is a fist-sized vital organ that has *one* job: to pump blood. If one assumes an average heart rate of 75 beats per minute, a human heart would beat approximately 108,000 times in one day, more than 39 million times in one year, and nearly 3 billion times during a 75-year lifespan. At rest, each of the major pumping chambers of the heart ejects approximately 70 mL blood per contraction in an adult. This would be equal to 5.25 liters of blood per minute and approximately 14,000 liters per day. Over one year, that would equal 10,000,000 liters of blood sent through roughly 100,000 km of blood vessels. In order to understand how that happens, it is necessary to understand the anatomy and physiology of the heart.

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Cardiovascular System – Heart Medical Terms

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Anatomy of the Heart

Location

The human heart is located within the thoracic cavity, between the lungs in the space known as the **mediastinum**. Figure 9.1 shows the position of the heart within the thoracic cavity. Within the mediastinum, the heart is separated from the other mediastinal structures by a tough membrane known as the pericardium, or pericardial sac, and sits in its own space called the **pericardial cavity**. The great vessels, which carry blood to and from the heart, are attached to the superior surface of the heart, which is called the base. The base of the heart is located at the level of the third costal cartilage. The inferior tip of the heart, the apex, lies just to the left of the sternum between the junction of the fourth and fifth ribs.

Concept Check

- On the diagram below (Figure 9.1), locate the **mediastinum**, the **pericardial cavity**, the **base** of the heart and the **apex** of the heart.
- Locate the largest vein in the body **superior vena cava**.

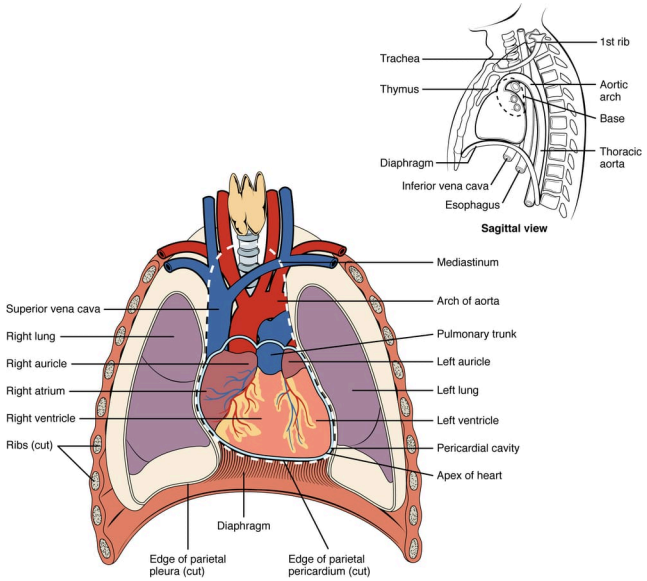


Figure 9.1. Position of the Heart in the Thorax. The heart is located within the thoracic cavity, medially between the lungs in the mediastinum. It is about the size of a fist, is broad at the top, and tapers toward the base. From Betts, et al., 2021. Licensed under CC BY 4.0.

Membranes and Layers of the Heart Walls

The heart and the roots of the great vessels are surrounded by a membrane known as the **pericardium** or **pericardial sac**. The pericardium consists of two distinct sub layers:

- The sturdy outer fibrous pericardium is made of tough, dense connective tissue that protects the heart and holds it in position.
- Separated by the **pericardialcavity** and containing pericardial fluid the inner serous pericardium consists of two layers:
  - the outer **parietal pericardium**, which is fused to the fibrous pericardium.
  - the inner **visceral pericardium**, or **epicardium**, which is fused to the heart and forms the outer layer of the heart wall.

The walls of the heart consist of three layers:

- The outer **epicardium**, which is another name for the visceral pericardium mentioned above.
- The thick, middle **myocardium**, which is made of muscle tissue and gives the heart its ability to contract.
- The inner **endocardium**, which lines the heart chambers and is the main component of the heart valves.

Concept Check

- Look at Figure 9.2 below, and name the layers of the heart wall and surrounding membranes, starting with the innermost layer.
- As shown on the diagram, suggest why is the **myocardium** layer is thicker than the **endocardium** layer?

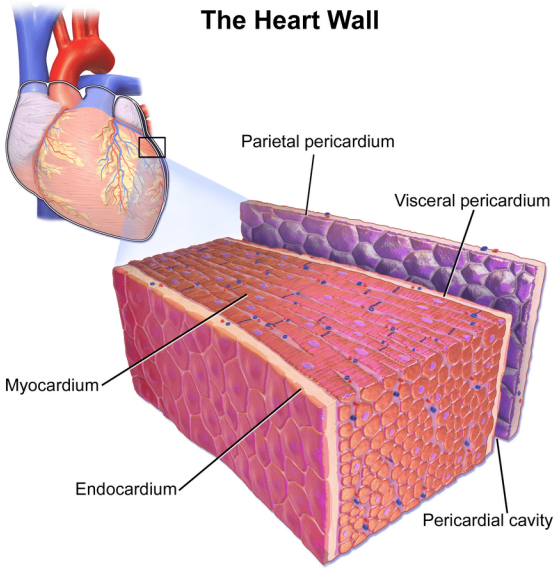


Figure 9.2. Layers of the Heart Wall. The pericardial membrane that surrounds the heart consists of three layers and the pericardial cavity. The heart wall also consists of three layers. The pericardial membrane and the heart wall share the epicardium From Blausen, 2014. Licensed under CC BY 3.0.

Internal Structures of the Heart

The heart consists of four chambers:

- The upper chambers are the right and left **atria** (singular: atrium).
- The lower chambers are the right and left **ventricles.**

The **interventricular septum** is a muscular wall that separates the right and left ventricles. The interatrial septum separates the right and left atria.

The atrium and ventricle on each side of the heart are separated by an atrioventricular (AV) valve:

- The right AV valve, or **tricuspid valve,** separates the right atrium and right ventricle.
- The left AV valve, or **bicuspid valve,** separates the left ventricle and the left atrium. This valve is also called the **mitral valve.**

There are also two semilunar valves:

- The **pulmonary valve** separates the right ventricle from the pulmonary trunk.
- The **aortic valve** separates the left ventricle from the aorta.

Anatomy Labeling Activity

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Physiology of the Heart

In order for the heart to do its job of pumping blood to the lungs and to the body, nutrients and oxygen must be supplied to the cells of the heart. The heart also needs to coordinate its contractions so that all parts are working together to pump blood effectively. To understand how all of this works together to give the heart its ability to pump blood, we will examine three interdependent aspects of heart function.

1. Circulation through the heart: Blood is pumped by the heart in order to provide oxygen and nutrients to every cell in the body.
2. The heart as an organ (coronary blood supply): The heart is an organ, made of cells and tissues which require their own blood supply.
3. The heart's electrical conduction system: The heart is able to independently generate and transmit instructions to the myocardium, in order to make it contract and pump the blood.

Circulation Through the Heart: The Heart as a Pump

The heart pumps blood to two distinct but linked circulatory systems called the pulmonary and systemic circuits. The **pulmonary circuit** transports blood to and from the lungs, where it picks up oxygen and drops off carbon dioxide. The **systemic circuit** transports freshly oxygenated blood to virtually all of the tissues of the body and returns relatively deoxygenated blood and carbon dioxide to the heart to be sent back to the pulmonary circulation.

Did You Know?

The heart sounds heard through a stethoscope are the sounds of the four heart valves opening and closing at specific times during one cardiac cycle.

1. Blood that is carrying carbon dioxide and waste products from the body tissues is returned to the **right atrium** via the superior vena cava and the inferior vena cava.
2. From the right atrium, the deoxygenated blood moves through the **tricuspid valve** into the right ventricle.
3. The **right ventricle** pumps deoxygenated blood through the **pulmonary valve** into the **pulmonary trunk**, which splits into the **right and left pulmonary arteries**, leading toward the lungs. These arteries branch many times before reaching the **pulmonary capillaries**, where gas exchange occurs: carbon dioxide exits the blood and oxygen enters. The pulmonary arteries are the only arteries in the postnatal body that carry deoxygenated blood. Did you notice that they are often colored blue on diagrams of the heart?
4. Freshly oxygenated blood returns from the lungs to the **left atrium** via the **pulmonary veins**. These veins are the only veins

in the body that carry highly oxygenated blood, and are often colored red on heart images.
5. From the left atrium, the blood moves through the **mitral valve** into the **left ventricle.**
6. The left ventricle pumps blood through the **aortic valve**, into the **aorta**, delivering blood to all parts of the body.

Pulmonary Circuit

Blood exiting from the right ventricle flows into the pulmonary trunk, which bifurcates into the two pulmonary arteries. These vessels branch to supply blood to the pulmonary capillaries, where gas exchange occurs within the lung alveoli. Blood returns via the pulmonary veins to the left atrium.

Concept Check

- On Figure 9.3 below, use your finger to trace the pathway of blood flowing through the left side of the heart, naming each of the following structures as you encounter them: right and left pulmonary veins, left atrium, mitral valve, left ventricle, aortic valve, aorta.

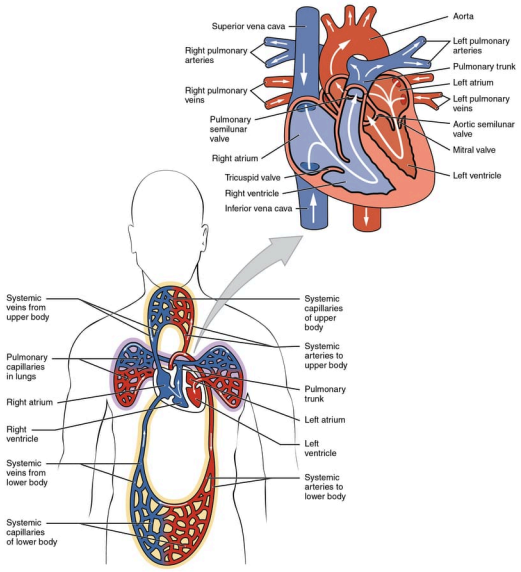


Figure 9.3. Dual System of the Human Blood Circulation. Blood flows from the right atrium to the right ventricle, where it is pumped into the pulmonary circuit. The blood in the pulmonary artery branches is low in oxygen but relatively high in carbon dioxide. Gas exchange occurs in the pulmonary capillaries (oxygen into the blood, carbon dioxide out), and blood high in oxygen and low in carbon dioxide is returned to the left atrium. From here, blood enters the left ventricle, which pumps it into the systemic circuit. Following exchange in the systemic capillaries (oxygen and nutrients out of the capillaries and carbon dioxide and wastes in), blood returns to the right atrium and the cycle is repeated. From Betts, et al., 2021. Licensed under CC BY 4.0.

Cardiac Cycle

The process of pumping and circulating blood is active, coordinated and rhythmic. Each heartbeat represents one cycle of the heart receiving blood and ejecting blood.

- **Diastole** is the portion of the cycle in which the heart is relaxed and the atria and ventricles are filling with blood. The AV valves are open, so that blood can move from the atria to the ventricles.
- **Systole**is the portion of the cycle in which the heart contracts, AV valves slam shut, and the ventricles eject blood to the lungs and to the body through the open semilunar valves. Once this phase ends, the semilunar valves close, in preparation for another filling phase.

Heart Terms not Easily Broken into Word Parts

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Heart Abbreviations

Many terms and phrases related to the cardiovascular system- heart are abbreviated.
Learn these common abbreviations by expanding the list below.

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Diseases and Disorders

Cardiomyopathy

The heart of a well-trained athlete can be considerably larger than the average person's heart. This is because exercise results in an increase in muscle cells called hypertrophy . Hearts of athletes can pump blood more effectively at lower rates than those of non-athletes. However, when an enlarged heart is not the result of exercise, it may be due to **hypertrophic cardiomyopathy**. The cause of an abnormally enlarged heart muscle is unknown, but the condition is often undiagnosed and can cause sudden death in apparently otherwise healthy young people (Betts, et al., 2021).

Other types of cardiomyopathy include:

- **Dilated cardiomyopathy**, which also has an unknown cause and is seen in people of any age. In this disorder, one of the ventricles of the heart is larger than normal.
- **Arrhythmogenic cardiomyopathy**, an inherited condition which results in irregular heart rhythms.
- **Restrictive cardiomyopathy**, which is a complication of other conditions which cause the myocardium to scar or stiffen (Centers for Disease Control and Prevention, 2019).

Cardiomyopathy may also be caused by myocardial infarctions, myocardial infections, pregnancy, alcohol or cocaine abuse, autoimmune and endocrine diseases. Because the myocardium is responsible for contracting and pumping blood, patients with cardiomyopathy experience impaired heart function which may lead to heart failure. (Centers for Disease Control and Prevention, 2019). To learn more about cardiomyopathy visit the CDC's cardiomyopathy web page.

Heart Failure

Heart failure is defined as the inability of the heart to pump enough blood to meet the needs of the body. It is also called **congestive heart failure (CHF).** This condition causes swelling in the lower extremities and shortness of breath, due to a buildup

of fluid in the lungs. It may be caused by cardiomyopathy and it may lead to hypertension and heart valve disorders (Heart & Stroke, n.d.). To learn more, visit the Heart & Stroke's congestive heart failure web page.

Valvular Heart Disease

Concept check

Do you remember the **names** and **locations** of the 4 heart valves?

The four heart valves open and close at specific times during the cardiac cycle, in order to ensure that blood flows in only one direction through the heart. This requires that these valves open and close completely. Infections such as rheumatic disease or bacterial endocarditis can affect the heart valves and result in scar tissue formation which interferes with valve function. Other causes of heart valve disease include: congenitally malformed valves, autoimmune diseases, and other cardiovascular diseases such as aortic aneurysms and atherosclerosis (Centers for Disease Control and Prevention, 2019a).

Heart valve disease may be asymptomatic, or cause dyspnea, arrhythmias, fatigue and other symptoms. It is often detected when a heart murmur is heard through a stethoscope (Centers for Disease Control and Prevention, 2019a).

- **Mitral Valve Prolaspse**
  - The mitral (bicuspid) valve is diseased or malformed and is not able to close completely, allowing the regurgitation of blood back into the left atrium during systole. Because some of the blood goes back into the atrium, insufficient blood is pumped out of the ventricle into the systemic circulation. This inability to close properly and the resulting regurgitation may also be found in other heart valves (Centers for Disease Control and Prevention, 2019a).
- **Aortic Stenosis**
  - The aortic valve is narrowed and hardened, preventing it from opening fully and allowing sufficient blood to travel to the systemic circulation. Any heart valve can be stenosed, but this disorder most often affects the aortic valve (Centers for Disease Control and Prevention, 2019a).

Visit the CDC's page on valvular heart disease to learn more.

Aneurysms

An aneurysm is a defect in the wall of an artery in which the wall becomes thin and weak and starts to balloon out as blood pulses against the vessel wall. This can happen to any artery and even to the myocardial walls. Aneurysms sometimes occur in the portion of the aorta that is in the thorax (see Figure 9.4). If these aneurysms start to leak between layers of the vessel wall, the condition is known as aortic dissection. If an aortic or cardiac aneurysm bursts, there is sudden, massive internal bleeding (Centers for Disease Control and Prevention, 2019b).

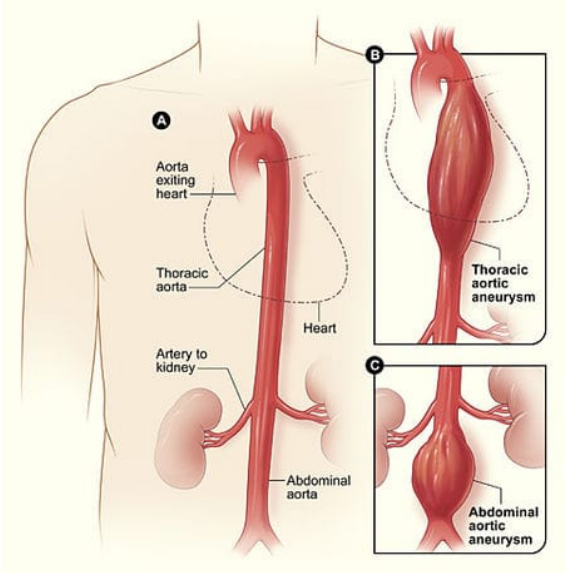


Figure 9.4 Arteries of the Thoracic and Abdominal Regions. The thoracic aorta gives rise to the arteries of the visceral and parietal branches. (Picture: Wikimedia. Aortic aneurysm)

People who smoke, have hypertension, hypercholesterolemia, and/or atherosclerosis have an increased risk of developing aneurysms. Having a family history of aneurysms or certain genetic diseases may also increase a person's risk of developing an aneurysm.

Aneurysms are often asymptomatic and may be detected incidentally during diagnostic tests that are being done for other reasons. They are sometimes repaired surgically and sometimes treated with medications such as antihypertensives (Centers for Disease Control and Prevention, 2019b; Tittley, n.d.). Visit the Society for Vascular Surgery's page on thoracic aortic aneurysms to learn more.

Heart Defects

Fetal circulation is different from postnatal circulation. There are 2 extra openings in the fetal heart, the foramen ovale and the ductus arteriosus, which allow blood circulation that bypasses the immature fetal lungs. The fetal blood is reoxygenated by the mother's lungs and transported between mother and fetus via the placenta. These two openings usually close around the time of birth (Betts, et al., 2021).

Septal defects are commonly first detected through auscultation. Unusual heart sounds may be detected because blood is not flowing and valves are not closing correctly. Medical imaging is ordered to confirm or rule out a diagnosis. In many cases, treatment may not be needed.

- **Patent ductus arteriosus** is a congenital condition in which the ductus arteriosus fails to close. If untreated, the condition can result in congestive heart failure.
- **Patent foramen ovale** is one type of atrial septal defect (ASD), due to a failure of the hole in the interatrial septum to close at birth.
  - As much as 20 – 25 percent of the general population may have a patent foramen ovale, most have the benign, asymptomatic version but in extreme cases a surgical repair is required to close the opening permanently.
- **Tetralogy of Fallot** is a congenital condition that may also occur from exposure to unknown environmental factors; it occurs when there is an opening in the interventricular septum caused by blockage of the pulmonary trunk, normally at the pulmonary semilunar valve. This allows blood that is relatively low in oxygen from the right ventricle to flow into the left ventricle and mix with the blood that is relatively high in oxygen.
  - Symptoms include a distinct heart murmur, low blood oxygen percent saturation, dyspnea, polycythemia, clubbing of the fingers and toes, and in children, difficulty in feeding or failure to grow and develop.
  - It is the most common cause of cyanosis following birth. Other heart defects may also accompany this condition, which is typically confirmed by echocardiography imaging.
- In the case of severe septal defects, including both tetralogy of fallot and patent foramen ovale, failure of the heart to develop properly can lead to a condition commonly known as a **blue baby.** Regardless of normal skin pigmentation, individuals with

this condition have an insufficient supply of oxygenated blood, which leads to cyanosis, especially when active (Betts, et al., 2021).

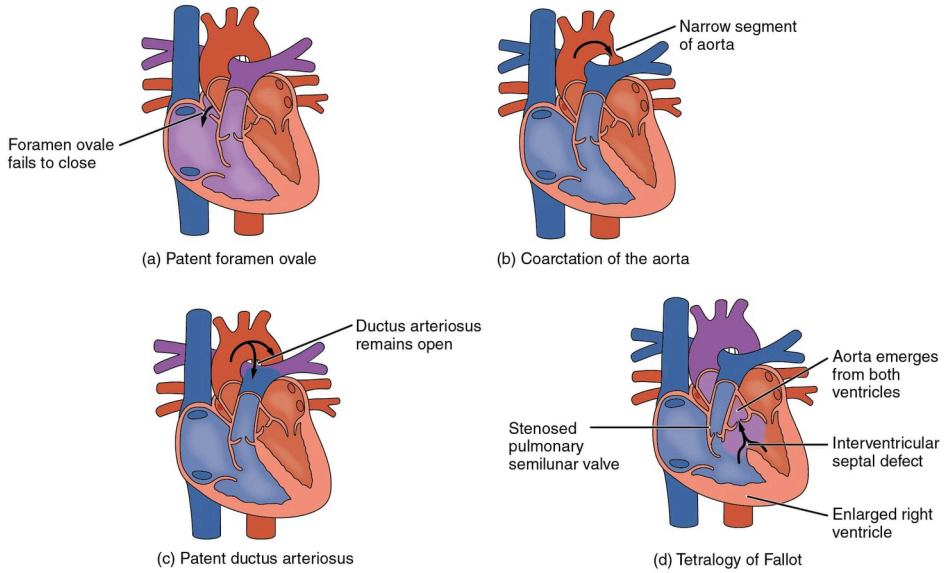


Figure 9.5. Congenital Heart Defects. (a) A patent foramen ovale defect is an abnormal opening in the interatrial septum, or more commonly, a failure of the foramen ovale to close. (b) Coarctation of the aorta is an abnormal narrowing of the aorta. (c) A patent ductus arteriosus is the failure of the ductus arteriosus to close. (d) Tetralogy of Fallot includes an abnormal opening in the interventricular septum. From Betts, et al., 2021. Licensed under CC BY 4.0.

Diseases of the Coronary Circulation

Coronary Artery Disease (CAD)

Coronary artery disease occurs when the buildup of plaque in the coronary arteries obstructs the flow of blood and decreases compliance of the vessels. This condition is called atherosclerosis. As the disease progresses and coronary blood vessels become more and more narrow, cells of the myocardium become ischemic, which causes symptoms of angina pectoris, in some patients. If untreated, coronary artery disease can lead to MI.

The image below shows the blockage of coronary arteries on an angiogram (Betts, et al., 2021).

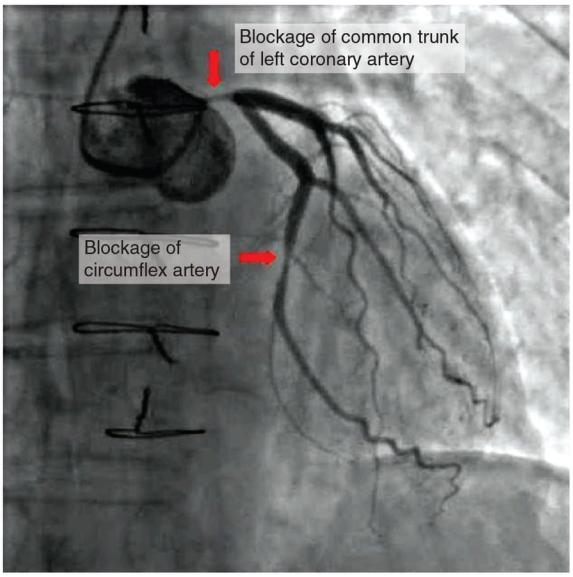


Figure 9.6. Angiogram of Atherosclerotic Coronary Arteries. In this coronary angiogram (X-ray), the dye makes visible two occluded coronary arteries. Such blockages can lead to decreased blood flow (ischemia) and insufficient oxygen (hypoxia) delivered to the cardiac tissues. If uncorrected, this can lead to cardiac muscle death (myocardial infarction). From Betts, et al., 2021. Licensed under CC BY 4.0.

CAD is progressive and chronic. Risk factors include smoking, family history, hypertension, obesity, diabetes, high alcohol consumption, lack of exercise, stress, and hyperlipidemia. Treatments may include medication, changes to diet and exercise, angioplasty with a balloon catheter, insertion of a stent, or coronary artery bypass graft (CABG) (Betts, et al., 2021).

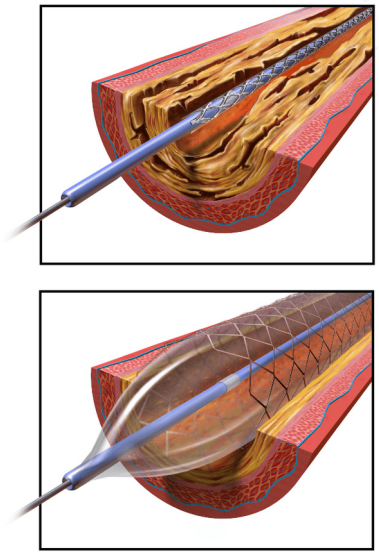


Figure 9.7 Angioplasty-Before and after image of Balloon Inflated with Stent From Blausen, 2014. Licensed under CC BY 3.0.

- **Angioplasty** is a procedure in which the occlusion is mechanically widened with a balloon. A specialized catheter with an expandable tip is inserted into a blood vessel in the arm or leg, and then directed to the site of the occlusion. At this point, the balloon is inflated to compress the plaque material and to open the vessel to increase blood flow. Once the balloon is deflated and retracted, a stent consisting of a specialized mesh is typically inserted at the site of occlusion to reinforce the weakened and damaged walls and prevent re-occlusion.

image

, via Wikimedia Commons" src="https://upload.wikimedia.org/wikiped...2_CABG_All.png" alt="Single, Double, Triple and Quadruple Bypass Image" width="937" height="469"> Figure 9.8 Single, Coronary Artery Bypass Graft (CABG). Double, Triple and Quadruple Bypass Image. From Blausen, 2014. Licensed under CC BY 3.0. BY 3.0.

- **Coronary bypass surgery (Coronary artery bypass graft CABG)** is a surgical procedure which grafts a replacement vessel obtained from another part of the body to bypass the occluded area. (Betts, et al., 2021).

Myocardial Infarction

Myocardial infarction (MI) is the medical term for a heart attack.

An MI normally results from a lack of blood flow to a region of the heart, resulting in death of the cardiac muscle cells. An MI often occurs when a coronary artery is blocked by the buildup of atherosclerotic plaque. It can also occur when a piece of an atherosclerotic plaque breaks off and travels through the coronary arterial system until it lodges in one of the smaller vessels. MIs may be triggered by excessive exercise, in which the partially occluded artery is no longer able to pump sufficient quantities of blood, or severe stress, which may induce spasm of the smooth muscle in the walls of the vessel (Betts, et al., 2021).

Did you know?

It is estimated that between 22 and 64 percent of myocardial infarctions are silent MIs.

In the case of **acute MI (AMI)**, there is often sudden pain beneath the sternum (retrosternal pain) called angina pectoris, often radiating down the left arm in males but not in female patients. Other common symptoms include dyspnea, palpitations, nausea and vomiting, diaphoresis, anxiety, and syncope. Many of the symptoms are shared with other medical conditions, including anxiety attacks and simple indigestion, so differential diagnosis is critical (Betts, et al., 2021).

An MI can be confirmed by examining the patient's ECG.

Other diagnostic tests include:

- echocardiography.
- CT.
- MRI.
- Common blood tests indicating an MI include elevated levels of creatine kinase MB and cardiac troponin, both of which are released by damaged cardiac muscle cells (Betts, et al., 2021).

MIs may induce dangerous heart rhythms and even cardiac arrest. Important risk factors for MI include coronary artery disease, age, smoking, high blood levels of LDL, low levels of HDL, hypertension, diabetes mellitus, obesity, lack of physical exercise, chronic kidney disease, excessive alcohol consumption, and use of illegal drugs (Betts, et al., 2021).

Diseases of the (Electrical) Conduction System

Arrhythmia

Did you know?

Arrhythmia does *not* mean an absence of a heartbeat! That would be asystole, or flat line!
Arrhythmia is defined as the absence of a *regular* rhythm, meaning that the heart rate is either too fast, too slow or just irregular.

The heart's natural pacemaker, the sinoatrial (SA) node initiates an electrical impulse 60-90 times per minute in a resting adult. This impulse travels through the heart's conduction system in order to ensure a smooth, coordinated pumping action. This electrical activity can be detected and recorded through the skin using an electrocardiograph. Arrhyhmias may occur when the SA node fails to initiate an impulse, or when the conduction system fails to transmit that impulse through the heart.

In the event that the electrical activity of the heart is severely disrupted, cessation of electrical activity or fibrillation may occur. In fibrillation, the heart beats in a wild, uncontrolled manner, which prevents it from being able to pump effectively.

- **Atrial fibrillation** is a serious condition, but as long as the ventricles continue to pump blood, the patient's life may not be in immediate danger.
- **Ventrical fibrillation** is a medical emergency that requires life support, because the ventricles are not effectively pumping

blood, left untreated ventricular fibrillation may lead to brain death.

The most common treatment is **defibrillation** which uses special paddles to apply a charge to the heart from an external electrical source in an attempt to establish a normal sinus rhythm. A defibrillator effectively stops the heart so that the SA node can trigger a normal conduction cycle. **External automated defibrillators (EADs**) are being placed in areas frequented by large numbers of people, such as schools, restaurants, and airports. These devices contain simple and direct verbal instructions that can be followed by non-medical personnel in an attempt to save a life (Betts, et al., 2021).

Abnormal Heart Rates

Bradycardia is the condition in which resting adult heart rate drops below 60 bpm. a client exhibiting symptoms such as weakness, fatigue, dizziness, syncope, chest discomfort, palpitations or respiratory distress may indicate that the heart is not providing sufficient oxygenated blood to the tissues. If the patient is not exhibiting symptoms then bradycardia is not considered clinically significant. The term **relative bradycardia** may be used with a patient who has a HR in the normal range but is still suffering from these symptoms. Most patients remain asymptomatic as long as the HR remains above 50 bpm.

Tachycardia is the condition in which the resting rate is above 100 bpm. Tachycardia is not normal in a resting patient and may be detected in pregnant women or individuals experiencing extreme stress. Some individuals may remain asymptomatic, but when present, symptoms may include dizziness, shortness of breath, rapid pulse, heart palpitations, chest pain, or syncope. Treatment depends upon the underlying cause but may include medications, implantable cardioverter defibrillators, ablation, or surgery (Betts, et al., 2021).

Heart Block

A **heart block** refers to an interruption in the normal conduction pathway. Heart blocks are generally named after the part of the conduction system that is causing the problem. For example, bundle branch blocks occur within either the left or right atrioventricular bundle branches.

Medical Terms in Context

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Medical Specialties and Procedures Related to the Heart

Cardiologists and Cardiovascular Surgeons

Cardiologists are medical doctors that specialize in diagnosing and treating heart disease non-invasively. Cardiovascular/thoracic surgeons provide surgical treatments for the heart and other thoracic organs (American Medical Association, 2020). To learn more about these specialists please visit the AMA's Specialty Profilesweb page.

Cardiology Technologists

Cardiology Technologists complete a college training program and perform diagnostic tests such as electrocardiography, stress testing, Holter monitor testing, ambulatory blood pressure testing, as well as pacemaker monitoring and programming (American College of Cardiology). Please visit the American College of Cardiology webpage for more information.

Cardiovascular Perfusionists

Cardiovascular perfusionists complete a college training program and are responsible for operation of the heart-lung bypass machine during open heart surgery. They also monitor the patient's vitals, administering IV fluids, and other drugs (Mayo Clinic). Please visit the Mayo Clinic: Cardiovascular Perfusion page for more information.

Test Yourself

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10: Cardiovascular System – Blood Vessels and Blood

Learning Objectives

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

Blood Vessels and Blood Word Parts

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

Query 10.1

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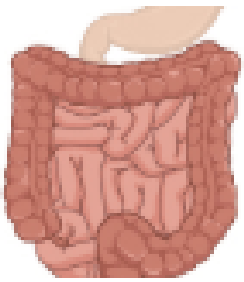
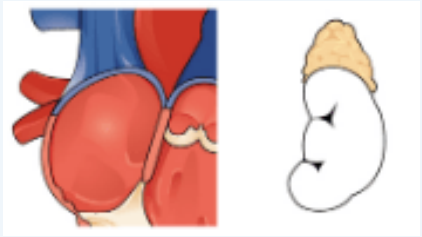
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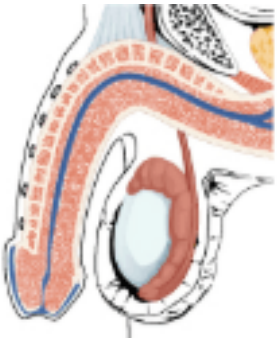
Introduction to the Blood Vessels and Blood

Our large, complex bodies need blood to deliver nutrients to and remove wastes from our trillions of cells. The heart, as discussed in the previous chapter, pumps blood throughout the body in a network of blood vessels. Together, these three components—blood, heart, and vessels—makes up the cardiovascular system.

Virtually every cell, tissue, organ, and system in the body is impacted by the circulatory system. This includes the generalized and more specialized functions of transport of materials, capillary exchange, maintaining health by transporting white blood cells and various immunoglobulins (antibodies), hemostasis, regulation of body temperature, and helping to maintain **acid-base** balance. Table 10.1 summarizes the important relationships between the circulatory system and the other body systems.

Table 10.1 Interaction of the Circulatory System with Other Body Systems. A table depicting the various body systems and the role of the circulatory system in each. Adapted from Betts, et al., 2021. Licensed under CC BY 4.0.

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Digestive  Digestive System	Absorbs nutrients and water; delivers nutrients (except most lipids) to liver for processing by hepatic portal vein; provides nutrients essential for hematopoiesis and building hemoglobin.
Endocrine  Endocrine System	Delivers hormones: atrial natriuretic hormone (peptide) secreted by the heart atrial cells to help regulate blood volumes and pressures; epinephrine, ANH, angiotensin II, ADH, and thyroxine to help regulate blood pressure; estrogen to promote vascular health in women and men.
Integumentary  Integumentary System	Carries clotting factors, platelets, and white blood cells for hemostasis, fighting infection, and repairing damage; regulates temperature by controlling blood flow to the surface, where heat can be dissipated; provides some coloration of integument; acts as a blood reservoir.
Lymphatic  Lymphatic System	Transports various white blood cells, including those produced by lymphatic tissue, and immunoglobulins (antibodies) throughout the body to maintain health; carries excess tissue fluid not able to be reabsorbed by the vascular capillaries back to the lymphatic system for processing.

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Muscular  Muscular System	Provides nutrients and oxygen for contraction; removes lactic acid and distributes heat generated by contraction; muscular pumps aid in venous return; exercise contributes to cardiovascular health and helps to prevent atherosclerosis.
Nervous  Nervous System	Produces cerebrospinal fluid (CSF) within choroid plexuses; contributes to blood-brain barrier; cardiac and vasomotor centers regulate cardiac output and blood flow through vessels via the autonomic system.
Reproductive  Reproductive System	Aids in erection of genitalia in both sexes during sexual arousal; transports gonadotropic hormones that regulate reproductive functions.
Respiratory  Respiratory System	Provides blood for critical exchange of gases to carry oxygen needed for metabolic reactions and carbon dioxide generated as byproducts of these processes.

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Skeletal  Skeletal System	Provides calcium, phosphate, and other minerals critical for bone matrix; transports hormones regulating buildup and absorption of matrix including growth hormone (somatotropin), thyroid hormone, calcitronins, and parathyroid hormones; erythropoietin stimulates myeloid cell hematopoiesis; some level of protection for select vessels by bony structures.
Urinary  Urinary System	Delivers 20% of resting circulation to kidneys for filtering, reabsorption of useful products, and secretion of excesses; regulates blood volume and pressure by regulating fluid loss in the form of urine and by releasing the enzyme renin that is essential in the renin-angiotensin-aldosterone mechanism.

Table 10.1 Interaction of the Circulatory System with Other Body Systems. A table depicting the various body systems and the role of the circulatory system in each. Adapted from Betts, et al., 2021. Licensed under CC BY 4.0

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Media 10.1 Blood Vessels, Part 1 – Form and Function: Crash Course A&P #27 [Online video]. Copyright 2015 by CrashCourse.

Cardiovascular System – Blood Vessels and Blood Medical Terms

Query 10.2

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Anatomy of the Blood Vessels

Blood pumped by the heart flows through a series of vessels known as arteries, arterioles, capillaries, venules, and veins before returning to the heart.

- **Arteries** transport blood away from the heart and branch into smaller vessels, forming arterioles.
- **Arterioles** distribute blood to capillary beds, the sites of exchange with the body tissues.
- A **capillary** is a microscopic channel that supplies blood to the tissues themselves, a process called **perfusion.**
  - Exchange of gases and other substances occurs in the capillaries between the blood and the surrounding cells and their tissue fluid (interstitial fluid).
  - For capillaries to function, their walls must be leaky, allowing substances to pass through.
  - Capillaries lead back to small vessels known as **venules.**
- **Venules** are small veins that converge into larger veins.
- A **vein** is a blood vessel that conducts blood toward the heart
  - Compared to arteries, veins are thin-walled vessels with large and irregular lumens
  - Larger veins are commonly equipped with valves that promote the unidirectional flow of blood toward the heart and prevent backflow toward the capillaries caused by the inherent low blood pressure in veins as well as the pull of gravity
  - Other ways in which the body assists the transport of venous blood back to the heart involve contractions of skeletal muscles in the extremities (see figure below), as well as pressure variations caused by breathing motion in the chest.

Concept Check

- Select the correct bolded word: Arteries always carry blood **away from/towards** the heart
- Select the correct bolded word: Veins always carry blood **away from/towards** the heart.

Both arteries and veins have the same three distinct tissue layers, called **tunics**, for the garments first worn by ancient Romans. From the most interior layer to the outer, these tunics are the **tunica intima,** the **tunica media**, and the **tunica externa**. The smooth muscle in the middle layer, the tunica media, provides the vessel with the ability to vasoconstrict and vasodilate as needed to ensure sufficient blood flow. The table below compares the features of arteries and veins.

Table 10.2. Comparison of Arteries and Veins. From Betts, et al., 2021. Licensed under CC BY 4.0.

CHARACTERISTIC	ARTERIES	VEINS
Direction of blood flow	Conducts blood away from the heart	Conducts blood toward the heart
General appearance	Rounded	Irregular, often collapsed
Pressure	High	Low
Wall thickness	Thick	Thin

CHARACTERISTIC	ARTERIES	VEINS
Relative oxygen concentration	Higher in systemic arteries Lower in pulmonary arteries	Lower in systemic veins Higher in pulmonary veins
Valves	Not present	Present most commonly in limbs and in veins inferior to the heart

The Major Arteries and Veins in the Human Body

Many arteries and veins share the same names, parallel one another throughout the body, and are very similar on the right and left sides of the body. For example, you will find a pair of **femoral** arteries and a pair of femoral veins, with one vessel on each side of the body. In contrast, some vessels closer to the midline of the body, such as the aorta, are unique and not paired. Names of vessels may change with location. Like a street that changes name as it passes through an intersection, an artery or vein can change names as it passes an anatomical landmark. For example, the left **subclavian** artery becomes the **axillary** artery as it passes into the axillary region, and then becomes the **brachial** artery as it enters the upper arm. The next two diagrams illustrate the major arteries and veins in the human body.

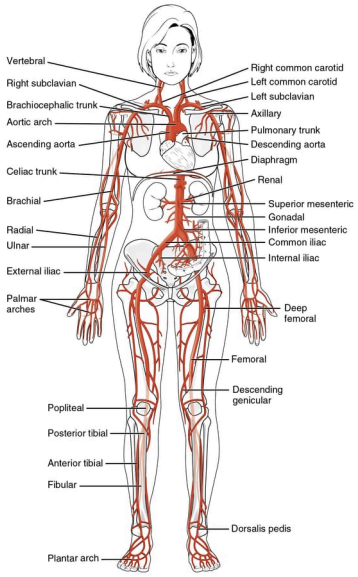


Figure 10.1 Systemic Arteries. The major systemic arteries shown here deliver oxygenated blood throughout the body. From Betts, et al., 2021. Licensed under CC BY 4.0.

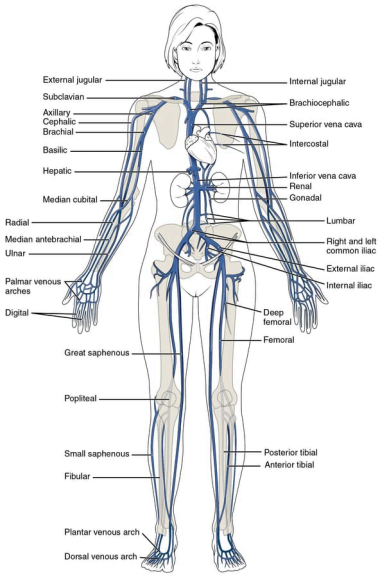


Figure 10.2 Major Systemic Veins of the Body. The major systemic veins of the body are shown here in an anterior view. From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

- Without looking back at the images of the main arteries and veins of the body, can you **name** and **locate** 3 arteries and 3 veins in your body?

Physiology of the Blood Vessels

Arteries and veins transport blood in two distinct circuits: the **systemic circuit** and the **pulmonary circuit**. Systemic arteries provide blood rich in oxygen to the body's tissues. The blood returned to the heart through systemic veins has less oxygen, since much of the oxygen carried by the arteries has been delivered to the cells. In contrast, in the pulmonary circuit, arteries carry blood low in oxygen exclusively to the lungs for gas exchange. Pulmonary veins then return freshly oxygenated blood from the lungs to the heart to be pumped back out into systemic circulation.

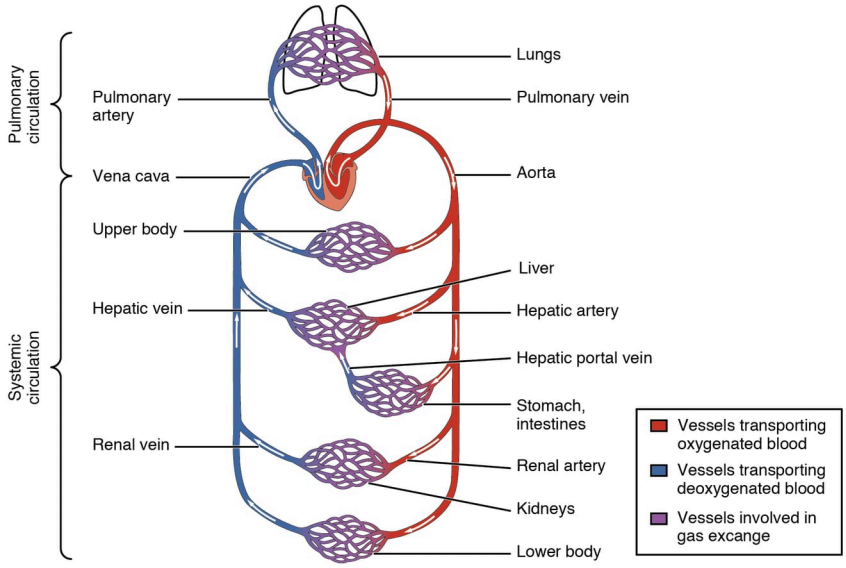


Figure 10.3 Cardiovascular Circulation. The pulmonary circuit moves blood from the right side of the heart to the lungs and back to the heart. The systemic circuit moves blood from the left side of the heart to the head and body and returns it to the right side of the heart to repeat the cycle. The arrows indicate the direction of blood flow, and the colors show the relative levels of oxygen concentration. From Betts, et al., 2021. Licensed under CC BY 4.0.

Blood Pressure

Blood pressure is the force exerted by blood upon the walls of the blood vessels or the chambers of the heart. Blood pressure may be measured in capillaries and veins, as well as the vessels of the pulmonary circulation; however, the general term 'blood pressure' refers to the pressure of blood flowing in the arteries of the systemic circulation. Blood pressure is one of the critical parameters measured on virtually every patient in every healthcare setting.

The technique used today was developed more than 100 years ago by a pioneering Russian physician, Dr. Nikolai Korotkoff. Turbulent blood flow through the vessels can be heard as a soft ticking while measuring blood pressure; these sounds are known as **Korotkoff sounds**. Blood pressure is measured in mm Hg and is usually obtained from the brachial artery using a sphygmomanometer and a stethoscope. Blood pressure is recorded as **systolic pressure** over **diastolic pressure.**

Did You Know?

120/80 mm Hg is a normal, healthy blood pressure. **60-100** beats per minute is a normal, resting, adult pulse.

Five variables influence blood flow and blood pressure:

- Cardiac output
- Vessel Compliance
- Volume of the blood
- Viscosity of the blood
- Blood vessel length and diameter

Pulse

Each time the heart ejects blood forcefully into the circulation, the arteries must expand and then **recoil** to accommodate the surge of blood moving through them. This expansion and recoiling of the arterial wall is called the **pulse** and allows us to measure heart rate. Pulse can be palpated manually by placing the tips of the fingers across an artery that runs close to the body surface, such as the radial artery or the common carotid artery. These sites and other pulse sites are shown in the figure below.

Both the rate and the strength of the pulse are important clinically. A high or irregular pulse rate can be caused by physical activity or other temporary factors, but it may also indicate a heart condition. The pulse strength indicates the strength of ventricular

contraction and cardiac output. If the pulse is strong, then systolic pressure is high. If it is weak, systolic pressure has fallen, and medical intervention may be warranted.

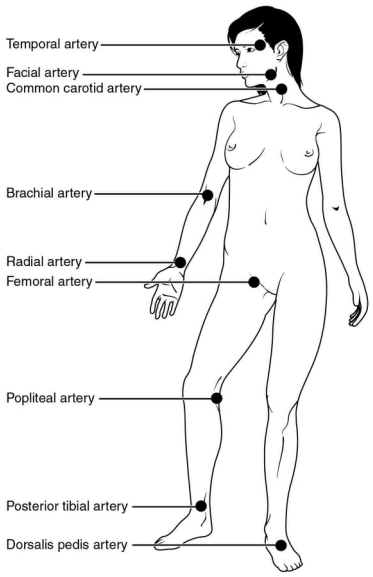


Figure 10.4 Pulse Sites. The pulse is most readily measured at the radial artery, but can be measured at any of the pulse points shown. From Betts, et al., 2021. Licensed under CC BY 4.0.

The Composition (Anatomy) of Blood and the Functions of the Components

Blood is a connective tissue made up of cellular elements and an extracellular matrix. The cellular elements are referred to as the **formed elements and** include **red blood cells (RBCs)**, **white blood cells (WBCs)**, and **platelets**. The extracellular matrix, called **plasma**, makes blood unique among connective tissues because it is fluid. This fluid, which is mostly water, perpetually suspends the formed elements and enables them to circulate throughout the body within the cardiovascular system.

Did You Know?

Blood constitutes approximately 8% of adult body weight.

In the laboratory, blood samples are often centrifuged in order to separate the components of blood from one another (see the figure below). Erythrocytes are the heaviest elements in blood and settle at the very bottom of the tube. Above the erythrocyte layer we see the **buffy coat**, a pale, thin layer of leukocytes and thrombocytes, which together make up less than 1% of the sample of whole blood. Above the buffy coat is the blood plasma, normally a pale, straw-colored fluid, which constitutes the remainder of the sample.

In normal blood, about 45 percent of a sample is erythrocytes, which is referred to as the hematocrit. The hematocrit of any one sample can vary significantly, however, about 36–50 percent, according to gender and other factors. Not counting the buffy coat, which makes up less than 1% of the blood, we can estimate the mean plasma percentage to be the percent of blood that is not erythrocytes: approximately 55%.



Figure 10.5 Composition of Blood: Two tubes of EDTA-anticoagulated blood. Left tube: after standing, the RBCs have settled at the bottom of the tube. Reused from Libretext Anatomy & Physiology

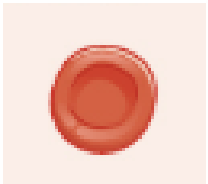
Blood Plasma

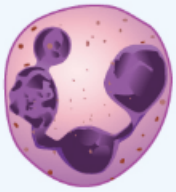
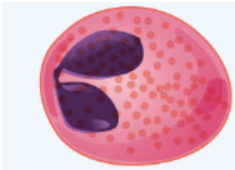
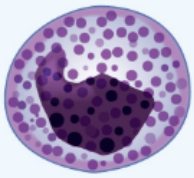
Like other fluids in the body, plasma is composed primarily of water. In fact, it is about 92% water. Dissolved or suspended within this water is a mixture of substances, most of which are proteins. The major components of plasma and their functions are summarized in the table below.

Formed Elements (Erythrocytes, Leukocytes, Thrombocytes)

The table below summarizes the main facts about the formed elements in blood.

Table 10.3 Summary of Formed Elements in Blood. Adapted from Betts, et al., 2021. Licensed under CC BY 4.0.

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (µL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
Erythrocytes (red blood cells)  Red Blood Cell	n/a	5.2 million (4.4-5.0 million)	Flattened biconcave disk; no nucleus; pale red colour	Transport oxygen and some carbon dioxide between tissues and lungs	Lifespan of approximately 120 days

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (μL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
Leukocytes (white blood cells)	n/a	7000 (5000 – 10,000)	Obvious dark-staining nucleus	All function in body defenses	Exit capillaries and move into tissues; lifespan of usually a few hours or days
Leukocytes (white blood cells) Types	**Granulocytes including neutrophils, eosinophils, and basophils**	**4360 (1800-9950)**	**Abundant granules in cytoplasm; nucleus normal lobed**	**Nonspecific (innate) resistance to disease**	**Classified according to membrane-bound granules in cytoplasm**
	Neutrophils  Neutrophil Cell	4150 (1800-7300)	Nuclear lobes increase with age; pale lilac granules	Phagocytic; particularly effective against bacteria. Release cytotoxic chemicals from granules	Most common leukocyte; lifespan of minutes to days
	Eosinophils  Eosinophils Cell	165 (0-700)	Nucleus generally two-lobed; bright red-orange granules	Phagocytic cells; particularly effective with antigen-antibody complexes. Release antihistamines. Increase in allergies and parasitic infections	Lifespan of minutes to days
	Basophils  Basophil Cell	44 (0-150)	Nucleus generally two-lobed but difficult to see due to presence of heavy, dense, dark purple granules	Promotes inflammation	Least common leukocyte; lifespan unknown

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (μL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
	Agranulocytes including lymphocytes and monocytes	**2640 (1700-4950)**	**Lack abundant granules in cytoplasm; have a simple-shaped nucleus that may be indented**	**Body defenses**	**Group consists of two major cell types from different lineages**
	Lymphocytes   Lymphocytes Cell	2185 (1500-4000)	Spherical cells with a single often large nucleus occupying much of the cell's volume; stains purple; see in large (natural killer cells) and small (B and T cells) variants	Primarily specific (adaptive) immunity; T cells directly attack other cells (cellular immunity). B cells release antibodies (humoral immunity); natural killer cells are similar to T cells but nonspecific	Initial cells originate in bone marrow, but secondary production occurs in lymphatic tissue; several distinct subtypes; memory cells form after exposure to a pathogen and rapidly increase responses to subsequent exposure; lifespan of many years
	Monocytes  Monocytes Cell	455 (200-950)	Largest leukocyte with an indented or horseshoe-shaped nucleus	Very effective phagocytic cells engulfing pathogens or worn out cells; also serve as antigen-presenting cells (APCs) for other components of the immune system	Produced in red bone marrow; referred to as macrophages after leaving circulation
Platelets  Platelete Cells	n/a	350,000 (150,000 – 500,000)	Cellular fragments surrounded by a plasma membrane and containing granules; purple stain	Hemostasis plus release growth factors for repair and healing of tissue	Formed from megakaryocytes that remain in the red bone marrow and shed platelets into circulation

Erythrocytes

The most abundant formed elements in blood, erythrocytes are basically sacs packed with an oxygen-carrying compound called hemoglobin. Production of erythrocytes in the red bone marrow occurs at the staggering rate of more than 2 million cells per second. For this production to occur, raw materials including iron, copper, zinc B-vitamins, glucose, lipids, and amino acids must be present in adequate amounts. Erythrocytes live only 120 days on average, and thus must be continually replaced. Worn-out erythrocytes are phagocytized by macrophages and their hemoglobin is broken down. The breakdown products are recycled or removed as wastes.

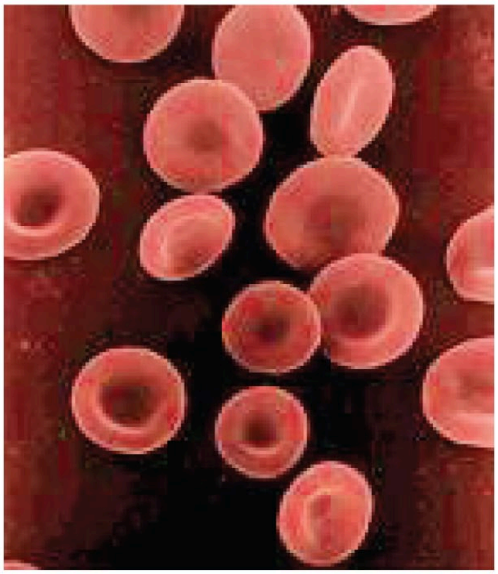


Figure 10.6 Shape of Red Blood Cells. Erythrocytes are biconcave discs with very shallow centers. This shape optimizes the ratio of surface area to volume, facilitating gas exchange. It also enables them to fold up as they move through narrow blood vessels. From Betts, et al., 2021. Licensed under CC BY 4.0.

Leukocytes

Leukocytes protect the body against invading microorganisms and body cells with mutated DNA, and they clean up debris, thus they are a major component of the body's defenses against disease. Figure 10.7 shows the different types of leukocytes. Leukocytes routinely leave the bloodstream to perform their **defensive** functions in the body's tissues, where they are often given distinct names, such as **macrophage or microglia, depending on their function.**

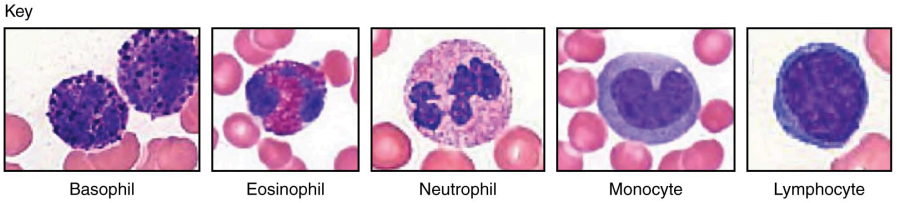


Figure 10.7 Leukocytes. (Micrographs provided by the Regents of University of Michigan Medical School © 2012). From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

- What is **hemoglobin**?
- Can you name the 5 types of **leukocytes**?

Lymphocytes

Lymphocytes are one of the types of leukocytes and will be discussed in more detail here, since they tie into the next chapter which discusses the body's defenses The three major groups of lymphocytes include natural killer cells, B cells, and T cells.

- **Natural killer (NK) cells** are capable of recognizing cells that do not express "self" proteins on their plasma membrane or that contain foreign or abnormal markers. These "nonself" cells include cancer cells, cells infected with a virus, and other cells with atypical surface proteins.
- **B lymphocytes (B cells)** and **T lymphocytes (T cells)**, play prominent roles in defending the body against specific pathogens (disease-causing microorganisms) and are involved in specific immunity. B cells undergo a maturation process in the bone marrow, whereas T cells undergo maturation in the thymus. This site of the maturation process gives rise to the name B and T cells.
  - **Plasma cells**, a type of B cell, produce the antibodies or immunoglobulins that bind to specific foreign or abnormal components of plasma membranes.
  - **T cells** provide immunity by physically attacking foreign or diseased cells.
  - **Memory cells** are a variety of both B and T cells that form after exposure to a pathogen and mount rapid responses upon subsequent exposures. Unlike other leukocytes, memory cells live for many years.

Platelets

After entering the circulation, approximately one-third of the newly-formed platelets migrate to the spleen for storage for later release in response to any rupture in a blood vessel. They then become activated to perform their primary function, which is to limit blood loss. Platelets remain only about 10 days, then are phagocytized by macrophages.

Platelets are key players in **hemostasis**, the process by which the body seals a ruptured blood vessel and prevents further loss of blood. Although rupture of larger vessels usually requires medical intervention, hemostasis is quite effective in dealing with small, simple wounds. There are three steps to the process: vascular spasm or vasoconstriction, the formation of a platelet plug, and coagulation (blood clotting). Failure of any of these steps will result in **hemorrhage.** The figure below summarizes the steps of hemostasis.

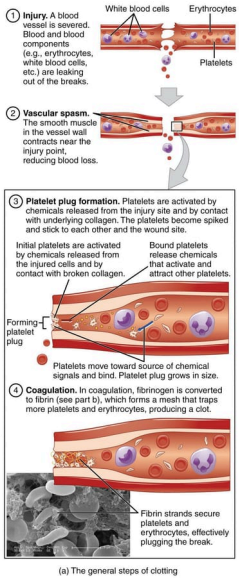


Figure 10.8 Hemostasis. (a) An injury to a blood vessel initiates the process of hemostasis. Blood clotting involves three steps. First, vascular spasm constricts the flow of blood. Next, a platelet plug forms to temporarily seal small openings in the vessel. Coagulation then enables the repair of the vessel wall once the leakage of blood has stopped. (b) The synthesis of fibrin in blood clots lead to a common pathway. (credit a: Kevin MacKenzie). From Betts, et al., 2021. Licensed under CC BY 4.0.

Fibrinolysis is the process in which a clot is degraded in a healing vessel. An **anticoagulant** is any substance that opposes coagulation. Several circulating plasma anticoagulants play a role in limiting the coagulation process to the region of injury and restoring a normal, clot-free condition of blood.

Concept Check

- Can you explain what happens in each step of **hemostasis**?
- Describe an **anticoagulant**.

Physiology of Blood

Although carrying oxygen and nutrients to cells and removing wastes from cells is the main function of blood, it is important to realize that blood also serves in defense, distribution of heat, and maintenance of homeostasis.

Transportation

- Nutrients from the foods you eat are absorbed in the digestive tract. Most of these travel in the bloodstream directly to the liver, where they are processed and released back into the bloodstream for delivery to body cells.
- Oxygen from the air you breathe diffuses into the blood, which moves from the lungs to the heart, which then pumps it out to the rest of the body.
- Endocrine glands scattered throughout the body release their products, called **hormones**, into the bloodstream, which carries them to distant target cells.
- Blood also picks up **cellular wastes** and byproducts, and transports them to various organs for removal. For instance, blood moves carbon dioxide to the lungs for **exhalation** from the body, and various waste products are transported to the kidneys and liver for excretion from the body in the form of urine or bile.

Defense

- Leukocytes protect the organism from disease-causing bacteria, cells with **mutated** DNA that could multiply to become cancerous, or body cells infected with viruses.
- When damage to the vessels results in bleeding, blood platelets and certain proteins dissolved in the plasma, interact to block the ruptured areas of the blood vessels involved. This protects the body from further blood loss.

Homeostasis

- If you were exercising on a warm day, your rising core body temperature would trigger several homeostatic mechanisms, including increased transport of blood from your core to your body periphery, which is typically cooler. As blood passes through the vessels of the skin, heat would be dissipated to the environment, and the blood returning to your body core would be cooler. In contrast, on a cold day, blood is diverted away from the skin to maintain a warmer body core. In extreme cases, this may result in frostbite.
- Blood helps to regulate the water content of body cells.
- Blood also helps to maintain the chemical balance of the body. Proteins and other compounds in blood act as buffers, which thereby help to regulate the pH of body tissues. The pH of blood ranges from 7.35 to 7.45.

Concept Check

These three terms all sound similar. Can you explain them by breaking down the word parts?

- Hemostasis
- Homeostasis
- Hematopoiesis

Blood Types

In order to understand blood types, it is important to understand several terms that relate to the body's **immune** functions

(discussed in detail in the next chapter)

- Antigens are substances that the body does not recognize as belonging to itself (“self”) and that therefore trigger a **defensive response** from the leukocytes of the immune system. Many people have antigens on the surfaces of their red blood cells. More than 50 antigens have been identified on erythrocyte membranes, but the most significant in terms of their potential harm to patients are classified in two groups: the ABO blood group and the Rh blood group.
- Antibodies are proteins which are produced by plasma cells in response to a “non-self” antigen being present in the body. Antibodies attach to the antigens on the plasma membranes of the erythrocytes in a blood transfusion and cause them to adhere to one another.
- Agglutination refers to the resulting clumps of red blood cells that are formed in such an antigen-antibody reaction. These clumps can block small blood vessels, thereby cutting of the supply of oxygen and nutrients to the tissues.
- Hemolysis, or the breakdown of the erythrocyte’s cell membrane, takes place as the clumps of red cells start to degrade. The resulting release of the cell’s contents, mainly hemoglobin, into the bloodstream can cause kidney failure.

ABO Blood Group

ABO blood types are **genetically** determined. Each type is determined by the presence or absence of certain antigens on the individual’s red blood cell membrane, as well as the presence or absence of certain antibodies. Normally the body must be exposed to a **foreign antigen** before an antibody can be produced. This is not the case for the ABO blood group, in which some blood types come preloaded with their own set of antibodies against another type. The figure below shows the ABO blood group as well as the universal donor and recipient in relation to blood transfusions.

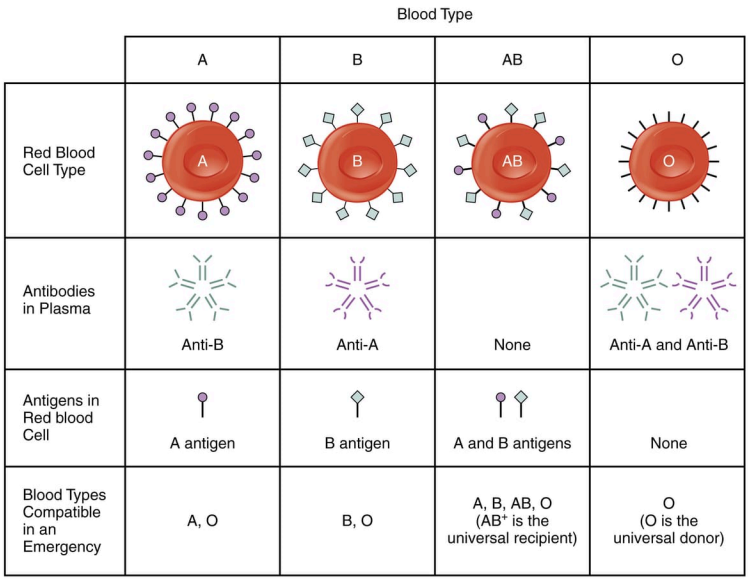


Figure 10.9 ABO Blood Groups. From Betts, et al., 2021. Licensed under CC BY 4.0.

- Blood Type A
  - People whose erythrocytes have **A antigens** on their erythrocyte membrane surface.
  - People who have type A blood, without any prior exposure to incompatible blood, have preformed **anti-B antibodies** circulating in their blood. These antibodies will cause a serious immune reaction if they encounter blood that has B antigens.
- Blood Type B
  - People whose erythrocytes have **B antigens.**
  - People with type B blood has inherent **anti-A antibodies.**
- Blood Type AB
  - People can also have **both A and B antigens** on their erythrocytes, in which case they are blood type AB.
  - Individuals with type AB blood, **do not have inherent antibodies** to either A or B antigens.
- Blood Type O
  - People with **neither A nor B antigens** are designated blood type O.
  - People with type O blood have **both anti-A and anti-B antibodies** circulating in their blood plasma.

Rh Blood Group

The **Rh blood group** is classified according to the presence or absence of a second erythrocyte **antigen** identified as Rh. Those who have the Rh D antigen present on their erythrocytes are described as Rh positive (Rh+) and those who lack it are Rh negative (Rh–). Note that the Rh group is distinct from the ABO group, so any individual, no matter their ABO blood type, may have or lack this Rh antigen. When identifying a patient's blood type, the Rh group is designated by adding the word positive or negative to the ABO type. For example, A positive (A+) means ABO group A blood with the Rh antigen present, and AB negative (AB–) means ABO group AB blood without the Rh antigen.

Hemolytic Disease of the Newborn (HDN)

Antibodies to the Rh antigen are produced only in Rh^- individuals after exposure to the antigen. This process, called sensitization, occurs following a transfusion with Rh-incompatible blood or, more commonly, with the birth of an Rh^+ baby to an Rh^- mother.

- In a **first pregnancy** problems are rare**,** since the baby's Rh^+ cells rarely cross the placenta. However, during or immediately after birth, the Rh^- mother can be exposed to the baby's Rh^+ cells (Figure below). Research has shown that this occurs in about 13–14 percent of such pregnancies. After exposure, the mother's immune system begins to generate anti-Rh antibodies.
- In a **second pregnancy** if a mother should conceive a Rh^+ baby, the Rh antibodies she has produced can cross the placenta into the fetal bloodstream and destroy the fetal RBCs. This condition, known as **hemolytic disease of the newborn (HDN)** or erythroblastosis fetalis. This may cause anemia in mild cases, but the agglutination and hemolysis can be so severe that without treatment the fetus may die in the womb or shortly after birth.
    - A drug known as RhoGAM, short for Rh immune globulin, can temporarily prevent the development of Rh antibodies in the Rh^- mother, thereby averting this potentially serious disease for the fetus. RhoGAM antibodies destroy any fetal Rh^+ erythrocytes that may cross the placental barrier. RhoGAM is normally administered to Rh^- mothers during weeks 26–28 of pregnancy and within 72 hours following birth.

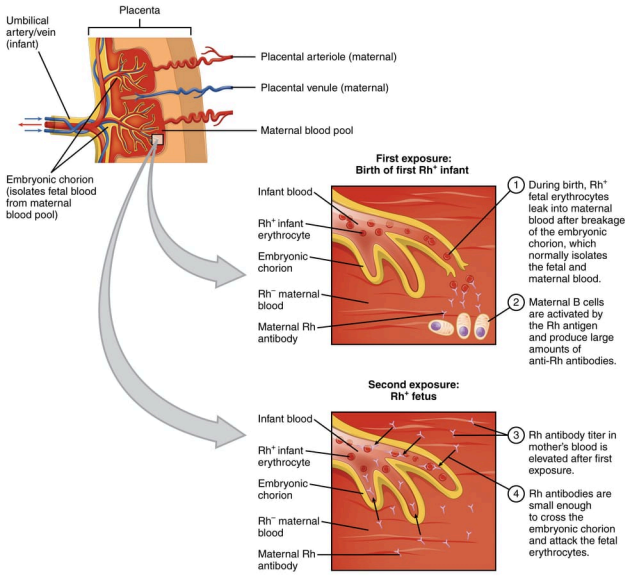


Figure 10.10 Erythroblastosis Fetalis. The first exposure of an Rh– mother to Rh+ erythrocytes during pregnancy induces sensitization. Anti-Rh antibodies begin to circulate in the mother's bloodstream. A second exposure occurs with a subsequent pregnancy with an Rh+ fetus in the uterus. Maternal anti-Rh antibodies may cross the placenta and enter the fetal bloodstream, causing agglutination and hemolysis of fetal erythrocytes. From Betts, et al., 2021. Licensed under CC BY 4.0.

Blood Transfusions

Figure 10.11 is an example of a commercially produced "bedside" card which enables quick typing of both a recipient's and donor's blood before transfusion. The card contains three reaction sites or wells. One is coated with an anti-A antibody, one with

an anti-B antibody, and one with an anti-D antibody (tests for the presence of Rh factor D). Mixing a drop of blood and saline into each well enables the blood to interact with a preparation of type-specific antibodies, also called anti-seras. Agglutination of RBCs in a given site indicates a positive identification of the blood antigens, in this case A and Rh antigens for blood type A+. To avoid serious and potentially fatal immune reactions, the donor's and recipient's blood types must match

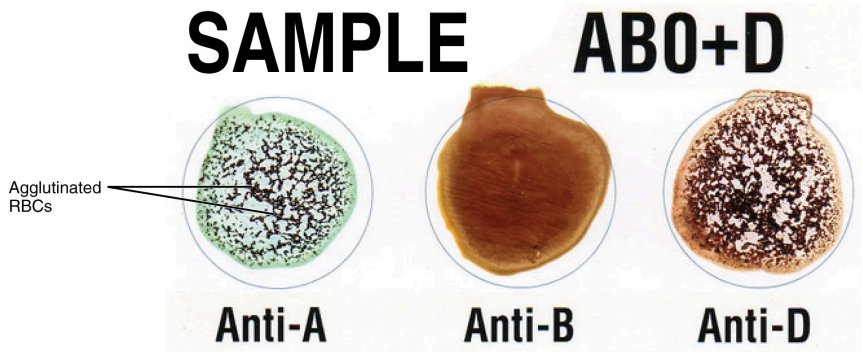


Figure 10.11. Cross Matching Blood Types. From Betts, et al., 2013. Licensed under CC BY 4.0.

To avoid transfusion reactions, it is best to transfuse only matching blood types; that is, a type B^+ recipient should ideally receive blood only from a type B^+ donor and so on. That said, in emergency situations, when acute hemorrhage threatens the patient's life, there may not be time for cross matching to identify blood type. In these cases, blood from a **universal donor** may be transfused.

Blood Vessel Medical Terms Not Easily Broken into Word Parts

Query 10.3

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this Interactive Content online

Common Diseases and Disorders of Blood Vessels and/or Blood

Arteriosclerosis

Arteriosclerosis is normally defined as the more generalized loss of compliance, "hardening of the arteries," whereas atherosclerosis is a more specific term for the build-up of plaque in the walls of the vessel and is a specific type of arteriosclerosis.

When arteriosclerosis causes vessel compliance to be reduced, pressure and resistance within the vessel increase. This is a leading cause of hypertension and coronary heart disease, as it causes the heart to work harder to overcome this resistance. Any artery in the body can be affected by these pathological conditions, and individuals who have pathologies like coronary artery disease, may also be at risk for other vascular injuries, like strokes or peripheral arterial disease.

Atherosclerosis is a type of arteriosclerosis in which plaques form when circulating triglycerides, cholesterol and other substances seep between the damaged endothelial lining cells and become trapped within the artery wall, resulting in narrowed arteries and impaired blood flow (see Figure 10.12) (Wikimedia Commons, 2019).

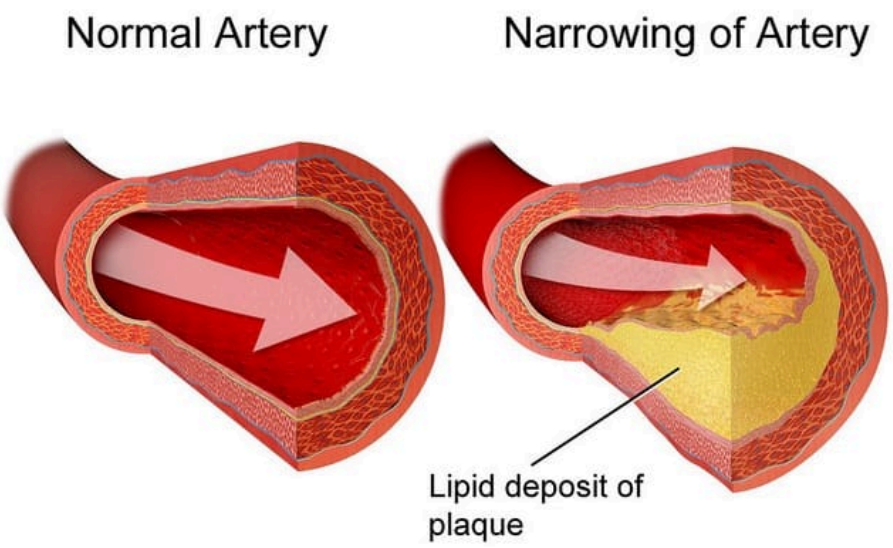


Figure 10.12 Atherosclerosis. This is an example of how build up of lipids (fat) in the artery prevents blood from flowing. From Blausen.com staff courtesy of Oregon State University, CC BY-SA 2.0, via Wikimedia Commons.

Sometimes a plaque can rupture, causing microscopic tears in the artery wall that allow blood to leak into the tissue on the other side. When this happens, platelets rush to the site to clot the blood. This clot can further obstruct the artery and—if it occurs in a coronary or cerebral artery—cause a sudden heart attack or stroke. Alternatively, plaque can break off and travel through the bloodstream as an embolus until it blocks a more distant, smaller artery.

Peripheral arterial disease (PAD, also called peripheral vascular disease, PVD), occurs when atherosclerosis affects arteries in the legs. A major risk factor for both arteriosclerosis and atherosclerosis is advanced age, as the conditions tend to progress over time. There is also a distinct genetic component, and pre-existing hypertension and/or diabetes also greatly increase the risk. However, obesity, poor nutrition, lack of physical activity, and tobacco use all are major risk factors.

Treatment of atherosclerosis includes lifestyle changes, such as weight loss, smoking cessation, regular exercise, and adoption of a diet low in sodium and saturated fats. Medications to reduce cholesterol and blood pressure may be prescribed. For blocked coronary arteries, angioplasty or coronary artery bypass graft (CABG) surgery may be warranted. In an carotid endarterectomy, plaque is surgically removed from the walls of a the carotid artery, which is the main source of oxygenated blood for the brain (Betts, et al., 2021).

Edema and Varicose Veins

Despite the presence of valves and the contributions of other anatomical and physiological adaptations that assist in moving blood through veins, over the course of a day, some blood will inevitably pool, especially in the lower limbs, due to the pull of gravity. Any blood that accumulates in a vein will increase the pressure within it, which can then be reflected back into the smaller veins, venules, and eventually even the capillaries. This increased pressure in the capillaries will push of fluids out of the capillaries and into the interstitial fluid, causing a condition called edema.

Most people experience a daily accumulation of tissue fluid, especially if they spend much of their work life on their feet (like most health professionals). However, clinical edema goes beyond normal swelling and requires medical treatment. Edema has many potential causes, including hypertension and heart failure, severe protein deficiency, renal failure, and many others. In order to treat edema, which is a sign rather than a discrete disorder, the underlying cause must be diagnosed and alleviated.



Figure 10.13 Varicose Veins. Varicose veins are commonly found in the lower limbs. (credit: Nini00). From Wikimedia Commons. Licensed under CC BY-SA 3.0.

Edema may be accompanied by varicose veins, especially in the superficial veins of the legs (see Figure 10.13). This disorder arises when defective valves allow blood to accumulate within the veins, causing them to distend, twist, and become visible on the surface of the skin. Varicose veins may occur in both sexes, but are more common in women and are often related to pregnancy. More than simple cosmetic blemishes, varicose veins are often painful and sometimes itchy or throbbing. Without treatment, they tend to grow worse over time. The use of support hose, as well as elevating the feet and legs whenever possible, may be helpful in alleviating this condition (Betts, et al., 2021).

Hypertension

Hypertension is defined as chronic and persistent blood pressure measurements of 140/90 mm Hg or above. Pressures between 120/80 and 140/90 mm Hg are defined as prehypertension. Hypertension is typically a silent disorder and patients may fail to recognize the seriousness of their condition and fail to follow their treatment plan, putting them at risk for a heart attack or stroke. Hypertension may also lead to an aneurysm, peripheral arterial disease, chronic kidney disease, or heart failure (Betts, et al., 2021).

Hemorrhage

Minor blood loss is managed by hemostasis and repair. Hemorrhage is a loss of blood that cannot be controlled by hemostatic mechanisms. Initially, the body responds to hemorrhage by initiating mechanisms aimed at increasing blood pressure and maintaining blood flow. Ultimately, however, blood volume will need to be restored, either through physiological processes or through medical intervention. If blood loss is less than 20 percent of total blood volume, fast-acting homeostatic mechanisms causing increased cardiac output and vasoconstriction, would usually return blood pressure to normal and redirect the remaining blood to the tissues. Blood volume will then need to be restored via slower-acting homeostatic mechanisms, to increase body fluids and erythrocyte production (Betts, et al., 2021).

Circulatory Shock

The loss of too much blood may lead to **circulatory shock**, a life-threatening condition in which the circulatory system is unable to maintain blood flow to adequately supply sufficient oxygen and other nutrients to the tissues to maintain cellular metabolism. It should not be confused with emotional or psychological shock. Typically, the patient in circulatory shock will demonstrate an increased heart rate but decreased blood pressure. Urine output will fall dramatically, and the patient may appear confused or lose consciousness. Unfortunately, shock is an example of a positive-feedback loop that, if uncorrected, may lead to the death of the patient (Betts, et al., 2021).

There are several recognized forms of shock:

- **Hypovolemic shock** in adults is typically caused by hemorrhage, although in children it may be caused by fluid losses related to severe vomiting or diarrhea.
- **Cardiogenic shock** results from the inability of the heart to maintain cardiac output. Most often, it results from a myocardial infarction (heart attack), but it may also be caused by arrhythmias, valve disorders, cardiomyopathies, cardiac failure, or simply insufficient flow of blood through the cardiac vessels.
- **Vascular shock** occurs when arterioles lose their normal muscular tone and dilate dramatically. It may arise from a variety of causes, and treatments almost always involve fluid replacement and medications, called inotropic or pressor agents, which restore tone to the muscles of the vessels.
- **Anaphylactic shock** is a severe allergic response that causes the widespread release of histamines, triggering vasodilation throughout the body.
- **Obstructive shock**, as the name would suggest, occurs when a significant portion of the vascular system is blocked. It is not always recognized as a distinct condition and may be grouped with cardiogenic shock, including pulmonary embolism and cardiac tamponade. Treatments depend upon the underlying cause and, in addition to administering fluids intravenously, often include the administration of anticoagulants, removal of fluid from the pericardial cavity, or air from the thoracic cavity, and surgery as required. The most common cause is a pulmonary embolism. Other causes include stenosis of the aortic valve; cardiac tamponade; and a pneumothorax (Betts, et al., 2021).

Blood Disorders

Erythrocyte Disorders

Changes in the levels of RBCs can have significant effects on the body's ability to effectively deliver oxygen to the tissues (Betts, et al., 2021).

Did You Know?

Did you know?
'O2 sat' or 'percent sat' is the percent saturation; that is, the percentage of hemoglobin sites occupied by oxygen in a patient's blood.

Anemia

The size, shape, and number of erythrocytes, and the number of hemoglobin molecules can have a major impact on a person's health. When the number of RBCs or hemoglobin is deficient, the general condition is called **anemia**. There are more than 400 types of anemia.

Anemia can be broken down into three major groups: those caused by blood loss, those caused by faulty or decreased RBC production, and those caused by excessive destruction of RBCs. In addition to these causes, various disease processes also can lead to anemias. These include chronic kidney diseases often associated with a decreased production of EPO, hypothyroidism, some forms of cancer, lupus, and rheumatoid arthritis (Betts, et al., 2021).

Blood Loss Anemias:

Causes:

- Bleeding from wounds or other lesions, including ulcers, hemorrhoids, inflammation of the stomach (gastritis), and some cancers of the gastrointestinal tract
  - The excessive use of aspirin or other nonsteroidal anti-inflammatory drugs such as ibuprofen can trigger ulceration and gastritis
- Excessive menstruation and loss of blood during childbirth.

Anemias Caused by Faulty or Decreased RBC Production:

- **Sickle cell anemia**

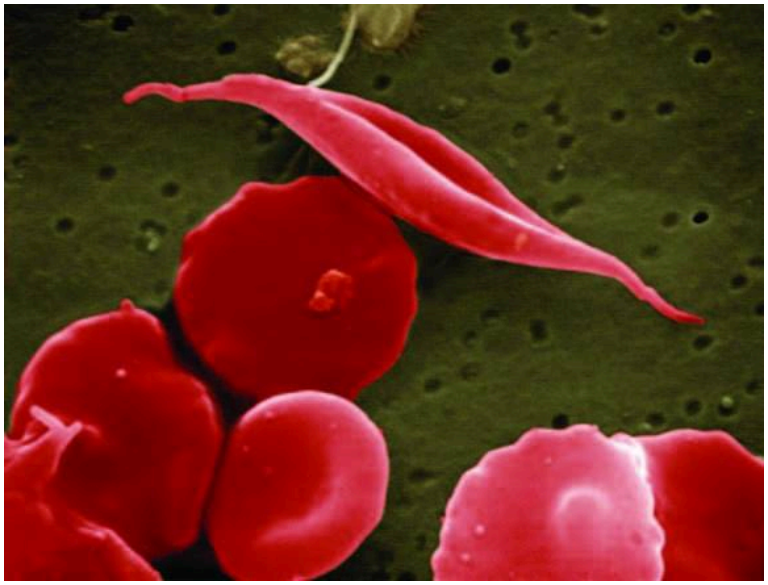


Figure 10.14 Sickle Cell Disease. (credit: NIH Image Gallery). From Flickr. Licensed under CC BY-NC 2.0.

  - A genetic disorder involving the production of an abnormal type of hemoglobin which delivers less oxygen to tissues and causes erythrocytes to assume a sickle (or crescent) shape. See Figure 10.14.
- **Iron deficiency anemia**
  - The most common type of anemia and results when the amount of available iron is insufficient to allow production of sufficient heme.
- **Vitamin deficiency anemia** (Generally insufficient vitamin B12 and folate).
- **Megaloblastic anemia** involves a deficiency of vitamin B12 and/or folate, often due to inadequate dietary intake.
- **Pernicious anemia** is caused by poor absorption of vitamin B12 and is often seen in patients with Crohn's disease, surgical removal of the intestines or stomach (common in some weight loss surgeries), intestinal parasites, and AIDS.
- **Aplastic anemia** is the condition in which myeloid stem cells are defective or replaced by cancer cells, resulting in insufficient quantities of RBCs being produced. This condition by be inherited, or it may be triggered by radiation, medication, chemotherapy, or infection.
- **Thalassemia** is an inherited condition typically occurring in individuals from the Middle East, the Mediterranean, African, and Southeast Asia, in which maturation of the RBCs does not proceed normally. The most severe form is called Cooley's anemia (Betts, et al., 2021).

Polycythemia

Polycythemia is an elevated RBC count and is detected in a patient's elevated hematocrit. It can occur transiently in a person who is dehydrated; when water intake is inadequate or water losses are excessive, the plasma volume falls. As a result, the hematocrit rises. A mild form of polycythemia is chronic but normal in people living at high altitudes. Some elite athletes train at high elevations specifically to induce this phenomenon. Finally, a type of bone marrow disease called polycythemia vera causes an excessive production of immature erythrocytes. Polycythemia vera can dangerously elevate the viscosity of blood, raising blood pressure and making it more difficult for the heart to pump blood throughout the body. It is a relatively rare disease that occurs more often in men than women, and is more likely to be present in elderly patients those over 60 years of age (Betts, et al., 2021).

Platelet Disorders/Clotting Disorders

Thrombocytosis

Thrombocytosis is a condition in which there are too many platelets. This may trigger thrombosis, a potentially fatal disorder. A **thrombus** (plural = thrombi) is an aggregation of platelets, erythrocytes, and even WBCs typically trapped within a mass of fibrin strands. While the formation of a clot is a normal step in hemostasis, thrombi can form within an intact or only slightly damaged blood vessel, adhering to the vessel wall and decreasing or obstructing the flow of blood. (Betts, et al., 2021).

Thrombophilia

Thrombophilia, also called hypercoagulation, is a condition in which there is a tendency to form thrombosis. This may be an inherited disorder or may be caused by other conditions including lupus, immune reactions to heparin, polycythemia vera, thrombocytosis, sickle cell disease, pregnancy, and even obesity.

When a portion of a thrombus breaks free from the vessel wall and enters the circulation, it is referred to as an **embolus**. An embolus that is carried through the bloodstream can be large enough to block a vessel critical to a major organ. When it becomes trapped, an embolus is called an **embolism**. In the heart, brain, or lungs, an embolism may accordingly cause a heart attack, a stroke, or a pulmonary embolism (Betts, et al., 2021).

Thrombocytopenia

Thrombocytopenia is a condition in which there is an insufficient number of platelets, possibly leading to ineffective blood clotting and excessive bleeding (Betts, et al., 2021).

Hemophilia

Hemophilia is a group of related genetic disorders in which certain plasma clotting factors are lacking or inadequate or nonfunctional. Patients with hemophilia bleed from even minor internal and external wounds, and leak blood into joint spaces after exercise and into urine and stool. Regular infusions of clotting factors isolated from healthy donors can help prevent bleeding in hemophiliac patients. At some point, genetic therapy will become a viable option (Betts, et al., 2021).

Leukocyte Disorders

Leukopenia

Leukopenia is a condition in which too few leukocytes are produced. If this condition is pronounced, the individual may be unable to ward off disease (Betts, et al., 2021).

Leukocytosis

Leukocytosis is excessive leukocyte proliferation. Although leukocyte counts are high, the cells themselves are often nonfunctional, leaving the individual at increased risk for disease (Betts, et al., 2021).

Leukemia

Leukemia is a cancer involving an abundance of leukocytes. It may involve only one specific type of leukocyte from either the myeloid line (myelocytic leukemia) or the lymphoid line (lymphocytic leukemia). In chronic leukemia, mature leukocytes accumulate and fail to die. In acute leukemia, there is an overproduction of young, immature leukocytes. In both conditions the cells do not function properly (Betts, et al., 2021).

Lymphoma

Lymphoma is a form of cancer in which masses of malignant T and/or B lymphocytes collect in lymph nodes, the spleen, the liver, and other tissues. As in leukemia, the malignant leukocytes do not function properly, and the patient is vulnerable to infection. Some forms of lymphoma tend to progress slowly and respond well to treatment. Others tend to progress quickly and require aggressive treatment, without which they are rapidly fatal (Betts, et al., 2021).

Other Conditions Related to Abnormal Leukocyte Counts

Table 10.4. Conditions Related to Abnormal White Blood Cell Counts. ***From Betts, et al., 2021. Licensed under CC BY 4.0.***

CELL TYPE	CONDITIONS RELATED TO HIGH COUNTS	CONDITIONS RELATED TO LOW COUNTS
Neutrophil	Infection, inflammation, burns, unusual stress	Drug toxicity, other disorders
Eosinophil	Allergies, parasitic worm infestations, some autoimmune diseases	Drug toxicity, stress
Basophil	Allergies, parasitic infections, hypothyroidism	Pregnancy, stress, hyperthyroidism
Lymphocyte	Viral infections, some cancers	chronic illness, immunosuppression (due to HIV or steroid therapy)
Monocyte	Viral or fungal infections, tuberculosis, some forms of leukemia, other chronic diseases	Bone marrow suppression

Bone Marrow Biopsy/Bone Marrow Transplant

Sometimes, a healthcare provider will order a **bone marrow biopsy**, a diagnostic test of a sample of red bone marrow, or a **bone marrow transplant**, a treatment in which a donor's healthy bone marrow—and its stem cells—replaces the faulty bone marrow of a patient. These tests and procedures are often used to assist in the diagnosis and treatment of various severe forms of anemia, such as thalassemia major and sickle cell anemia, as well as some types of cancer, specifically leukemia.

In the past, bone marrow sampling or transplant was very painful, as the procedure involved inserting a large-bore needle into the region near the iliac crest of the pelvic bones. Now, direct sampling of bone marrow can often be avoided as stem cells can be isolated in just a few hours from a sample of a patient's blood. The isolated stem cells are then grown in culture using the appropriate hemopoietic growth factors, and analyzed or sometimes frozen for later use.

For an individual requiring a transplant, a matching donor is essential to prevent the immune system from destroying the donor cells—a phenomenon known as tissue rejection. To treat patients with bone marrow transplants, it is first necessary to destroy the patient's own diseased marrow through radiation and/or chemotherapy. Donor bone marrow stem cells are then infused into the recipient's bloodstream, so that they can establish themselves in the recipient's bone marrow (Betts, et al., 2021).

Common Cardiovascular System – Blood, Abbreviations

Many terms and phrases related to the cardiovascular system – blood are abbreviated. Learn these common abbreviations by expanding the list below.

Query 10.4

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Medical Terms in Context

Query 10.5

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Medical Specialties and Procedures Related to the Blood Vessels and Blood

Vascular Surgeons

Vascular surgery is a specialty in which the physician treats diseases of the blood and lymphatic vessels. This includes repair and replacement of diseased or damaged vessels, removal of plaque from vessels, minimally invasive procedures including the insertion of venous catheters, and traditional surgery (Betts, et al., 2021; Society for Vascular Surgery, n.d.). For more information, please visit Society for Vascular Surgery website.

Hematologists

Hematologists are specialist physicians that diagnose and treat blood disorders. These physicians must be well-versed in a wide array of laboratory procedures, basic medical disciplines, and clinical medicine (American Medical Association, 2019). To learn more about hematologists, visit the American Medical Association's specialty profile on hematology

Vascular Sonographer

Vascular sonography is a challenging yet rewarding profession. As a sonographer working in this field, you'll use ultrasound machines to produce images of patients' veins and arteries using high-frequency sound waves. To learn more, visit the Vascular Sonography Credentials web page.

Phlebotomist

Phlebotomists are professionals trained to draw blood (phleb- = "a blood vessel"; -tomy = "to cut"). When more than a few drops of blood are required, phlebotomists perform a venipuncture, typically of a surface vein in the arm. They perform a capillary stick on a finger, an earlobe, or the heel of an infant when only a small quantity of blood is required. An arterial stick is collected from an artery and used to analyze blood gases. After collection, the blood may be analyzed by medical laboratories or perhaps used for transfusions, donations, or research (Betts, et al., 2021).

Medical Laboratory Scientist/Technician

Medical or clinical laboratories employ a variety of individuals in technical positions. Training is provided through a variety of institutions and certification is through the Canadian Society for Medical Laboratory Science. Specialized positions are:

- Medical technologist (MT) tests and analyzes blood, other body fluids, and tissue samples.
- Medical laboratory scientists (MLS) perform complex analyses of tissue, blood, and other body fluids.
- Medical laboratory assistants (MLA) spend the majority of their time receiving, preparing, testing, and processing specimen samples (American Society for Clinical Pathology, n.d.)

Test Yourself

Query 10.6

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11: Lymphatic and Immune Systems

Learning Objectives

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

Word Parts for the Lymphatic and Immune Systems

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for the Lymphatic and Immune Systems.

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Introduction to the Lymphatic and Immune Systems

The **lymphatic system** is a series of vessels, ducts, and trunks that remove interstitial fluid from the tissues and return it the blood. The lymphatic vessels are also used to transport dietary lipids and cells of the **immune system**. Cells of the immune system, lymphocytes, all come from the hematopoietic system of the bone marrow. Primary lymphoid organs, the bone marrow and thymus gland, are the locations where lymphocytes proliferate and mature. Secondary lymphoid organs are the site in which mature lymphocytes congregate to mount immune responses. Many immune system cells use the lymphatic and circulatory systems for transport throughout the body to search for and then protect against pathogens.

This chapter begins by describing the anatomy and physiology of the lymphatic system, whose immune functions lead us into a discussion of the body's multifaceted defenses, which together make up the immune system. Since the lymphatic system shares organs with a number of other body systems, the pathology discussed near the end of this chapter mainly focuses on disorders of the immune system.

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Lymphatic and Immune Systems Medical Terms

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Anatomy and Physiology of the Lymphatic System

The lymphatic vessels begin as open-ended capillaries, which feed into larger and larger lymphatic vessels, and eventually empty into the bloodstream. Along the way, the lymph travels through the lymph nodes, which are commonly found near the groin, armpits, neck, chest, and abdomen. Humans have about 500–600 lymph nodes throughout the body (see Figure 11.1). Several organs and tissues that participate in immunity are also part of the lymphatic system.

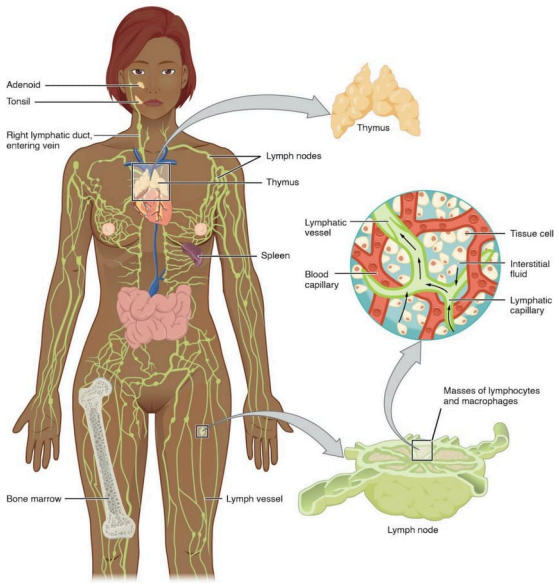


Figure 11.1 Anatomy of the Lymphatic System. Lymphatic vessels in the arms and legs convey lymph to the larger lymphatic vessels in the torso. From Betts, et al., 2021. Licensed under CC BY 4.0.

Did you know?

Lymphatic vessels and blood vessels are similar in structure and function. Lymph is not actively pumped by the heart, but is forced through the vessels by the movements of the body muscles. (Betts, et al., 2021).

Lymphatic Capillaries

An important function of the lymphatic system is to return the fluid (lymph) to the blood. Lymph may be thought of as recycled blood plasma. Blood pressure causes leakage of fluid from the blood capillaries, resulting in the accumulation of fluid in the interstitial space. In humans, 20 liters of plasma is released into the interstitial space of the tissues each day due to capillary leakage. The blood vessels reabsorb 17 liters of this interstitial fluid, leaving three liters in the tissues for the lymphatic system to transport back to the circulation. If the lymphatic system is damaged in some way, such as by being blocked by cancer cells or destroyed by injury, interstitial fluid accumulates in the tissue spaces, causing a condition called lymphedema.

Lymphatic capillaries, also called the terminal lymphatics, are vessels where interstitial fluid enters the lymphatic system to become lymph. Located in almost every tissue in the body, these vessels are interlaced among the arterioles and venules of the circulatory system in the soft connective tissues of the body. See Figure 11.2. Exceptions are the central nervous system, bone marrow, bones, teeth, and the cornea of the eye, which do not contain lymph vessels.

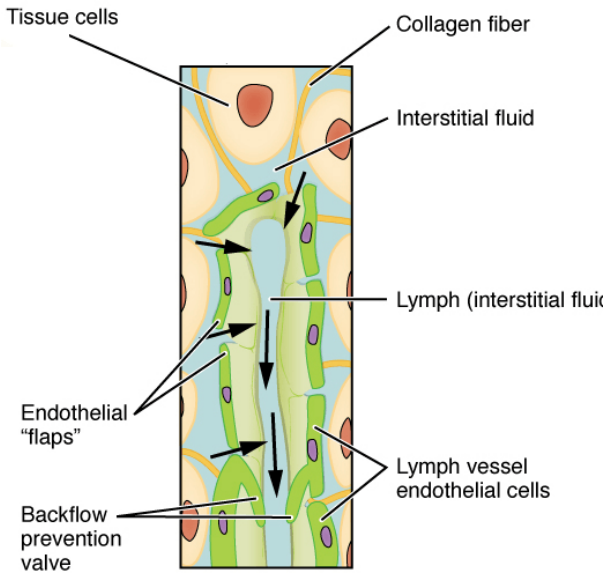


Figure 11.2 Lymphatic Capillaries. Lymphatic capillaries are interlaced with the arterioles and venules of the cardiovascular system. Collagen fibers anchor a lymphatic capillary in the tissue. Interstitial fluid slips through spaces between the overlapping endothelial cells that compose the lymphatic capillary. From CFCF, CC BY-SA 4.0, via Wikimedia Commons

Larger Lymphatic Vessels, Trunks, and Ducts

The lymphatic capillaries empty into larger lymphatic vessels, which are similar to veins in terms of their three-tunic structure and the presence of valves. These one-way valves are located fairly close to one another, and each one causes a bulge in the lymphatic vessel, giving the vessels a beaded appearance (see Figure 11.2).

In general, superficial lymphatics, follow the same routes as veins, whereas deep lymphatic vessels of the viscera generally follow the paths of arteries. The superficial and deep lymphatics eventually merge to form larger lymphatic structures known as **lymphatic trunks**. On the right side of the body, the right sides of the head, thorax, and right upper limb trunks drain lymph fluid into the right subclavian vein via the **right lymphatic duct** (see Figure 11.3). On the left side of the body, the trunks from the remaining portions of the body drain into the larger **thoracic duct**, which drains into the left subclavian vein. The thoracic duct itself begins just beneath the diaphragm in the **cisterna chyli.**

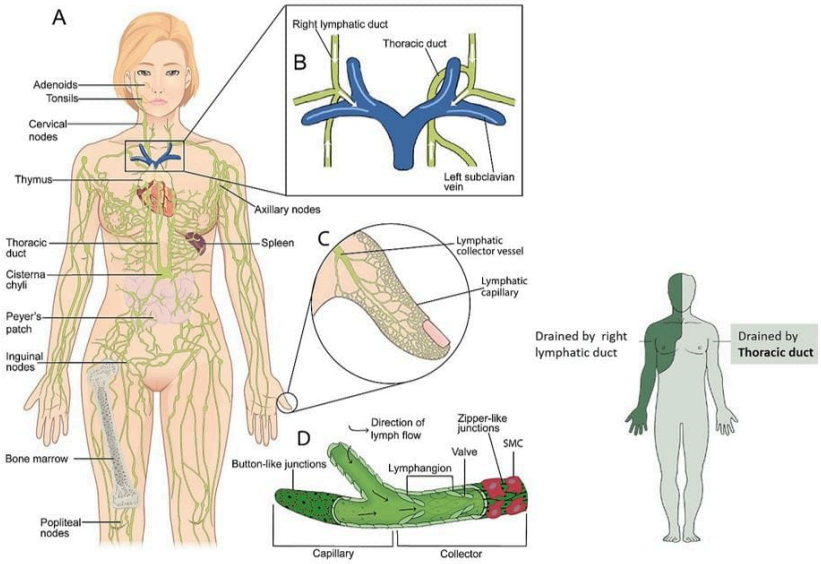


Figure 11.3 Lymphatic System. (A) The lymphatic system includes the primary and secondary lymphoid organs and a series of lymphatic vessels, providing a one-way drainage route from all tissues back ultimately to the blood circulation via the great veins in the neck. In the primary lymphoid organs (bone marrow and thymus) immune cell production and maturation takes place, whereas secondary lymphoid organs (lymph nodes, spleen, and mucosa associated lymphoid organs such as Peyer's patch, tonsils, and adenoids) are the sites for lymphocyte activation. (B) The thoracic duct is responsible for the lymph drainage coming from most of the body except for the right sides of the head and neck, the right side of the thorax and the right upper limb that drain primarily into the right lymphatic duct. Both ducts drain into the great veins of the neck. (C) The intricate dermal lymphatic capillary network drains downstream into the lymphatic collector vessels on route to the lymph nodes. (D) Oak leaf-shaped lymphatic capillary cells are connected via discontinuous junctions or buttons allowing the fluid to enter the system passively; the lymphatic collector endothelial cells, on the other hand, present with continuous junctions or zippers. Collectors differ from initial lymphatics by possessing intraluminal valves, smooth muscle cells (SMC) and a continuous basement membrane. Image in (A) is modified from OpenStax College under a CC BY 3.0 license. (C) modified from Open, Learn, Create under a CC BY-NC-SA 4.0 license.

Primary Lymphoid Organs

The **primary lymphoid organs** are the bone marrow and thymus gland. The lymphoid organs are where lymphocytes mature, proliferate, and are selected, which enables them to attack pathogens without harming the cells of the body.

- Bone Marrow
  - Recall that all blood cells, including lymphocytes, are formed in the red bone marrow. The B cell undergoes nearly all of its development in the red bone marrow, whereas the immature T cell, called a **thymocyte**, leaves the bone marrow and matures largely in the thymus gland.

- Thymus
  - The **thymus** gland, where T cells mature, is a bilobed organ found in the space between the sternum and the aorta of the heart (see Figure 11.4). Connective tissue holds the lobes closely together but also separates them and forms a capsule.
  - The loss of immune function with age is called immunosenescence. One major cause of age-related immune deficiencies is thymic involution.
    - The shrinking of the thymus gland begins at birth at a rate of about three percent tissue loss per year. This shrinking continues until 35–45 years of age then the rate declines to about one percent loss per year for the rest of one's life. At that pace, the total loss of thymic epithelial tissue and thymocytes would occur at about 120 years of age. So, in theory, 120 years could be the maximum life span.

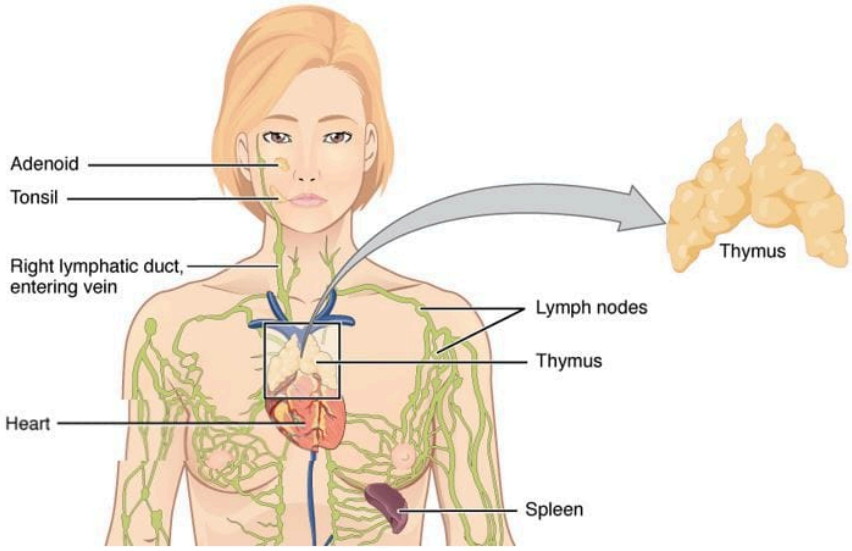


Figure 11.4 Location and Structure of the Thymus. Modified from Anatomy & Physiology, OpenStax. Licensed under CC BY 3.0, via Wikimedia Commons.

Concept Check

- Do you remember what the suffix “-oid” means?
- Can you explain the term **lymphoid**?

Did You Know?

The thymus gland produces a hormone called thymosin and is therefore also considered to be part of the endocrine system.

Secondary Lymphoid Organs

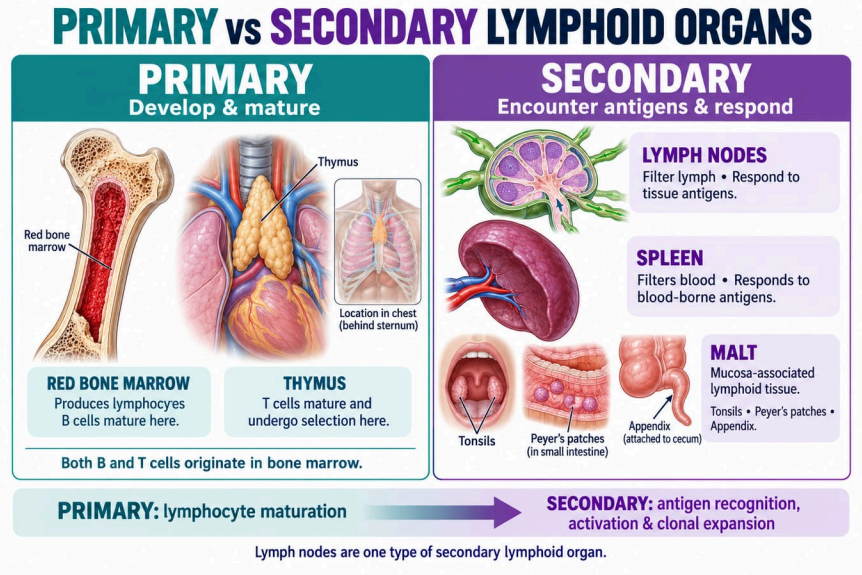


Figure 11.5 **Primary vs. Secondary Lymphoid Organs.** AI-generated using ChatGPT (OpenAI), October 19, 2026, at the request of Dr. Lisa Harding.Any copyright or related rights I hold in this image are dedicated to the public domain under CC0 1.0.

Lymphocytes develop and mature in the primary lymphoid organs, but they mount immune responses from the **secondary lymphoid organs,** which include the lymph nodes, spleen, and lymphoid nodules. A **naïve lymphocyte**is one that has left the primary organ, where it learned to function immunologically, and entered a secondary lymphoid organ where it waits to encounter an antigen against which it will mount a response.

Lymph Nodes

Lymph nodes function to remove debris and pathogens from the lymph, and are thus sometimes referred to as the "filters of the lymph" (see Figure 11.6). Any bacteria that infect the interstitial fluid are taken up by the lymphatic capillaries and transported to a regional lymph node. Dendritic cells and macrophages within this organ internalize and kill many of the pathogens that pass through, thereby removing them from the body. The lymph node is also the site of adaptive immune responses mediated by T cells, B cells, and accessory cells of the adaptive immune system.

Did You Know?

You can live without your spleen. Do you remember the term for "surgical removal of the spleen"?

Spleen

The **spleen** is a vascular organ that is somewhat fragile due to the absence of a capsule. It is about 12 cm long and is attached to the lateral border of the stomach. The spleen is sometimes called the "filter of the blood" because of its extensive vascularization and the presence of macrophages and dendritic cells that remove microbes and other materials from the blood, including dying red blood cells. The spleen also functions as the location of immune responses to blood-borne pathogens. (See Fig 11.6).

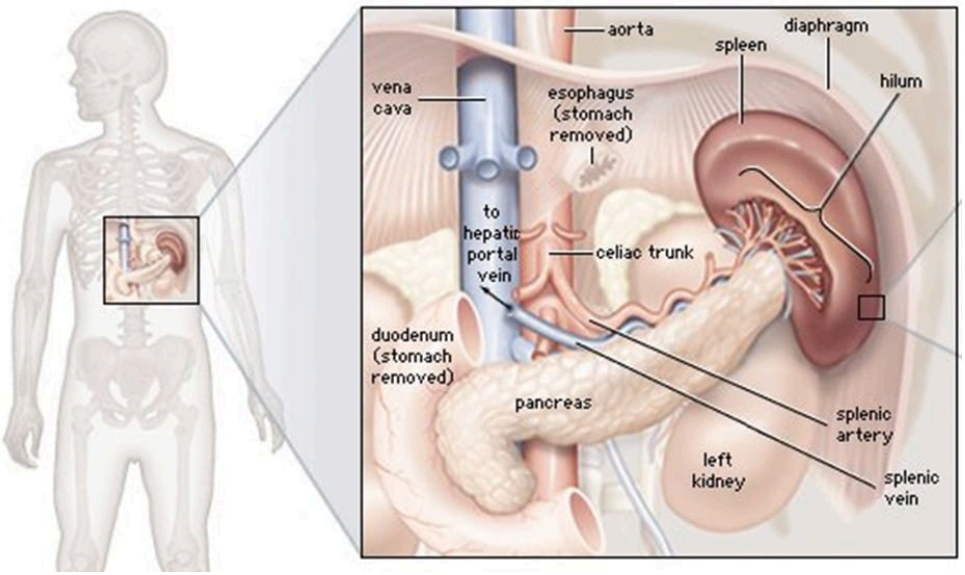


Figure 11.6 Spleen. The spleen is located in the left side of the abdominal cavity under the diaphragm. It is about the size of a fist and is well supplied with blood. The spleen is the primary filtering element for the blood. From Britannica Encyclopedia (2021). https://www.britannica.com/science/spleen-anatomy

Lymphoid Nodules

The other lymphoid tissues, the **lymphoid nodules**, consist of a dense cluster of lymphocytes without a surrounding fibrous capsule. These nodules are located in the respiratory and digestive tracts, areas routinely exposed to environmental pathogens.

Tonsils are lymphoid nodules located along the inner surface of the pharynx and are important in developing immunity to oral pathogens (see Figure 11.7). The tonsil located at the back of the throat, the pharyngeal tonsil, is sometimes referred to as the adenoid when swollen. Such swelling is an indication of an active immune response to infection. Tonsils have deep grooves called crypts, which accumulate all sorts of materials taken into the body through eating and breathing and actually "encourage" pathogens to penetrate deep into the tonsillar tissues where they are eliminated. A major function of tonsils is to help children's

bodies recognize, destroy, and develop immunity to common environmental pathogens so that they will be protected in their later lives. Tonsils are often removed in children who have recurring throat infections since swollen palatine tonsils can interfere with breathing and/or swallowing.

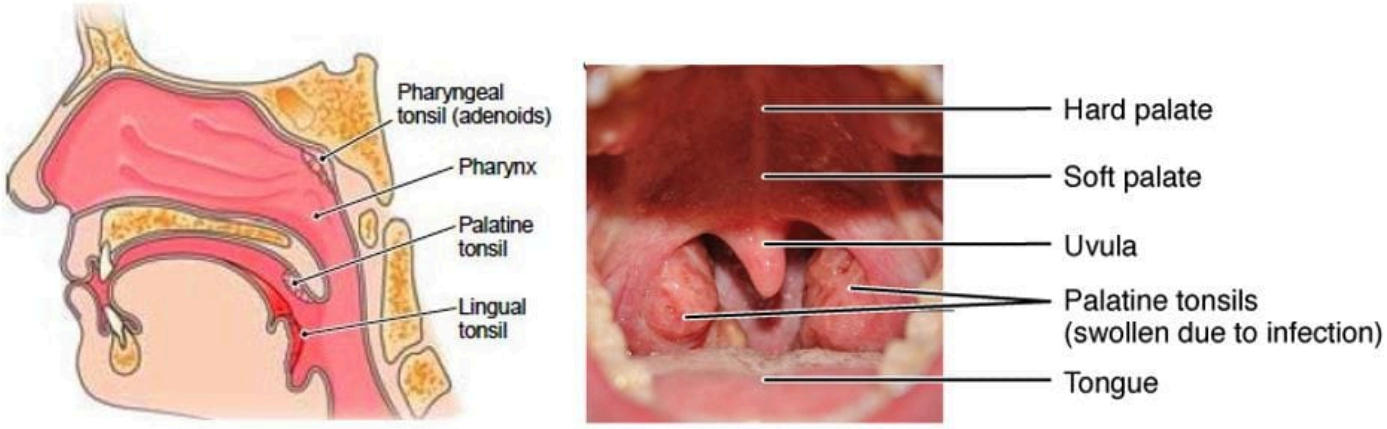


Figure 11.7. Locations of the Tonsils. (a) The pharyngeal tonsil is located on the roof of the posterior superior wall of the nasopharynx. The palatine tonsils lay on each side of the pharynx. Modified From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

Tonsils are named after their locations.

- Look at the figure above and determine which anatomical structure is closely associated with each set of tonsils and was therefore used to name the tonsils, for example, the **lingual tonsils** are named after the **tongue** (lingula).
- Can you tell which structures were used to name the **palatine tonsils** and the **pharyngeal tonsils**?

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Cells of the Innate Immune Response

Phagocytes: Macrophages and Neutrophils

A phagocyte is a cell that is able to surround and engulf a particle or cell, a process called **phagocytosis**. The phagocytes of the immune system engulf other particles or cells, either to clean an area of debris, old cells, or to kill pathogenic organisms such as bacteria. Macrophages, neutrophils, and dendritic cells are the major phagocytes of the immune system and are the body's fast acting, front line immunological defense against organisms that have breached barrier defenses and have entered the body.

Macrophagesnot only participate in innate immune responses but have also evolved to cooperate with lymphocytes as part of

the adaptive immune response. Macrophages exist in many tissues of the body, either freely roaming through connective tissues or fixed to reticular fibers within specific tissues such as lymph nodes. When pathogens breach the body's barrier defenses, macrophages are the first line of defense.

A **neutrophil**is a phagocytic cell that is attracted via chemotaxis from the bloodstream to infected tissues. contains cytoplasmic granules, which in turn contain a variety of vasoactive mediators such as histamine. Whereas macrophages act like sentries, always on guard against infection, neutrophils can be thought of as military reinforcements that are called into a battle to hasten the destruction of the enemy.

A **monocyte**is a circulating precursor cell that differentiates into either a macrophage or **dendritic cell**, which can be rapidly attracted to areas of infection by signal molecules of inflammation.

Natural Killer Cells

NK cells are a type of lymphocyte that have the ability to induce apoptosis in cells infected with pathogens such as *intracellular* bacteria and viruses. If apoptosis is induced before the virus has the ability to synthesize and assemble all its components, no infectious virus will be released from the cell, thus preventing further infection.

Concept Check

Do you know the difference between these terms?

- Intercellular
- Intracellular
- Interstitial

Cytokines and Chemokines

A **cytokine**is signaling molecule that allows cells to communicate with each other over short distances. Cytokines are secreted into the intercellular space, and the action of the cytokine induces the receiving cell to change its physiology. A **chemokine**is a soluble chemical mediator similar to cytokines except that its function is to attract cells (chemotaxis) from longer distances.

Early Induced Proteins

Early induced proteins are those that are not constitutively present in the body, but are made as they are needed early during the innate immune response. **Interferons** are an example of early induced proteins. Cells infected with viruses secrete interferons that travel to adjacent cells and induce them to make antiviral proteins. Thus, even though the initial cell is sacrificed, the surrounding cells are protected.

Inflammatory Response

The hallmark of the innate immune response is **inflammation**. Stub a toe, cut a finger, or do any activity that causes tissue damage and inflammation will result, with its four characteristics: **heat, redness, pain,** and **swelling** ("loss of function" is sometimes mentioned as a fifth characteristic). It is important to note that inflammation does not have to be initiated by an infection, but can also be caused by tissue injuries. The release of damaged cellular contents into the site of injury is enough to stimulate the response, even in the absence of breaks in physical barriers that would allow pathogens to enter (by hitting your thumb with a hammer, for example). The inflammatory reaction brings in phagocytic cells to the damaged area to clear cellular debris and encourages the entry of clotting factors to set the stage for wound repair. Inflammation also facilitates the transport of antigen to lymph nodes by dendritic cells for the development of the adaptive immune response. (Fig. 11.8).

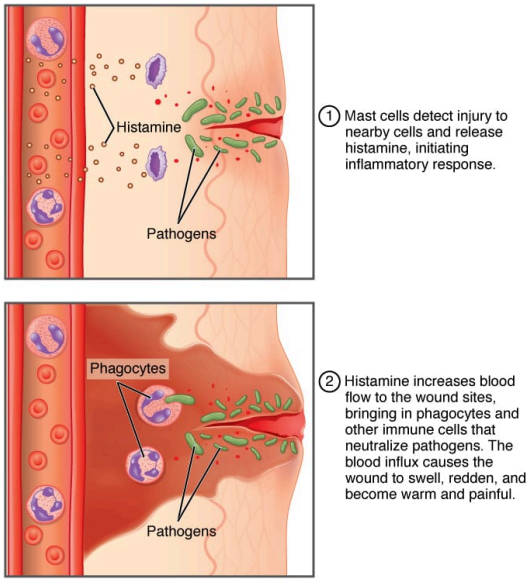


Figure 11.8 Inflammatory Response. From Betts, et al., 2021. Licensed under CC BY 4.0.

The above image summarizes the following events in the inflammatory response:

- The released contents of injured cells stimulate the release of substances from **mast cells** including histamine, leukotrienes, and prostaglandins.
- **Histamine** increases blood flow to the area by vasodilation, resulting in **heat** and **redness**. Histamine also increases the permeability of local capillaries, causing plasma to leak out and form interstitial fluid, resulting in **swelling**
- **Leukotrienes** attract neutrophils from the blood by chemotaxis.
  When local infections are severe, neutrophils are attracted to the sites of infections in large numbers, and as they phagocytose the pathogens and subsequently die, their accumulated cellular remains are visible as pus at the infection site.
- **Prostaglandins** cause vasodilation by relaxing vascular smooth muscle and are a major cause of the **pain** associated with inflammation. Nonsteroidal anti-inflammatory drugs such as aspirin and ibuprofen relieve pain by inhibiting prostaglandin production.

Concept Check

- Do you remember the suffix used to describe 'inflammation'?
- Describe what causes the pain associated with inflammation.

Acute inflammation is a short-term innate immune response to an insult to the body. If the cause of the inflammation is not resolved, however, it can lead to **chronic inflammation**, which is associated with major tissue destruction and fibrosis.

Phase 3: Adaptive Immune Response

Watch this video:

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Media 11.3 Immune System, Part 2: Crash Course A&P #46 [Online video]. Copyright 2015 by CrashCourse.

Benefits of the Adaptive Immune Response

- **Specificity**
  - The ability to specifically recognize and mount a response against almost any pathogen.
  - Antigens, are recognized by receptors on the surface of B and T lymphocytes.

- **Immunological Memory**
  - The first exposure to a pathogen is called a **primary adaptive response.**
  - Symptoms of a first infection, called primary disease, are always relatively severe because it takes time for an initial adaptive immune response to a pathogen to become effective.
  - Upon re-exposure to the same pathogen, a **secondary adaptive immune response**is generated, which is stronger and faster that the primary response, often eliminating the pathogen before it can cause damage or even symptoms.
  - This secondary response is the basis of **immunological memory**, which gives us immunity.

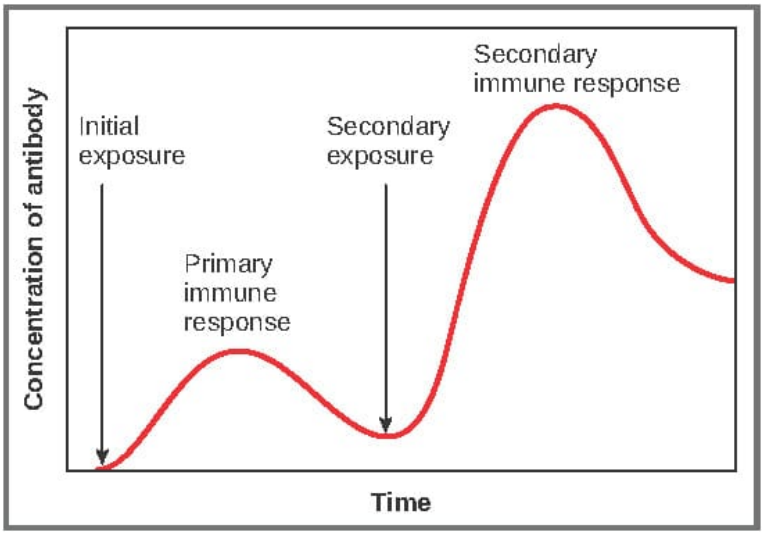


Figure 11.9 Primary and Secondary Antibody Responses. Antigen A is given once to generate a primary response and later to generate a secondary response. When a different antigen is given for the first time, a new primary response is made. From Betts, et al., 2021. Licensed under CC BY 4.0.

- **Self Recognition**
  - The ability to distinguish between self-antigens, those that are normally present in the body, and foreign antigens, those that might be on a potential pathogen.
  - As T and B cells mature, there are mechanisms in place that prevent them from recognizing self-antigen, preventing a damaging immune response against the body. When these mechanisms fail, their breakdown leads to autoimmune

diseases.

Lymphocytes: B Cells, T Cells, Plasma Cells

As stated above, lymphocytes are the primary cells of adaptive immune responses. These cells were introduced in the previous chapter and are summarized in the following table:

Table 11.1 Cells of the Adaptive Immune Response. From Betts, et al., 2021. Licensed under CC BY 4.0.

CELL TYPE	DESCRIPTION AND DETAILS
Plasma Cell	B cell (lymphocyte) that has been activated through exposure to an antigen and produces antibodies against that antigen (see the figure below) There are 5 classes of antibodies (IgM, IgG, IgE, IgA, IgD), each functioning in different ways: **IgM** promotes chemotaxis, opsonization, and cell lysis, making it a very effective antibody against bacteria at early stages of a primary antibody response **IgG** is the one that crosses the placenta to protect the developing fetus from disease and exits the blood to the interstitial fluid to fight extracellular pathogens **IgA** is the only antibody to leave the interior of the body to protect body surfaces. IgA is also of importance to newborns, because this antibody is present in mother's breast milk (colostrum), which serves to protect the infant **IgE** is associated with allergies and anaphylaxis
T Cell	Different T cell types have the ability to either secrete soluble factors that communicate with other cells of the adaptive immune response or destroy cells infected with intracellular pathogen ◦ Cytotoxic T Cell (Tc) kill target cells by inducing apoptosis using the same mechanism as NK cells: killing a virally infected cell before the virus can complete its replication cycle results in the production of no infectious particles ◦ Helper T Cell (Th) release cytokines, which help to develop and regulate other immune system cells ◦ Suppressor T Cell (also called regulatory T cell) control T Cell response, in order to prevent too many T cells from being formed during an immune repsonse
Memory Cell	B cells and T cells formed during primary exposure to a pathogen (see the figure below) Remain in the body for a long time after an infection and are able to mount a fast and effective immune response to a pathogen if it is encountered a second time, preventing the pathogen from causing disease

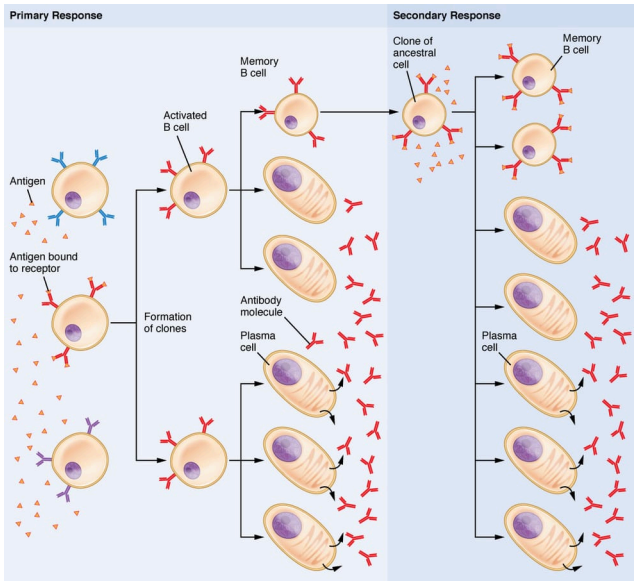


Figure 11.10 Clonal Selection of B Cells. During a primary B cell immune response, both antibody-secreting plasma cells and memory B cells are produced. These memory cells lead to the differentiation of more plasma cells and memory B cells during secondary responses. From Betts, et al., 2021. Licensed under CC BY 4.0.

Active Versus Passive Immunity

Immunity to pathogens, and the ability to control pathogen growth so that damage to the tissues of the body is limited, can be acquired by:

1. The active development of an immune response in the infected individual.
   or
2. The passive transfer of immune components from an immune individual to a non-immune one.

The downside to this passive immunity is the lack of the development of immunological memory. Once the antibodies are transferred, they are effective for only a limited time before they degrade.

Table 11.2 Active Versus Passive Immunity. From Betts, et al., 2021. Licensed under CC BY 4.0.

IMMUNITY	NATURAL	ARTIFICIAL
Active: resistance to pathogens acquired during an adaptive immune response	Result of memory cells formed during the adaptive immune response to a pathogen	Vaccine response. Through vaccination, one avoids the disease that results from the first exposure to the pathogen, yet reaps the benefits of protection from immunological memory. Vaccination was one of the major medical advances of the twentieth century and led to the eradication of smallpox and the control of many infectious diseases, including polio, measles, and whooping cough
Passive: transfer of antibodies from an immune person to a nonimmune person	Trans-placental antibodies from mother to fetus and maternal antibodies in breast milk protect newborn from infections	Immunoglobulin injections taken from animals previously exposed to a specific pathogen; a fast-acting method of temporarily protecting an individual who was possibly exposed to a pathogen

Evasion of the Immune System by Pathogens

The immune system and pathogens are in a slow, evolutionary race to see who stays on top. Early childhood is a time when the body develops much of its immunological memory that protects it from diseases in adulthood. Pathogens have shown the ability, however, to evade the body's immune responses, as described below.

- **Protective adaptations**: It is important to keep in mind that although the immune system has evolved to be able to control many pathogens, pathogens themselves have evolved ways to evade the immune response. An example is in *Mycobactrium tuberculosis*, which has evolved a complex cell wall that is resistant to the digestive enzymes of the macrophages that ingest them, and thus persists in the host, causing the chronic disease tuberculosis.

- **Multiple strains**: Bacteria sometimes evade immune responses because they exist in multiple strains, each having different surface antigens and requiring individual adaptive immune responses. One example is a small group of strains of *S. aureus*, called methicillin-resistant *Staphylococcus aureus (MRSA)*, which has become resistant to multiple antibiotics..

- **Antigen mutation:** Because viruses' surface molecules mutate continuously, viruses like influenza change enough each year that the flu vaccine for one year may not protect against the flu common to the next. New vaccine formulations must be derived for each flu season.

- **Genetic recombination:** An example is the influenza virus, which contains gene segments that can recombine when two different viruses infect the same cell. Recombination between human and pig influenza viruses led to the 2010 H1N1 swine flu outbreak.

- **Immunosuppression**: Pathogens, especially viruses, can produce immunosuppressive molecules that impair immune function.

Tissue Transplantation

With the use of tissue typing and anti-rejection drugs, transplantation of organs and the control of the anti-transplant immune response have made huge strides in the past 50 years.

Immunosuppressive drugs such as cyclosporine A have made transplants more successful, but tissue matching is still key. Family members, since they share a similar genetic background, are much more likely to share MHC molecules than unrelated individuals do.

One disease of transplantation occurs with bone marrow transplants, which are used to treat various diseases, including SCID and leukemia. Because the bone marrow cells being transplanted contain lymphocytes capable of mounting an immune response, and because the recipient's immune response has been destroyed before receiving the transplant, the donor cells may attack the recipient tissues, causing **graft-versus-host disease**. Symptoms of this disease, which usually include a rash and damage to the liver and mucosa, are variable, and attempts have been made to moderate the disease by first removing mature T cells from the donor bone marrow before transplanting it.

Immune Responses Against Cancer

It is clear that with some cancers, like Kaposi's sarcoma (see Figure 11.11), for example, that a healthy immune system does a good job at controlling them. This disease, which is caused by the human herpes virus, is almost never observed in individuals with strong immune systems. Other examples of cancers caused by viruses include liver cancer caused by the hepatitis B virus and cervical cancer caused by the human papilloma virus. As these last two viruses have vaccines available for them, getting vaccinated can help prevent these two types of cancer by stimulating the immune response.

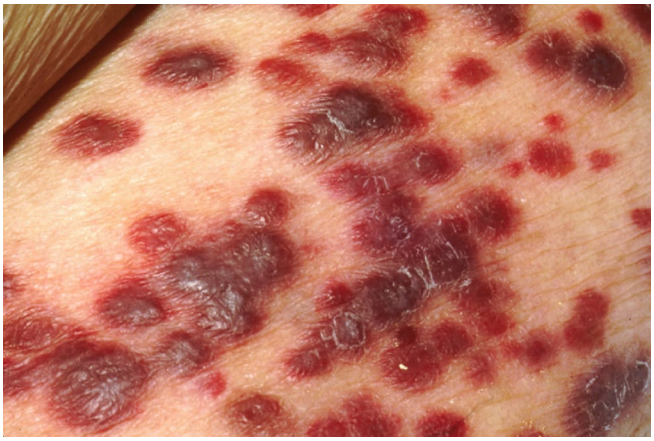


Figure 11.11 Kaposi's Sarcoma Lesions. (credit: National Cancer Institute). From Betts, et al., 2021. Licensed under CC BY 4.0.

On the other hand, as cancer cells are often able to divide and mutate rapidly, they may escape the immune response, just as certain pathogens such as HIV do.

There are three stages in the immune response to many cancers:

1. **Elimination** occurs when the immune response first develops toward tumor-specific antigens specific to the cancer and actively kills most cancer cells.
2. **Equilibrium** is the period that follows, during which the remaining cancer cells are held in check.
3. **Escape** of the immune response, and resulting disease, occurs because many cancers mutate and no longer express any specific antigens for the immune system to respond to.

This fact has led to extensive research in trying to develop ways to enhance the early immune response to completely eliminate the early cancer and thus prevent a later escape. One method that has shown some success is the use of cancer vaccines. These differ from other vaccines in that they are directed against the cells of one's own body. Treated cancer cells are injected into cancer patients to enhance their anti-cancer immune response and thereby prolong survival. The immune system has the capability to detect these cancer cells and proliferate faster than the cancer cells do, thus overwhelming the cancer in a similar way as they do for viruses. Cancer vaccines are being developed for malignant melanoma and renal (kidney) cell carcinoma.

Immune Responses and Stress

In order to protect the entire body from infection, the immune system is required to interact with other organ systems, sometimes in complex ways. For example, hormones such as cortisol (naturally produced by the adrenal cortex) and prednisone (synthetic) are well known for their abilities to suppress T cell immune mechanisms, hence, their prominent use in medicine as long-term, anti-inflammatory drugs.

One well-established interaction of the immune, nervous, and endocrine systems is the effect of stress on immune health. In the human vertebrate evolutionary past, stress was associated with the fight-or-flight response, largely mediated by the central nervous system and the adrenal medulla. This stress was necessary for survival since fighting or fleeing usually resolved the problem in one way or another. It has been found that short-term stress diverts the body's resources towards enhancing innate immune responses. This has the ability to act fast and would seem to help the body prepare better for possible infections associated with the trauma that may result from a fight-or-flight exchange.

On the other hand, there are no physical actions to resolve most modern day stresses, including short-term stressors like taking examinations and long-term stressors such as being unemployed or losing a spouse. The effect of stress can be felt by nearly every organ system, and the immune system is no exception (see Table 11.3). Chronic stress, unlike short-term stress, may inhibit immune responses even in otherwise healthy adults. The suppression of both innate and adaptive immune responses is clearly associated with increases in some diseases.

Table 11.3 Effects of Stress on Body Systems. From Betts, et al., 2021. Licensed under CC BY 4.0.

SYSTEM	STRESS-RELATED ILLNESS
Integumentary system	Acne, skin rashes, irritation
Nervous system	Headaches, depression, anxiety, irritability, loss of appetite, lack of motivation, reduced mental performance
Muscular and skeletal systems	Muscle and joint pain, neck and shoulder pain
Circulatory system	Increased heart rate, hypertension, increased probability of heart attacks
Digestive system	Indigestion, heartburn, stomach pain, nausea, diarrhea, constipation, weight gain or loss
Immune system	Depressed ability to fight infections
Male reproductive system	Lowered sperm production, impotence, reduced sexual desire
Female reproductive system	Irregular menstrual cycle, reduced sexual desire

Anatomy Labeling Activity

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Medical Terms not Easily Broken into Word Parts

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Lymphatic and Immune System Abbreviations

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Diseases and Disorders of the Lymphatic and Immune Systems

The immune response can be under-reactive or over-reactive, leading to a state of disease. The factors that maintain immunological homeostasis are complex and incompletely understood.

Underactive Immune System: Immunodeficiencies

Suppressed immunity can result from inherited genetic defects or by acquiring viruses (Betts, et al., 2021).

Inherited Immunodeficiencies/SCID

While many inherited immunodeficiencies exist, the most serious is **severe combined immunodeficiency disease (SCID)**. This complex disease is caused by many different genetic defects which result in impaired B cell and T cell arms of the adaptive immune response. Children with this disease usually die of opportunistic infections within their first year of life unless they receive a bone marrow transplant. Such a procedure had not yet been perfected for David Vetter, the “boy in the bubble,” who was treated for SCID by having to live in a sterile plastic cocoon for the 12 years before his death from infection in 1984. One of the features that make bone marrow transplants work as well as they do is the proliferative capability of hematopoietic stem cells of the bone marrow. Only a small amount of bone marrow from a healthy donor is given intravenously to the recipient. It finds its own way to the bone where it populates it, eventually reconstituting the patient’s immune system, which is usually destroyed beforehand by treatment with radiation or chemotherapeutic drugs (Betts, et al., 2021).

New treatments for SCID using gene therapy, inserting nondefective genes into cells taken from the patient and giving them back, have the advantage of not needing the tissue match required for standard transplants. Although not a standard treatment, this approach holds promise, especially for those in whom standard bone marrow transplantation has failed (Betts, et al., 2021).

Acquired Immunodeficiency/HIV and AIDS

Although many viruses cause suppression of the immune system, only HIV wipes it out completely. HIV is transmitted through semen, vaginal fluids, and blood, and can be caught by risky sexual behaviors and the sharing of needles by intravenous drug users. There are sometimes, but not always, flu-like symptoms in the first 1 to 2 weeks after infection. The presence of anti-HIV antibodies indicates a positive HIV test. Because seroconversion takes different lengths of time in different individuals, multiple HIV tests are given months apart to confirm or eliminate the possibility of infection.

After seroconversion, the amount of virus circulating in the blood drops and stays at a low level for several years. During this time, the levels of CD4 T cells decline steadily, until at some point, the immune response is so weak that opportunistic disease and eventually death result.

Treatment for the disease consists of drugs that target virally encoded proteins that are necessary for viral replication but are absent from normal human cells. By targeting the virus itself and sparing the cells, this approach has been successful in significantly prolonging the lives of HIV-positive individuals (Betts, et al., 2021).

Overactive Immune System: Hypersensitivities and Autoimmune Diseases

Hypersensitivities

Over-reactive immune responses include the hypersensitivities: allergies and inflammatory responses to nonpathogenic environmental substances (Betts, et al., 2021). The table below compares different hypersensitivities.

Table 11.4 Table Summarizing Types of Hypersensitivities. From Betts, et al., 2021. Licensed under CC BY 4.0.

TYPE OF HYPERSENSITIVITY	DETAILS AND EXPLANATION
Type I	◦ Allergies and allergic asthma ◦ Major symptoms of inhaled allergens are the nasal edema and runny nose caused by the increased vascular permeability and increased blood flow of nasal blood vessels ◦ 'Immediate Hypersensitivity': usually rapid and occur within just a few minutes ◦ Mild allergies are usually treated with antihistamines ◦ Severe allergies that may cause anaphylactic shock, which can be fatal within 20 to 30 minutes if untreated; epinephrine raises blood pressure and relaxes bronchial smooth muscle and is routinely used to counteract the effects of anaphylactic shock
Type II	◦ Occurs during mismatched blood transfusions and blood compatibility diseases such as erythroblastosis fetalis
Type III	◦ Occurs with diseases such as systemic lupus erythematosus
Type IV	◦ 'Delayed hypersensitivity'-takes 24-72 hours to develop ◦ A standard cellular immune response in which the first exposure to an antigen is called **sensitization**, such that on re-exposure, an immune response results ◦ The classical test for delayed hypersensitivity is the tuberculin test for tuberculosis, where bacterial proteins from *M. tuberculosis* are injected into the skin. A couple of days later, a positive test, as indicated by an induration, means that the patient has been exposed to the bacteria and exhibits a cellular immune response to it ◦ Another type of delayed hypersensitivity is contact sensitivity, where substances such as the metal nickel cause a red and swollen area upon contact with the skin in an individual who was previously sensitized to the metal.

Autoimmune Responses

The worst cases of the immune system over-reacting are autoimmune diseases in which the immune systems begin to attack cells of the patient's own body, causing chronic inflammation and significant damage. The trigger for these diseases is often unknown, although environmental and genetic factors are likely involved. Treatments are usually based on resolving the symptoms using immunosuppressive and anti-inflammatory drugs. Figure 11.12 below provides two examples of autoimmune diseases: rheumatoid arthritis (RA) and systemic lupus erythematosus (SLE) (Betts, et al., 2021).

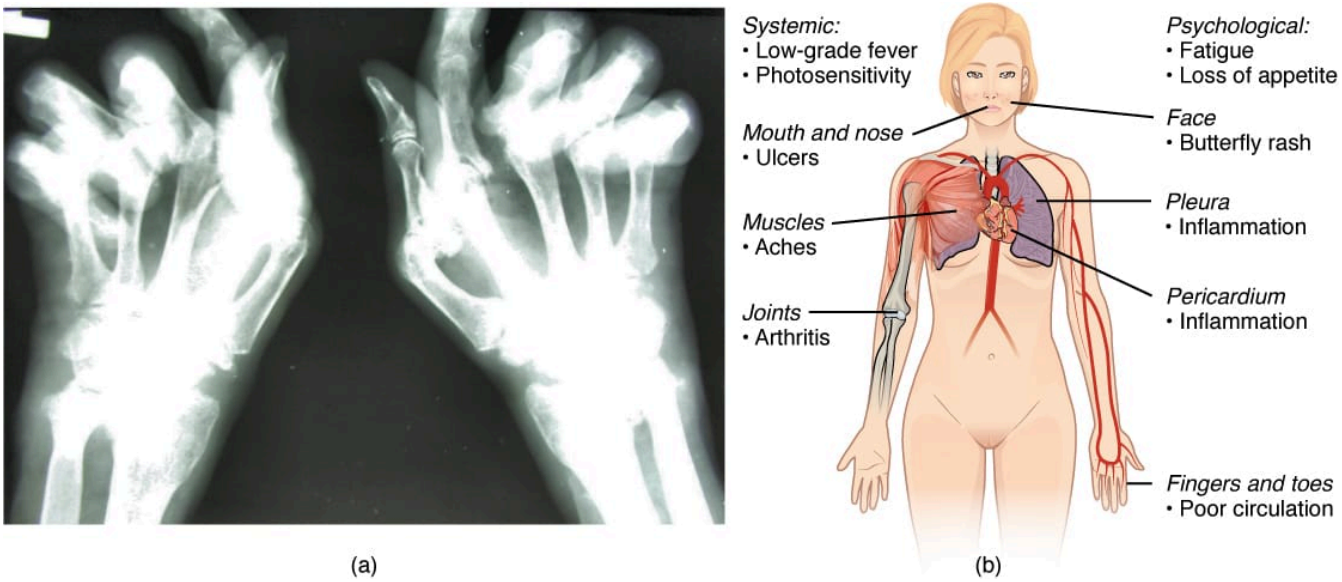


Figure 11.12 Autoimmune Disorders: Rheumatoid Arthritis and Lupus. (a) Extensive damage to the right hand of a rheumatoid arthritis sufferer is shown in the x-ray. (b) The diagram shows a variety of possible symptoms of systemic lupus erythematosus. From Betts, et al., 2021. Licensed under CC BY 4.0.

Overall, there are more than 80 different autoimmune diseases, which are a significant health problem in the elderly. Table 14.5 below lists several of the most common autoimmune diseases, the antigens that are targeted (autoantigen or "self" antigen), and the resulting tissue damage (Betts, et al., 2021).

Table 11.5 Autoimmune Diseases. From Betts, et al., 2021. Licensed under CC BY 4.0.

DISEASE	AUTOANTIGEN	SYMPTOMS
Celiac disease	Tissue transglutaminase	Damage to small intestine
Diabetes mellitus type I	Beta cells of pancreas	Low insulin production; inability to regulate serum glucose
Graves' disease	Thyroid-stimulating hormone receptor (antibody blocks receptor)	Hyperthyroidism
Hashimoto's thyroiditis	Thyroid-stimulating hormone receptor (antibody mimics hormone and stimulates receptor)	Hypothyroidism
Lupus erythematosus	Nuclear DNA and proteins	Damage of many body systems
Myasthenia gravis	Acetylcholine receptor in neuromuscular junctions	Debilitating muscle weakness
Rheumatoid arthritis	Joint capsule antigens	Chronic inflammation of joints

Lymphoma

Lymphoma was briefly discussed in the previous chapter.

Medical Terms in Context

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Medical Specialties and Procedures Related to the Lymphatic and Immune Systems

Clinical Immunology/Allergy is a medical specialty that diagnoses and treats diseases of the immune system (American Academy of Allergy Asthma and Immunology, 2021). For more information, please visit the 'About Careers in Allergy/Immunology' page from the American Academy of Allergy Asthma and Immunology.

Skin testing (for allergies) is done by a clinical immunologist/allergist to identify allergens in Type I hypersensitivity. In skin testing, allergen extracts are injected into the epidermis, and a positive result of the wheal and flare response usually occurs within 30 minutes. The soft center is due to fluid leaking from the blood vessels and the redness is caused by the increased blood flow to the area that results from the dilation of local blood vessels at the site (Betts, et al., 2021).

Test Yourself

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12: Diagnostic Tests and Procedures (Including Radiology and Nuclear Medicine)

Learning Objectives

- Apply the rules of medical language to build, analyze, spell, pronounce, abbreviate, and define terms related to diagnostic tests and procedures
- Identify meanings of key word components related to laboratory testing, ultrasound, nuclear medicine, radiology, and clinical procedures
- Spell medical terms related to diagnostic tests and procedures and use correct abbreviations
- Categorize terms related to common laboratory tests, ultrasound procedures, nuclear medicine scans, radiology procedures, and clinical procedures
- Use appropriate medical terms to describe common diagnostic tests and clinical procedures
- Identify common abbreviations for diagnostic tests and procedures and explain their meanings

This chapter will explore diagnostic tests and procedures that are typically performed in a hospital and other medical settings. Tests and procedures occur every day in health care, and many of us have likely had a number of these tests ourselves. This chapter has been organized into lab tests, diagnostic imaging, and clinical procedures. The diagnostic imaging section includes X-rays, ultrasounds, nuclear medicine, and MRIs. Tests and procedures will be explained, abbreviations will be listed where applicable, and important considerations will be discussed. A large assortment of images and some videos will assist you with your learning. Exercises are also provided throughout, as well as a final review to solidify what you have learned.

Almost everyone has had some form of lab work done, and lab work is completed numerous times a day in hospitals, clinics, and specialized facilities that function only to obtain blood and other samples to be analyzed. In hospitals, patients often have blood drawn at the bedside, and on some specialty units, nurses draw blood from central lines. Usually, for patients in the hospitals, nurses collect urine and swabs of bodily fluids and then send those to the lab for analysis. Although the manner in which samples are collected varies, the end result is the same—the samples are all processed in a lab. The more common types of lab work are discussed below, but of course, there are also other tests that can be ordered and completed. Figure 12.1 and Figure 12.2 show samples being analyzed.

lab tech using a microscope

Figure 12.1

samples being analyzed

Figure 12.2

Alanine transaminase (ALT): This blood test detects an enzyme called alanine transaminase. ALT is found mostly in the liver and kidneys, and an increase in circulating ALT suggests liver damage or possibly muscle damage.

Albumin: This blood test detects albumin which is a protein found in blood that is produced in the liver and is a carrier of many lipid-soluble vitamins and other hydrophobic compounds. A decrease in circulating albumin may suggest a nutritional deficiency or poor liver function.

Total protein: Similar to albumin, a measure of total blood protein is useful to assess for malnutrition or possibly chronic disorders such as inflammatory bowel disease.

Alkaline phosphatase (ALP): This blood test measures the level of ALP, an enzyme found in the liver and other tissues such as bone. An elevated ALP level is commonly caused by liver disease or other pathologies that increase cell damage, which leads to the release of ALP in the blood.

Aspartate amino transferase (AST): This blood test measures the level of AST, which is found in the heart and liver and is needed in nitrogen metabolism. It is a useful lab test for detecting liver damage. The ratio of ALT to AST can also be used to differentiate between disorders such as alcoholic versus nonalcoholic fatty liver disease.

Bilirubin: This test measures the amount of bilirubin in blood serum. High levels cause jaundice and suggest liver dysfunction

and disease.

Blood urea nitrogen (BUN): This blood test detects urea, which is a waste product of amino acid metabolism and is filtered out of the blood by the kidneys. It is also the primary means of nitrogen disposal. Pathologies that affect the kidneys can affect the amount of urea in the blood.

Calcium (Ca): Calcium is one of the most important minerals in the body and is essential for the proper functioning of muscles, nerves, and cardiac tissue. It is also needed for blood clotting and bone formation. This lab test measures the level of calcium in the blood and will show whether it is elevated or decreased.

Complete blood count (CBC): A CBC test checks the levels of 10 different components of every major cell in your blood. This test is helpful in diagnosing leukemia, infection, blood disorders, anemia, and nutritional deficiencies (Healthline, 2021).

Key Concept

tube of blood with CBC results behind it

Figure 12.3

The main components of a CBC are the following:

- **Red blood cells:** Cells that are responsible for carrying oxygen throughout the body
- **White blood cells:** Immune system cells found in the blood
- **Platelets:** Small cells that control blood clotting
- **Hemoglobin:** Protein in the red blood cells that carries oxygen to organs and tissues, and carbon dioxide back to the lungs
- **Hematocrit:** The percentage of blood made up of red blood cells

Cholesterol test: This test measures the amount of cholesterol in the blood. Cholesterol is found in many dietary sources such as animal fats, oils, egg yolks, and milk. Normal values are 120-200 mg/dL, and high levels are associated with blockage of arteries and heart disease.

Key Concept

When assessing cholesterol, the following factors are measured:

- **High-density lipoprotein (HDL):** HDL is desirable because it removes excess cholesterol from peripheral tissues and carries it to the liver for removal or use.
- **Low-density lipoprotein (LDL):** LDL is called “bad cholesterol” because it can contribute to atherosclerosis by depositing excess cholesterol in the walls of blood vessels.
- **Triglycerides:** This is a measurement of circulating triacylglycerols, and increased triglyceride levels may suggest endocrine deficiencies or metabolic defects.
- **Total cholesterol:** This measurement takes into account various forms of cholesterol in circulation. It is the total HDL, LDL, and 20% of the triglyceride measurement.

Creatine kinase (CK) test: Creatine kinase is a blood enzyme normally found in heart muscle, brain tissue, and skeletal muscles. A blood test to check the level of CK can show whether there has been damage to the heart, skeletal muscles, brain, and sometimes other parts of the body (Government of Alberta, 2022).

Creatinine test: This test measures the amount of creatinine, a nitrogen-containing waste material, in blood serum or plasma and is the most commonly used test for kidney function. Creatinine is normally produced as a protein breakdown product in muscle and is excreted by the kidneys in urine. Creatinine levels are a good indicator of how the kidneys are (or are not) working.

Creatinine clearance test: This test measures the the rate at which creatinine is filtered from the blood by the kidneys (Cleveland

Clinic, 2022). It is used to assess kidney function by comparing the levels of creatinine in urine and in blood. Low levels indicate that the kidneys are not functioning effectively enough to clear creatinine from the bloodstream and then filter it into the urine. Abnormal levels of creatinine could possibly be a sign of kidney failure (Cleveland Clinic, 2022).

Culture: For a culture test, bodily fluids are taken and cultured in the lab to determine whether bacteria, viruses, or fungi are present. Swabs are often used to take samples of bodily fluids from various areas of the body, including the nose, groin, rectum, mouth, and any wounds. The sample is then sent to the lab, and a substance is added to it to increase the growth of bacteria, fungi, or viruses. Some substances grow within a couple days, but others, such as fungi, take longer. If nothing grows, then the culture is negative, but when something does, the growth is analyzed through a microscope to determine what type of virus, bacteria, or fungus is present (Doyle & McCutcheon, 2020). Figure 12.4 and Figure 12.5 show examples of cultures and the manner in which growth can appear. The different colours and patterns t are indicative of different bacteria, viruses, or fungi.

culture and sensitivity test

Figure 12.4

culture and sensitivity test

Figure 12.5

Culture and sensitivity (C&S): This test is similar to the culture test but includes a sensitivity component as well. Sensitivity testing determines the best course of treatment for whatever virus, bacteria, or fungus is present. For example, when bacteria is present, the sensitivity test would determine the best antibiotic to use to treat the infection (Carter & Rutherford, 2020).

Electrolyte panel: This test measures the levels of major electrolytes in the body.

Key Concept

The main components of an electrolyte panel are listed below:

- **Sodium** is vital to many normal body processes, including nerve and muscle function. Low sodium levels (**hyponatremia**) can be suggestive of illness, diarrhea, or malnutrition. On the other hand, high sodium levels (**hypernatremia**) are often caused by dehydration or endocrine disorders such as Cushing's syndrome or diabetes insipidus.
- **Potassium** is critical for the heart to work effectively. High or low potassium levels are often a result of unmanaged diabetes.
- **CO_2 (carbon dioxide, bicarbonate)** is produced from several oxidative pathways and is removed in the form of bicarbonate or through hemoglobin transport. High CO_2 could suggest a renal, respiratory, and/or metabolic concern.
- **Chloride** is a negatively charged ion that works with the other electrolytes listed above to help regulate both fluid and the acid-base (pH) balance in the body.

Glucose test: This test measures the level of glucose in the blood. Blood glucose levels can be assessed via blood work, at home by the patient, or in the hospital by a nurse at the bedside. Patients with diabetes require regular monitoring of their blood glucose to help them achieve close-to-normal blood glucose levels for as much of the time as possible (Doyle & McCutcheon, 2020). The benefits of maintaining a blood glucose level that is consistently within the range of 4–7 mmol/L will reduce the short-term, potentially life-threatening complications of low blood sugar (**hypoglycemia**) and the severity of the long-term complications of high blood sugar (**hyperglycemia**) (Doyle & McCutcheon, 2020). Figure 12.6 and Figure 12.7 show a person taking their own blood sample for glucose testing. Similar, though more complicated, glucose-testing machines can be found on hospital units for nurses to test patients' blood sugar.

blood glucose monitor using finger

Figure 12.6

blood glucose monitor machine

Figure 12.7

Fasting blood sugar (FBS): This test is similar to the glucose test, but it is done first thing in the morning before the person eats or drinks anything that day. This provides a good indication of how the person's body maintains glucose levels.

Glucose tolerance test (GTT): This test assesses how well a person's body can maintain blood glucose levels when sugar is introduced into their diet. The person's blood sugar is checked first thing in the morning, before they eat, and then they ingest

a high-sugar drink. After a period of time, their blood sugar is reassessed. Pregnant women are often asked to take this test to assess for gestational diabetes.

Hematocrit: The hematocrit test measures the percentage red blood cells in a sample of whole blood. It determines how much of a person's blood is made up of red blood cells (Carter & Rutherford, 2020).

Human chorionic gonadotropin (hCG): The hormone hCG creates an suitable environment for a developing embryo during pregnancy. A pregnant woman's body increases production of this hormone, and hCG accumulates in the maternal bloodstream and is excreted in the urine. Detection of hCG can be done through a urine sample, and exact levels can be accessed via a blood test (Betts et al., 2013).

International normalized ratio (INR): This blood test is used to monitor the therapeutic effects of warfarin, an anticoagulant (Ernstmeyer & Christman, 2020).

Prostate specific antigen (PSA): PSA is a protein produced by normal cells of the prostate gland, and this test measures the level of PSA in the blood. The blood level of PSA is often elevated in men with prostate cancer (National Cancer Institute, 2022).

Platelet count: This test measures the number of platelets in a blood sample (Healthline, 2021).

Prothrombin time (PT): This blood test measures how long it takes for a patient's blood to clot. Similar to the INR test, PT is used to monitor the effects of warfarin in preventing clot formation (Ernstmeyer & Christman, 2020).

Partial thromboplastin time (PTT): This blood test is used to monitor how long it takes for a patient's blood to clot but focuses on the effectiveness of anticoagulant therapies. It is used to determine whether therapeutic ranges have been achieved (Ernstmeyer & Christman, 2020).

Red blood cell count (RBC): This test measures the amount of red blood cells in a blood sample (Healthline, 2021).

Fecal occult blood test: This is a test for blood in a fecal sample. A small amount of fecal output is put onto a card, and the sample is viewed under a microscope to look for blood (Carter & Rutherford, 2020). Figure 12.8 below shows an example of the card that is used for analysis.

test for blood in a fecal sample, card for analysis

Figure 12.8

Stool culture: In this test, a small fecal sample is collected and analyzed for abnormal bacterial growth using a culture test (Carter & Rutherford, 2020).

Thyroid function test: This test assesses the concentration of various endocrine hormones in the blood (Betts et al., 2013).

blood for thyroid test

Figure 12.9

Troponin test: This test measures the level of troponin in the blood. The presence of troponin indicates heart injury and is used to determine whether a patient has experienced a heart attack.

Uric acid test: High levels of uric acid in a blood test indicate that the patient may have gout. Gout is a form of arthritis caused by uric acid crystals deposited in a joint, often the big toe (Betts et al., 2013).

Urinalysis (U/A): A urine sample can be assessed by placing a dipstick into the sample (Figure 12.10) or analyzed in the lab (Figure 12.11).

urine sample can be assessed by placing a dipstick into the sample

Figure 12.10

urine in sample container

Figure 12.11

Key Concept

Urine samples can be assessed for many different components, including the following:

- **Specific gravity (SG):** Specific gravity indicates how concentrated the urine is.
- **pH:** Urine is typically slightly acidic, about pH 6, but can range from pH 4.5 to 8.
- **Protein:** An estimate of the amount of albumin in the urine; normally, there should be no protein or just a small amount of protein in the urine.
- **Glucose:** The presence of glucose in urine is called glucosuria and can result from an excessively high glucose level in the blood, such as may be seen in individuals with uncontrolled diabetes.
- **Ketones:** Ketones are intermediate products of fat metabolism and can be produced when an individual does not eat enough carbohydrates, such as in fasting conditions or when eating a high-protein diet; ketones are not normally found in urine.
- **Hemoglobin and myoglobin:** The presence of hemoglobin in a urine sample indicates blood in the urine (hematuria); a small number of RBCs are normally present in urine, but an increased amount give a positive test result.
- **Leukocyte esterase:** This enzyme is present in most white blood cells (WBCs), and few white blood cells are normally present in urine; however, a significant number of WBCs in urine may indicate inflammation in the urinary tract or kidneys.
- **Nitrite:** Some types of bacteria convert nitrate, which is normally present in urine, to nitrite, which is not normally present.
- **Bilirubin:** Bilirubin is not present in the urine of healthy individuals, and its presence is an early indicator of liver disease.
- **Urobilinogen:** This sustance is normally present in urine in low concentrations, but a positive test result may indicate liver disease such as viral hepatitis, cirrhosis, or liver damage from drug use or toxic substances, or conditions such as hemolytic anemia.

Urine for culture and sensitivity: This test involves taking a urine sample to the lab to be cultured in order to detect and identify bacteria in the urine. If bacteria are present, then a sensitivity test is completed (Carter & Rutherford, 2020).

24-hour urine collection: In this test, all urinary output is collected over a 24-hour period. The analysis of urinary output over this extended period of time provides a greater indication of normal or abnormal kidney function (Carter & Rutherford, 2020).

White blood cell count (WBC): This test measures the amount of white blood cells in a blood sample.

Interactive Content

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Diagnostic Imaging: Radiology

In 1895, German physicist Wilhelm Röntgen was experimenting with electrical current when he discovered that invisible “rays” could pass through his flesh and leave an outline of his bones on a screen coated with a metal compound (Betts et al., 2013). He then made the first record of the internal parts of a living human with an image of his wife’s hand. This record eventually became known as an “X-ray.” Once this discovery was made, advancements came quickly, and by 1900, X-rays had become widely used. They could detect a variety of injuries and diseases, which led to great advancements in patient care and outcomes (Betts et al., 2013). Figure 12.12 and Figure 12.13 show some of the early X-rays taken by Röntgen.

early X-rays taken by Röntgen

Figure 12.12

early X-rays taken by Röntgen

Figure 12.13

Modern Use of X-Rays

The use of X-rays is commonplace in health care today, and most people have had at least one X-ray (Betts et al., 2013). Even though they are very common, most of us do not know how X-rays work. X-rays are emitted from a specialized machine that directs the rays through a particular part of the body and toward a specially treated metallic plate. The beam of radiation from the X-ray machine results in darkening of the X-ray plate (Betts et al., 2013). Different tissues show up as different shades; X-rays are only slightly impeded by soft tissues, which show up as varying shades pf grey, whereas hard tissues, such as bone, block the rays and appear white. Metal and contrast dyes also appear white. Structures containing air will look black. As a result, X-rays are best used to visualize hard body structures such as teeth and bones (Betts et al., 2013).

X-rays can depict a two-dimensional image of any body region but only from a single angle (Betts et al., 2013). If a more detailed or three-dimensional image is needed, then another form of test would be indicated and these will be discussed later in the chapter. The two figures below show examples of both portable (Figure 12.14) and stationary (Figure 12.15) X-ray machines.

portable x-ray

Figure 12.14

stationary X-ray machine

Figure 12.15

Specific Types of X-Rays

A selection of different types of X-rays and specialty tests are discussed below. They are, of course, not all the possible tests, but they will give you a foundation of knowledge of the common types of X-rays that are key aspects of patient care in a medical setting.

Chest X-ray (CXR): This is a very common form of X-ray and can be used in cases of trauma, pain, or illness. A CXR can help diagnose infections such as pneumonia or an accumulation of fluid such as pleural effusion. It can be very helpful in treating various forms of trauma; for example, in Figure 12.16, the patient was stabbed with a knife. Figure 12.17 shows a patient who has an implanted defibrillator but no other anomalies.

chest x-ray

Figure 12.17

chest x-ray

Figure 12.16

Computed tomography (CT): A CT is a type of X-ray that shows images in cross-section, which provides much more detail and helps to assess a patient. Although not always used, contrast material (dye) can be injected into the bloodstream to highlight structures; for example, for a liver CT. During a CT, the patient lies on a horizontal table, and the X-ray tube, which is in a ring assembly, spins around the patient, as can be seen in Figure 12.18. Figure 12.19 shows an example of a CT scan.

Computed tomography

Figure 12.18

image of Computed tomography

Figure 12.19

Barium (Ba) tests: To better visualize internal organs, some X-rays use a contrast medium called barium that is swallowed or given to the patient in the form of an enema. When tissues are very similar in appearance to the structures around them, the barium helps differentiate them. Malignant tissues, for example, often display differently when contrast is used compared to normal tissues. Figure 12.20 is an example of an X-ray with barium contrast.

Barium (Ba) tests

Figure 12.20

Key Concept

Barium is just one type of contrast medium. There are a number of different forms of imaging contrast (gas, liquid, suspension) that can be delivered by mouth, per rectum, or via intravenous or intraarterial routes. Each delivery mode has unique uses and applications in diagnostic imaging.

Mammography: This test creates images by passing X-rays through breast tissue. Mammography is predominantly used to image female breast tissue, as can be seen in Figure 12.21, but it is also capable of imaging male breast tissue to assess a palpable nodule or mass. This test is often ordered as part of a regular health screen, as well as in cases where anomalies, such as cysts or tumours, may be present. Figure 12.21 shows the machine used to take mammograms, and Figure 12.22 is a mammogram image.

Mammography machine

Figure 12.21

Mammography image

Figure 12.22

Endoscopic retrograde cholangiopancreatography (ERCP): An ERCP is a complex procedure that combines an upper gastrointestinal endoscopy and an X-ray (NIDDK, 2016). It is used to diagnose and treat issues in the bile and pancreatic ducts. Figure 12.23 shows the procedure being performed, and Figure 12.24 is an example of how a scan would look when completed.

Endoscopic retrograde cholangiopancreatography (ERCP) being performed

Figure 12.23

what Endoscopic retrograde cholangiopancreatography (ERCP) might look like

Figure 12.24

Urography: This test is used to evaluate the kidneys, ureters, and bladder. It can be used to diagnose anomalies such as cancer and assist with assessing patients experiencing abnormal urinary symptoms such as hematuria. Urography is very similar to a **kidney, ureters, bladder (KUB) X-ray**, which also provides imagining of the organs and structures of the urinary and gastrointestinal systems. Figure 12.25 and Figure 12.26 show examples of urograms.

Urography image

Figure 12.25

Urography image

Figure 12.26

Fluoroscopy: This test uses live X-rays to visualize anatomic structures. It is best used to depict active physical movements, including intestinal peristalsis or swallowing; for example, an esophogram and upper gastrointestinal series. Fluoroscopy is shown in the video below, which shows a patient swallowing barium sulphate and gas-forming granules. The barium can be seen moving down the esophagus and digestive tract while the gas rises to the highest point of the intestinal tract based on the patient's position. The barium and gas help outline the inner lining of the esophagus and the intestines.

Video

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Video credit: *Burbridge, B. (n.d.). Fluoroscopy of the pharynx and upper esophagus [Video]. In E. Mah & B. Burbridge,* Undergraduate Diagnostic Imaging Fundamentals: Chapter 3: Fluoroscopy. *University of Saskatchewan. https://openpress.usask.ca/app/uploads/sites/34/2019/02/3.17-Fluoroscopy-cine-2.mp4, licensed under CC-BY-NC-SA 4.0*

Angiography: This test uses a fluoroscopy unit with advanced features, including software applications to assist with complex arterial and body interventional procedures beyond the capabilities of a normal fluoroscopy unit. Figure 12.27 shows an angiography machine, and Figure 12.28 provides an example of a cardiac angiogram.

angiography machine

Figure 12.27

cardiac angiogram image

Figure 12.28

Key Concept

Cardiac catheterization image

Figure 12.29

Cardiac catheterization (often called **cardiac cath** or **coronary angiogram**) involves placing a very small, flexible catheter into a blood vessel in the groin, arm, or neck (Johns Hopkins, 2022). The catheter is then passed through the blood vessel into the aorta and into the heart. Once the catheter is in position, several tests may be done, including measuring the pressure within the heart chamber, recording oxygen levels, and taking blood samples (Johns Hopkins, 2022). Contrast dye can be injected to check blood flow, while X-rays are used to assist with visualization.

Concept Check

Diagnostic Imaging: Nuclear Medicine, Ultrasound, and MRI

This section will discuss other common forms of diagnostic imaging. The physician's choice of which type of imaging will be used for a particular patient is determined by the patient's condition, history, need, and the availability of testing. For example, not all hospitals will be able to offer an MRI or nuclear medicine. Three of the more common types of imaging, other than radiology, are discussed in detail below, and examples of scans are provided.

Nuclear Medicine

nuclear medicine scanner in a hospital

Fig. 12.30

Nuclear medicine tests and procedures have one main commonality—the use of a radioactive substance to enhance the scan. The patient is injected with a radioactive pharmaceutical agent and becomes the source of the radiation required to produce the nuclear medicine images. The pharmacologic agent concentrates in different organs and tissues based on the patient's physiology and the components of the agent. Fig. 12.30 is an image of a nuclear medicine scanner in a hospital. After the patient is injected with the radioactive pharmaceutical agent, they lie on the machine's table in a supine position while the machine detects the emitted radiation.

A number of areas of the body can be assessed using radioactive substances to enhance the images; for example, a **thyroid scan**, shown in Fig. 12.31, is a common procedure. For **bone scans**, the radioactive substance technetium-99m is used because it contains diphosphonate, which interacts physiologically with living bone. As a result, when the scan is done, radioactivity is shown as arising from the patient's bones. Fig. 12.32 shows an example of a pediatric bone scan. Similarly, a **renal scan** shows the kidneys, ureters, and bladder as the pharmacologic agent is metabolized and concentrated in these tissues. **Lung scans** can be done to provid a better understand of any pathology that may be present in a patient's respiratory system.

thyroid scan

Fig. 12.31

pediatric bone scan

Fig. 12.32

A **multigated acquisition scan (MUGA)** is a diagnostic test used to evaluate the pumping action of the ventricles of the heart

(Cleveland Clinic, 2022). Similar to the tests mentioned above, a small amount of radioactive tracer is injected into a patient's vein, then a technician uses a camera to detect the radiation that is released by the tracer. This results in computer-generated, movie-like images of the beating heart. This test results in a very detailed record of the heart's pumping function (Cleveland Clinic, 2022). Fig. 12.33 is an example of a MUGA scan.

MUGA scan images

Fig. 12.33

MUGA scan machine

Fig. 12.34

A **positron emission tomography (PET)** scan is an imaging test that is used to reveal the metabolic or biochemical function of tissues and organs (Betts et al., 2013). The PET scanner (Fig. 12.34) also uses a radioactive substance to show both normal and anomalous metabolic activity. PET scans are often used to diagnose conditions such as heart disease, the spread of cancer, certain forms of infection, brain abnormalities, bone disease, and thyroid disease (Betts et al., 2013).

Positron emission tomography – Computed tomography (PET-CT) is a combination of PET and CT scans. It provides a simultaneous CT scan while the PET scan is being completed (Betts et al., 2013). The appeal of this approach is that it is possible to overlay (fuse) one image with the other to match the activity level of positron emission with the anatomy seen on the CT. Fig. 12.35 and Fig. 12.36 show different forms of PET-CTs, though both are examples of patients with multiple lymphomas.

multiple lymphomas PET-CT scan

Fig. 12.35

multiple lymphomas PET-CT scan

Fig. 12.36

Ultrasound

A majority of the general population has likely had an ultrasound or knows someone who has. Often we think of pregnancy when discussing ultrasounds; however, this type of imaging can be used for many other physiological functions as well. For diagnostic purposes, ultrasounds are used for most parts of the human body. They can assist with studying heart function, blood flow in the neck or extremities, certain conditions such as gallbladder disease, and fetal growth and development.

Ultrasounds rely on high-frequency, inaudible sound arising from a hand-held transducer, or probe, to create images. The transducer emits ultrasounds roughly 5% of the time, then listens for the returning echoes 95% of the time. An acoustic gel is used to help facilitate ultrasound transmission when it is applied to the probe and to the patient's skin to minimize the air-gap between the probe and the skin. The main disadvantages of ultrasound imaging are that the image quality is heavily operator-dependent and that ultrasounds are unable to penetrate bone and gas. Fig 12.37 shows an example of a technician preforming an ultrasound on a patient, and Fig. 12.38 is an example of a gallbladder ultrasound.

gallbladder ultrasound

Fig. 12.38

someone performing an ultrasound

Fig. 12.37

Doppler ultrasound can analyze flowing fluids, the presence of blood clots, and determine whether there is a frequency shift over the length of a structure. Colour can also be applied to the image to represent the direction of blood flow. Blood flowing toward the transducer is orange-red, and blood flowing away is blue. The varying colours in Doppler ultrasounds can be seen in Fig. 12.39 and Fig. 12.40.

Doppler ultrasound

Fig. 12.39

Doppler ultrasound

Fig. 12.40

An **echocardiogram** is a type of sonogram that may be ordered if a vascular disorder is suspected. It is a combination of an ultrasound that monitors blood flow and electrodes that monitor heart rhythm. Abnormal heart sounds can indicate a valve or septal disorder, and an echocardiogram can assist with diagnosis.

Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is a noninvasive medical imaging technique based on nuclear magnetic resonance discovered in the 1930s; matter exposed to magnetic fields and radio waves emits radio signals that can be converted to images (Betts et al., 2013). In 1970, a physician named Raymond Damadian noticed that malignant tissue gave off different signals than normal body tissue. He applied for a patent for the first MRI scanning device, which was in use clinically by the early 1980s (Betts et al., 2013). The early MRI scanners were crude and basic, but advances in digital computing and electronics led to advancements in MRIs, which resulted in them becoming the most precise technique for medical imaging, especially to discover tumours. Figure 12.41 shows an MRI machine, and Figure 12.42 is a detailed MRI scan of the lumbar spine, which demonstrates the detail available with this form of imaging. MRI also has the significant advantage of not exposing patients to radiation. The drawbacks of MRI scans include their much higher cost and patient discomfort with the procedure (Betts et al., 2013).

MRI machine

Figure 12.41

detailed MRI scan of the lumbar spine

Figure 12.42 lumbar spine

The MRI scanner subjects the patient to such powerful electromagnets that the scan room must be shielded (Betts et al., 2013). The patient must also be enclosed in a metal tube-like device for the duration of the scan, which can sometimes be as long as 90 minutes, and can be uncomfortable and impractical for very ill patients (Betts et al., 2013). The device is also very noisy so that, even with earplugs, patients can become anxious. This problem has been partially overcome with the development of “open” MRI scanning, which does not require the patient to be entirely enclosed in the metal tube. Patients with iron-containing metallic implants, such as internal sutures and prosthetics, cannot undergo MRI scanning because it can dislodge these implants (Betts et al., 2013).

Functional MRIs (fMRIs), which can detect the concentration of blood flow in certain parts of the body, are increasingly being used to study the activity in parts of the brain during various body activities. This technology helps us learn more about the locations of different brain functions and about brain abnormalities.

Concept Check

Diagnostic Imaging: Example Scans

This section will provide some extra examples of diagnostic imagining scans. They are included purely to add to your knowledge about diagnostic imagining that you have already learned about in this chapter. They are also provided for those with interest in seeing and learning more detail about diagnostic imaging scans.

chest x-ray

Figure 12.43

chest x-ray

Figure 12.44

The two images above are chest X-rays (CXR) with an outline added to emphasize the normal physiological structures.

chest x-ray

Figure 12.45

chest x-ray with enlarged heart

Figure 12.46

Figure 12.45 is a chest X-ray (CXR) of a patient with an enlarged aortic knob—the enlarged white area at the top of the chest. Figure 12.46 is a CXR of a patient with an enlarged heart.

chest x-ray one lung is fully collapsed

Figure 12.47

the lower portions of both lung are collapsed on chest x-ray

Figure 12.48

Both images above show patients with atelectasis, a fully or partially collapsed lung. In Figure 12.47, one lung is fully collapsed (the white area), and in Figure 12.48, the lower portions of both lung are collapsed.

patient has large bilateral pleural effusions on chest x-ray

Figure 12.49

In Figure 12.49, the patient has large bilateral pleural effusions, a build-up of fluid in the lungs.

The two images below show normal abdominal X-rays; Figure 12.50 also includes the four abdominal quadrants written on the X-ray. These can then be compared to Figure 12.51 and 12.52 that show abdominal X-rays of a patient with generalized bowel dilation. Figure 12.53 which also shows a normal abdominal X-ray; however, you can see the presence of artifacts—a bellybutton piercing and buttons on the patient's clothing. Finally, Figure 12.54 shows a patient with toxic megacolon.

normal abdominal X-rays

Figure 12.50

normal abdominal X-rays

Figure 12.51

shows generalized bowel dilation

Figure 12.52

shows generalized bowel dilation

Figure 12.53

normal abdominal X-ray; however, you can see the presence of artifacts—a bellybutton piercing and buttons on the patient's clothing

Figure 12.54

toxic megacolon

Figure 12.55

child has swallowed a foreign object

Figure 12.56

child has swallowed a foreign object

Figure 12.57

The two figures above (12.56 and 12.57) are of the same pediatric patient. You can see that the child has swallowed a foreign object.

MRI showing the difference between healthy lungs, COPD lungs, and lungs affected by asthma.

Figure 12.58

Figure 12.58 is an MRI showing the difference between healthy lungs, COPD lungs, and lungs affected by asthma.

Figure 12.59

Figure 12.60

Both images above are of the same patient. Figure 12.59 is of the patient's left shoulder pre-operatively with a clavicle fracture; the second image 12.60 shows the patient post-op with the fracture repaired.

post-op x-ray of pelvis

Figure 12.61

pre-op x-ray of pelvis

Figure 12.62

The two figures above are also of the same patient. Figure 12.62 is an X-ray of the pelvis pre-operatively for a fixation of a pelvic fracture; Figure 12.61 shows the patient post-op with the fracture repaired.

pediatric patient with a bullet in their arm

Figure 12.63

X-ray of a patient with facial trauma

Figure 12.64

Figure 12.63 shows a pediatric patient with a bullet in their arm, and Figure 12.64 is an X-ray of a patient with facial trauma. The final image below 12.65 is a full-body X-ray of a patient with bilateral femur fractures.

full-body X-ray of a patient with bilateral femur fractures

Figure 12.65

Diagnostic Tests

A vast number of clinical tests and procedures are carried out in medical settings every day. This section will focus on the most common ones done in a hospital on a day-to-day basis and are used, in some way, for diagnostic purposes. Although a number of other clinical procedures can be performed, especially on more specialized units in a hospital, those discussed below are a good representation of the clinical tests and procedures you will likely see in your future medical career. Figure 12.66 and Figure 12.67 show doctors performing physical examinations on patients.

doctors performing physical examinations on patients, auscultating

Figure 12.66

doctors performing physical examinations on patients, looking into ear with otoscope

Figure 12.67

Amniocentesis: In this procedure, a physician takes a sample of amniotic fluid from a pregnant woman. Not all pregnancies require this test; it is performed to determine whether the fetus has any chromosomal disorders. Amniocentesis may be suggested as an option for a patient if such disorders are suspected or if the patient is over a certain age because that can increase the risk that the fetus may present with a chromosomal disorder. The physician uses a syringe guided by an ultrasound, as shown in Figure 12.68, to take a sample of amniotic fluid, which is then sent to the lab for analysis.

taking a sample of amniotic fluid

Figure 12.68 Amniocentesis

Arthrocentesis: In this test, a syringe is used to remove fluid from a joint. Possible reasons for this procedure would be to test the fluid or to remove fluid that may be causing the patient discomfort (Carter & Rutherford, 2020).

Aspiration: This medical procedure involves the removal of something from the body (NLM, 2022). The substance may vary; however, it could potentially be body fluids, part of a bone, or air. Aspiration is used when a physician performs a biopsy and is the act of using a needle to withdraw a sample to be sent to the lab.

Auscultation: This test involves placing a stethoscope over a part of the body, most often the lungs, heart, or abdomen, and listening for either the lack of sounds or appropriate sounds for that area. Heart sounds can be heard with a classic stethoscope, but with a cardiac stethoscope, as shown in Figure 12.69, it is also possible to hear the opening and closing of valves within the heart. Listening to lung sounds can determine whether there is equal air entry to both lungs and whether or not fluid if present. Finally, the abdomen can be assessed to determine whether there are bowel sounds, or a lack thereof, which could indicate the absence of movement through the gastrointestinal tract.

listening to heart sounds with a classic stethoscope

Figure 12.69

Biopsy (Bx): This procedure involves taking a sample of material from the body and sending it to the lab for analysis. Biopsies are often completed to determine whether a growth is cancerous or benign. Figure 12.70 explains how a liver biopsy is performed, and Figure 12.71 shows a sample obtained from a biopsy.

shows how a liver biopsy is performed

Figure 12.70

shows sample biopsy

Figure 12.71

Key Concept

A **bone marrow biopsy** is a specific type of biopsy that involves taking a sample of bone marrow (Carter & Rutherford, 2020). Often, this is used in the diagnosis and treatment of various severe forms of anemia, such as **thalassemia major** and **sickle cell anemia**, as well as some types of cancer, specifically **leukemia**. The instruments used to obtain a bone marrow sample are shown in Figure 12.72, and Figure 12.73 shows the procedure and the area of the body that the sample is typically taken from.

instruments used to obtain a bone marrow sample are shown

Figure 12.72

shows where a bone marrow sample is taken

Figure 12.73

Bronchoscopy: This procedure involves visualization of trachea and bronchi with a bronchoscope. Some common reasons for a bronchoscopy include chronic cough, infection, or an anomaly on a chest X-ray or other scan (Johns Hopkins, 2022). Bronchoscopies can also be used to take samples or remove foreign objects from the airway (Carter & Rutherford, 2020).

Colonoscopy: In this procedure, a colonoscope is used to visualize the large intestine and rectum. A colonoscopy may be recommended for patients who have unexplained weight loss, abdominal pain, changes to bowel movements, or bleeding from the anus (NIDDK, 2017). This procedure can also be beneficial for cancer and polyp screening.

Cystoscopy: This procedure is completed with a cystoscope and, as shown in Figure 12.74, involves visualizing the bladder. The cystoscope is inserted via the urethra and passed into the bladder (NHS, 2022). This test is used to check for bladder and urethral issues. The images appear similar to what is seen in Figure 12.75. Patients may have this procedure if they experience hematuria, recurrent urinary tract infections, pelvic pain, or difficulty urinating. Biopsy samples can also be taken during the cystoscopy, and bladder stones may also be removed (Carter & Rutherford, 2020).

Cystoscopy

Figure 12.74

images of cystoscopy

Figure 12.75

Digital rectal exam (DRE): In this procedure, a physician palpates the prostate to check for masses or anomalies. This is often done in conjunction with a **prostate-specific antigen (PSA) test** to assess for prostate cancer (Carter & Rutherford, 2020).

Electrocardiogram (ECG): This procedure can be performed by various medical professionals, including technicians, nurses, or physicians. An ECG is a recording of the electrical activity of the heart. Electrodes are placed on the patient's chest, arms, and legs to create the electrical reading. It only takes a few minutes for the electrocardiograph to produce the electrical record. This test is done to assess for myocardial infarctions, arrhythmias, and other heart issues.

Electroencephalogram (EEG): In an EEG, electrodes are applied to a patient's scalp to measure electrical activity in the brain. This test is used to help diagnose seizures, psychiatric conditions, tumours, and other brain disorders such as inflammation and injuries (Carter & Rutherford, 2020).

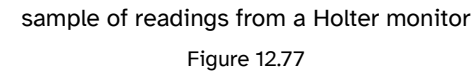
Electromyography (EMG): This procedure assesses the function of nerve cells that control muscles. Electrodes can either be attached to the skin or inserted into muscles to record electrical impulses. An EMG can assist with the diagnosis of nerve issues in different muscles and peripheral nerves (Carter & Rutherford, 2020).

Gastroscopy: For this test, a physician places a flexible gastroscope through the patient's mouth and passes it down their throat to the stomach (Cancer Research UK, 2022). This allows the physician to view the entire upper digestive tract and take biopsy samples, which can help in the treatment of conditions such as stomach ulcers (Carter & Rutherford, 2020).

Holter monitor: This test is similar to an ECG, but the main difference is that the patient wears the Holter monitor for a 24-hour period (sometimes longer), and electrical readings are taken for the whole duration. This gives the physician a better idea of the patient's cardiac electrical activity throughout their day, versus an ECG, which only takes readings for a short time. Figure 12.76 shows a patient wearing a Holter monitor, and Figure 12.77 is a sample of readings from a Holter monitor.

Holter monitor

Figure 12.76



sample of readings from a Holter monitor

Figure 12.77

Lumbar puncture (LP): Also known as a **spinal tap**, this procedure involves withdrawing a sample of cerebrospinal fluid from the lower lumbar region, as shown in Figure 12.78. The sample is taken from that location in the spine because the spinal cord ends in the upper lumbar region. Samples of cerebrospinal fluid are analyzed in the lab to diagnose, or rule out, diseases that affect the nervous system.

Lumbar puncture (LP)

Figure 12.78

Ophthalmoscopy: This procedure can be completed by a physician or a specialist of the eye and involves visualization of the exterior and interior of a patient's eye. It can assist with the diagnosis of eye injures and pathologies such as glaucoma and cataracts (Carter & Rutherford, 2020).

Otoscopy: Using an otoscope, a physician will visualize the inner ear, tympanic membrane, and ear canal during this assessment. Otoscopy may be done for various reasons, including pain or foreign objects in the ear, or pathologies such as infections that affect the ear (Carter & Rutherford, 2020). The procedure is shown in Figure 12.79, and Figure 12.80 is an example of what a physician may see when performing the procedure.

Otoscopy

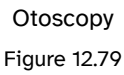


Figure 12.79

What you see during Otoscopy

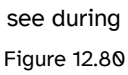


Figure 12.80

Palpation: Physicians, nurses, and other healthcare professionals use palpation in their assessment of patients. To perform the procedure, the healthcare professional uses their hands to assess for pain, tenderness, and distention. An abdominal assessment, for example, often involves palpating the four abdominal quadrants for bladder or bowel distention. Pain or tenderness could possibly indicate an inflammatory condition or bowel obstruction (Doyle & McCutcheon, 2020).

Pap smear: Also referred to as a **pap test**, this procedure involves collecting cells from the cervix. This is done to test for changes in the cells that may indicate cancer or to assess whether cancer may develop in the future (Mayo Clinic, 2022a). A pap smear should be part of regular health screening for women, and the interval between tests varies depending on age and prior medical history.

Percussion: This is similar to palpation in that it involves a physical assessment of the patient using the hands. In this case, however, it involves tapping, which produces different sounds and this helps determine if the underlying tissues are filled with air, fluid or a solid tissue. For example, over the abdomen, to assess for rigidity and pain (Doyle & McCutcheon, 2020).

Paracentesis: This procedure uses a hollow needle to remove fluid from the abdominal cavity (Figure 12.81). Paracentesis is performed when a person has a swollen, painful abdomen and problems breathing because there is too much fluid in the abdomen (Canadian Cancer Society, 2022a). Removing the fluid helps relieve these symptoms, and often the fluid, shown in Figure 12.82, is sent to the lab for analysis.

Paracentesis

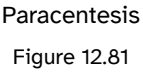


Figure 12.81

drainage from a Paracentesis

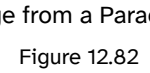


Figure 12.82

Phlebotomy: A very common procedure, phlebotomy involves taking blood from a vein, often in the arm, and then sending the blood to the lab for analysis (WebMD, 2022). This procedure can assist with the diagnosis of many different pathologies and illnesses.

Spirometry: This test assesses how well the lungs are working by measuring air volume. Measurements are taken for respiratory volume, tidal volume, expiratory reserve volume, residual volume, and respiratory capacity. All of these factors play a role in the amount of air we breathe in, keep in our lungs after expiration, and breathe out (Carter & Rutherford, 2020). Figure 12.83 demonstrates how the procedure is completed as the patient breathes into the machine.

Spirometry

Figure 12.83

Stress test: Also known as an **exercise stress test**, this procedure shows how well a patient's heart works during physical activity (Mayo Clinic, 2022b). It usually involves having the patient walk on a treadmill, as seen in Figure 12.84, or ride a stationary bike. While the patient is moving, heart rhythm, blood pressure, and breathing are monitored. This test is typically ordered when a patient has a history of cardiac illness or concerns.

person having a exercise stress test

Figure 12.84

Thoracentesis: This procedure drains fluid from the space between the lungs and the wall of the chest (the pleural space), as shown in Figure 12.85. A hollow needle or plastic tube is inserted through the chest wall to remove fluid (Canadian Cancer Society, 2022b). This alleviates breathing difficulty and can help diagnose lung issues because a fluid sample is usually sent to the lab for analysis (Carter & Rutherford, 2020). Figure 12.86 shows a chest X-ray of a patient who requires a thoracentesis for pleural effusion, a condition in which there is fluid build-up in the pleural space, as shown by the white area where the lung should be.

Thoracentesis

Figure 12.85

chest X-ray of a patient who requires a thoracentesis for pleural effusion

Figure 12.86

Concept Check

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13: Digestive System

Learning Objectives

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

Digestive System Word Parts

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

Query 13.1

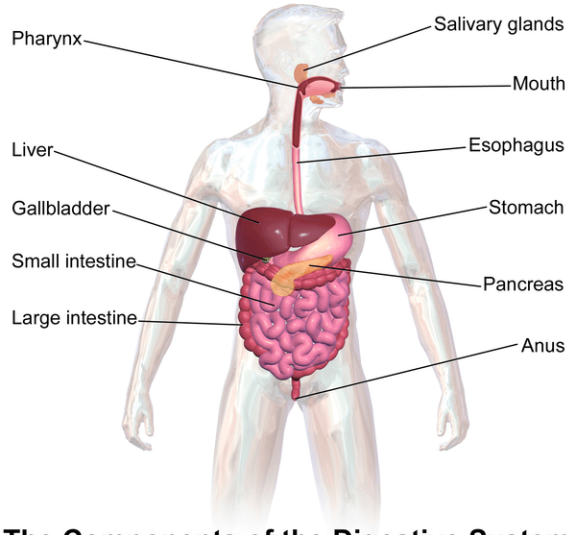
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Introduction to the Digestive System

The digestive system is continually at work, yet people seldom appreciate the complex tasks it performs in a choreographed biologic symphony. Consider what happens when you eat an apple. Of course, you enjoy the apple's taste as you chew it, but in the hours that follow, unless something goes amiss and you get a stomachache, you don't notice that your digestive system is working. You may be taking a walk or studying or sleeping, having forgotten all about the apple, but your stomach and intestines are busy digesting it and absorbing its vitamins and other nutrients. By the time any waste material is excreted, the body has appropriated all it can use from the apple. In short, whether you pay attention or not, the organs of the digestive system perform their specific functions, allowing you to use the food you eat to keep you going.

This chapter examines the structure and functions of these organs, and explores the mechanics and chemistry of the digestive processes. The function of the digestive system is to break down the foods you eat, release their nutrients, and absorb those nutrients into the body. Although the small intestine is the workhorse of the system, where the majority of digestion occurs, and where most of the released nutrients are absorbed into the blood or lymph, each of the digestive system organs makes a vital contribution to this process (see Figure 13.1).



The Components of the Digestive System

Figure 13.1 Components of the Digestive System. All digestive organs play integral roles in the life-sustaining process of digestion. Medical gallery of Blausen Medical 2014. ISSN 2002-4436., CC BY 3.0, via Wikimedia Commons.

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Digestive System Medical Terms

Now that you have memorized the word parts see if you can break down the following Digestive terms and define them.

Query 13.2

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Practice with this activity:

Query 13.3

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Anatomy (Structures) of the Digestive System

The Mouth

The cheeks, tongue, and palate frame the mouth, which is

Did You Know?

You can eat upside down. Food doesn't need gravity to reach your stomach. Peristalsis, a wave-like muscle movement, pushes food along.

also called the **oral cavity** (or buccal cavity). The structures of the mouth are illustrated in Figure 13.2.

The pocket-like part of the mouth that is framed on the inside by the gums and teeth, and on the outside by the cheeks and lips is called the **oral vestibule**. The main open area of the mouth, or oral cavity proper, runs from the gums and teeth to the fauces.

When you are chewing, you do not find it difficult to breathe simultaneously. The next time you have food in your mouth, notice how the arched shape of the roof of your mouth allows you to handle both digestion and respiration at the same time. This arch is called the palate. The anterior region of the palate serves as a wall (or septum) between the oral and nasal cavities as well as a rigid shelf against which the tongue can push food. It is created by the maxillary and palatine bones of the skull and, given its bony structure, is known as the hard palate. If you run your tongue along the roof of your mouth, you'll notice that the hard palate ends in the posterior oral cavity, and the tissue becomes fleshier. This part of the palate, known as the **soft palate**, is composed mainly of skeletal muscle. You can therefore manipulate, subconsciously, the soft palate—for instance, to yawn, swallow, or sing (see Figure 13.2).

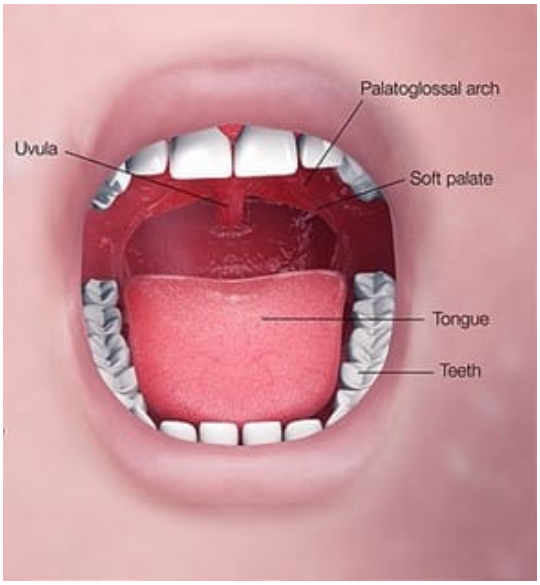


Figure 13.2 3D Medical Animation Mouth. Including uvula, teeth, tongue, soft palate, and palatoglossal arch. https://www.scientificanimations.com, CC BY 4.0, via Wikimedia Commons

A fleshy bead of tissue called the **uvula** drops down from the center of the posterior edge of the soft palate. Although some have suggested that the uvula is a vestigial organ, it serves an important purpose. When you swallow, the soft palate and uvula move upward, helping to keep foods and liquid from entering the nasal cavity. Unfortunately, it can also contribute to the sound produced by snoring. Two muscular folds extend downward from the soft palate, on either side of the uvula. Between these two folds are the palatine tonsils, clusters of lymphoid tissue that protect the pharynx. The lingual tonsils are located at the base of the tongue.

Tongue

Perhaps you have heard it said that the **tongue** is the strongest muscle in the body. Those who stake this claim cite its strength proportionate to its size. Although it is difficult to quantify the relative strength of different muscles, it remains indisputable that the tongue is a workhorse, facilitating **ingestion**, **mechanical digestion**, **chemical digestion** (lingual lipase), sensation (of taste, texture, and temperature of food), swallowing, and vocalization.

The top and sides of the tongue are studded with papillae (see Figure 13.3).

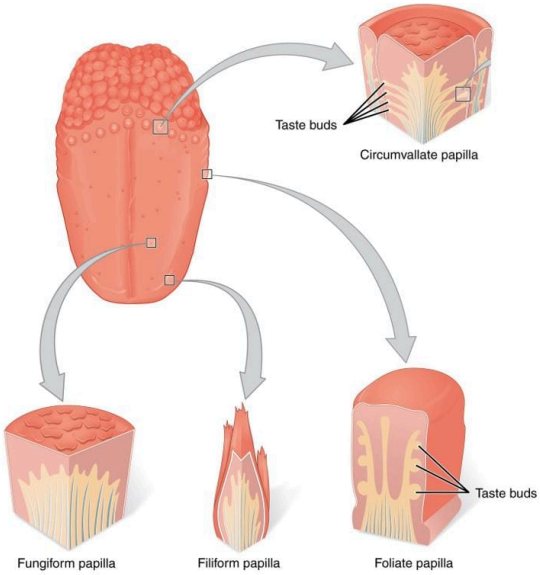


Figure 12.3 The Tongue. This view of the tongue shows the locations and types of papillae. OpenStax, CC BY 4.0, via Wikimedia Commons.

Salivary Glands

Many small **salivary glands** are housed within the mucous membranes of the mouth and tongue. These minor exocrine glands are constantly secreting **saliva**, either directly into the oral cavity or indirectly through ducts, even while you sleep. In fact, an average of 1 to 1.5 liters of saliva is secreted each day. Usually just enough saliva is present to moisten the mouth and teeth. Secretion increases when you eat, because saliva is essential to moisten food and initiate the chemical breakdown of carbohydrates. Small amounts of saliva are also secreted by the **labial glands** in the lips. In addition, the **buccal glands** in the cheeks, palatal glands in the palate, and lingual glands in the tongue help ensure that all areas of the mouth are supplied with adequate saliva.

Concept Check

- Describe how the **anatomy** of the **mouth** permits breathing and chewing at the same time
- Explain the role **saliva** performs in the digestive system

Pharynx

The pharynx (throat) is involved in both digestion and respiration. It receives food and air from the mouth, and air from the

nasal cavities. When food enters the pharynx, involuntary muscle contractions close off the air passageways. A short tube of skeletal muscle lined with a **mucous membrane**, the pharynx runs from the posterior oral and nasal cavities to the opening of the esophagus and larynx. It has three subdivisions. The most superior, the nasopharynx, is involved only in breathing and speech. The other two subdivisions, the **oropharynx** and the **laryngopharynx**, are used for both breathing and digestion. The oropharynx begins inferior to the nasopharynx and is continuous below with the laryngopharynx. The inferior border of the laryngopharynx connects to the esophagus, whereas the anterior portion connects to the larynx, allowing air to flow into the bronchial tree.

Esophagus

The esophagus is a muscular tube that connects the pharynx to the stomach. It is approximately 25.4 cm (10 in) in length, located posterior to the trachea, and remains in a collapsed form when not engaged in swallowing. As you can see in Figure 13.4, the esophagus runs a mainly straight route through the mediastinum of the thorax. To enter the abdomen, the esophagus penetrates the diaphragm through an opening called the esophageal hiatus.

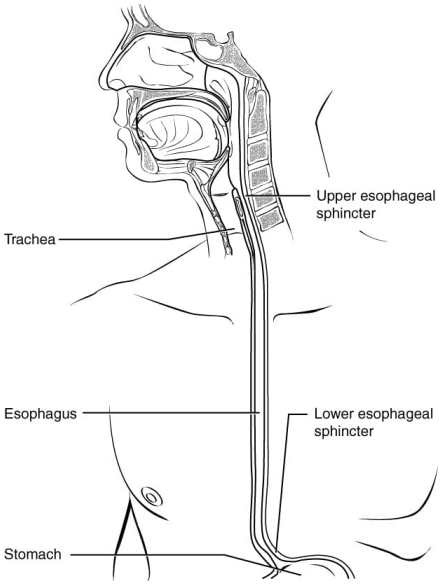


Figure 13.4 Esophagus. The upper esophageal sphincter controls the movement of food from the pharynx to the esophagus. The lower esophageal sphincter (LES) controls the movement of food from the esophagus to the stomach. From Betts, et al., 2021. Licensed under CC BY 4.0.

Passage of Food Through the Esophagus

The upper **esophageal sphincter**, controls the movement of food from the pharynx into the esophagus. The upper two-thirds of the esophagus consists of both smooth and skeletal muscle fibers. A series of contractions called **peristalsis** push food through the esophagus and into the stomach. Just before the opening to the stomach is an important ring-shaped muscle called the lower esophageal sphincter (LES). Recall that sphincters are muscles that surround tubes and serve as valves, closing the tube when the sphincters contract and opening it when they relax. This sphincter opens to let food pass into the stomach and closes to keep it there.

Stomach

There are four main regions in the **stomach**: the cardia, fundus, body, and pylorus (see Figure 13.5). The **cardia** (or cardiac region) is the point where the esophagus connects to the stomach and through which food passes into the stomach. Located inferior to the diaphragm, above and to the left of the cardia, is the dome-shaped **fundus**. Below the fundus is the **body**, the main part of the stomach. The funnel-shaped **pylorus** connects the stomach to the duodenum.

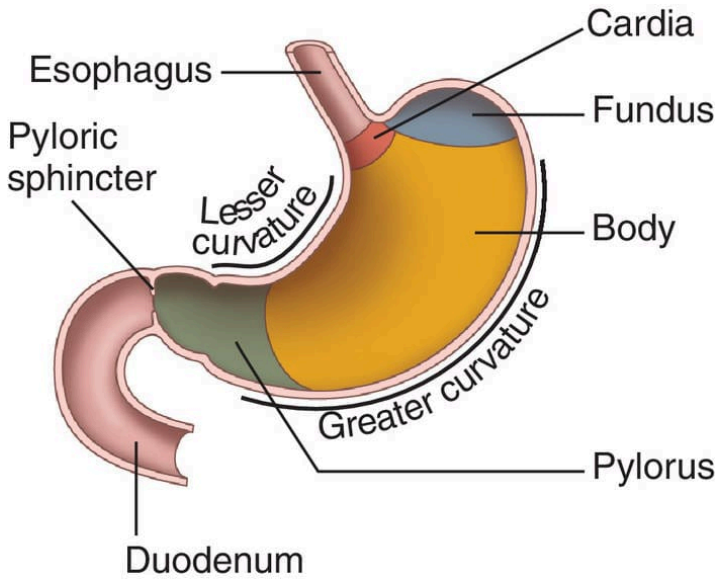


Figure 12.5 Regions of the Stomach. The stomach has four major regions: the cardia, fundus, body, and pylorus. From Farlex, 2021.

Small Intestines

Did You Know?

Your body absorbs 90 per cent of our nutrients through the **small intestine**, into your blood.

Chyme released from the stomach enters the **small intestine**, which is the primary digestive organ in the body. Not only is this where most digestion occurs, it is also where practically all absorption occurs. The longest part of the **alimentary canal**, the small intestine is about 3.05 meters (10 feet) long in a living person (but about twice as long in a cadaver due to the loss of muscle tone). Since this makes it about five times longer than the large intestine, you might wonder why it is called “small.” In fact, its name derives from its relatively smaller diameter of only about 2.54 cm (1 in), compared with 7.62 cm (3 in) for the large intestine. As we’ll see shortly, in addition to its length, the folds and projections of the lining of the small intestine work to give it an enormous surface area, more than 100 times the surface area of your skin. This large surface area is necessary for complex processes of digestion and absorption that occur within it.

The coiled tube of the small intestine is subdivided into three regions. From proximal (at the stomach) to distal, these are the duodenum, jejunum, and ileum (see Figure 13.6).

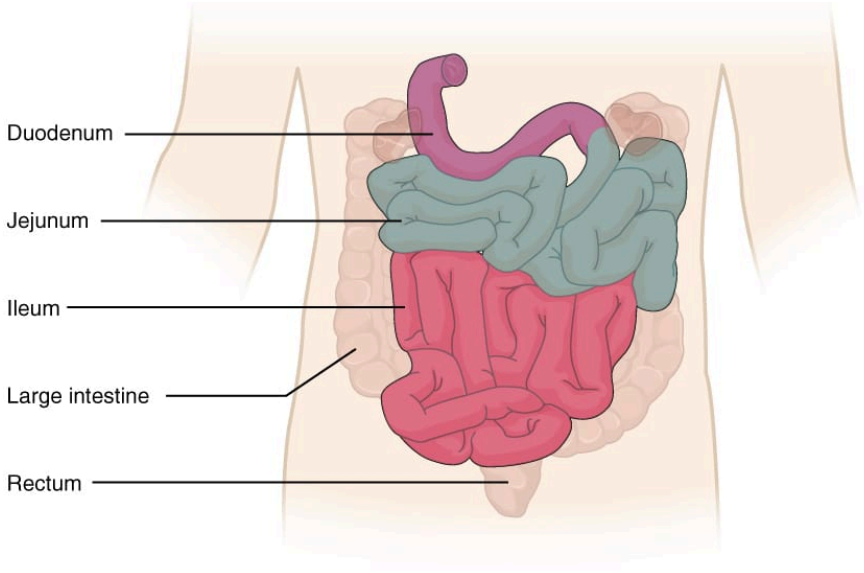


Figure 13.6 Small Intestine. The three regions of the small intestine are the duodenum, jejunum, and ileum. From Betts, et al., 2021. Licensed under CC BY 4.0.

Large Intestines

The **large intestine** is the terminal part of the alimentary canal. The primary function of this organ is to finish absorption of nutrients and water, synthesize certain vitamins, form feces, and eliminate feces from the body.

The large intestine runs from the appendix to the anus. It frames the small intestine on three sides. Despite its being about one-half as long as the small intestine, it is called large because it is more than twice the diameter of the small intestine, about 3 inches.

The large intestine is subdivided into four main regions: the cecum, the colon, the rectum, and the anus. The ileocecal valve, located at the opening between the ileum and the large intestine, controls the flow of **chyme** from the small intestine to the large intestine.

Cecum

The first part of the large intestine is the **cecum**, a sac-like structure that is suspended inferior to the ileocecal valve. It is about 6 cm (2.4 in) long, receives the contents of the ileum, and continues the absorption of water and salts. The **appendix** (or vermiform appendix) is a winding tube that attaches to the cecum. Although the 7.6-cm (3-in) long appendix contains lymphoid tissue, suggesting an immunologic function, this organ is generally considered vestigial. However, at least one recent report assumes a survival advantage conferred by the appendix: In diarrheal illness, the appendix may serve as a bacterial reservoir to repopulate the enteric bacteria for those surviving the initial phases of the illness. Moreover, its twisted anatomy provides a haven for the accumulation and multiplication of enteric bacteria.

Colon

The cecum blends seamlessly with the **colon**. Upon entering the colon, the food residue first travels up the **ascending colon** on the right side of the abdomen. At the inferior surface of the liver, the colon bends to become the **transverse colon**. The region defined as hindgut begins with the last third of the transverse colon and continues on. Food residue passing through the transverse colon travels across to the left side of the abdomen. From there, food residue passes through the **descending colon**, which runs down the left side of the posterior abdominal wall. After entering the pelvis inferiorly, it becomes the s-shaped **sigmoid colon**, which extends medially to the midline (see Figure 13.7). The ascending and descending colon, and the rectum (discussed next) are located in the retroperitoneum.

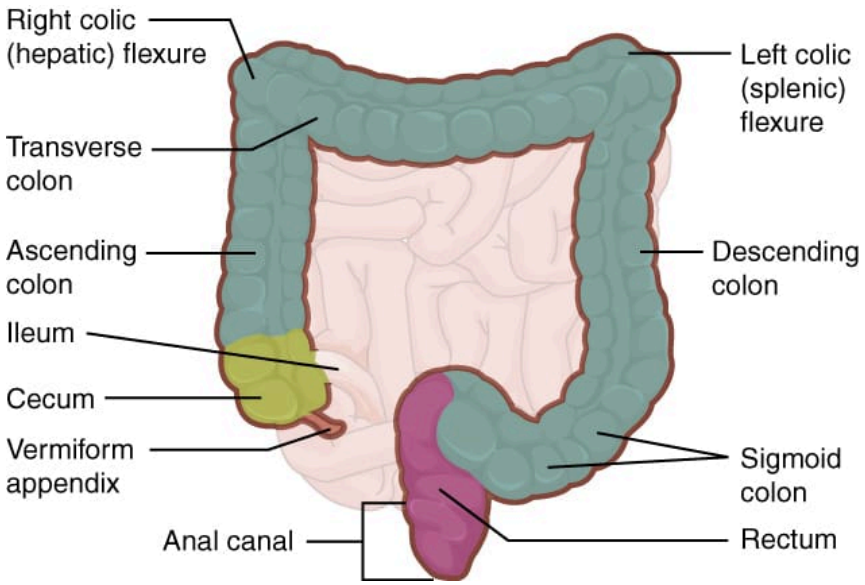


Figure 13.7 Large Intestine. The large intestine includes the cecum, colon, and rectum. From Betts, et al., 2021. Licensed under CC BY 4.0.

Accessory Organs of Digestion

Chemical digestion in the small intestine relies on the activities of three accessory digestive organs: the liver, pancreas, and gallbladder (see Figure 12.8). The digestive role of the liver is to produce bile and export it to the duodenum. The gallbladder primarily stores, concentrates, and releases bile. The pancreas produces pancreatic juice, which contains digestive enzymes and bicarbonate ions, and delivers it to the duodenum.

Concept Check

On the Figure 13.8 diagram locate the following **anatomical organs** and consider how these organs **support** the digestive process

- Liver
- Pancreas
- Gallbladder

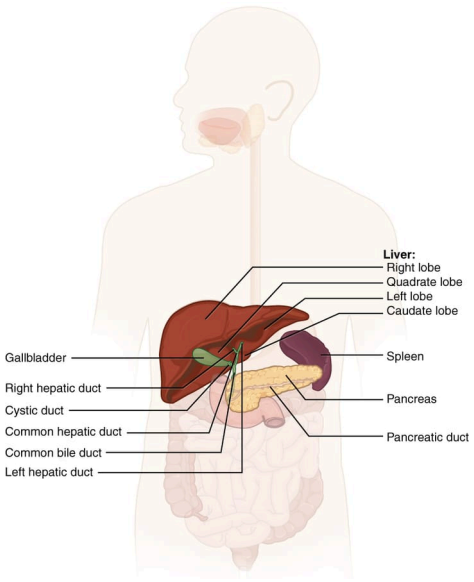


Figure 13.8 Accessory Organs. The liver, pancreas, and gallbladder are considered accessory digestive organs, but their roles in the digestive system are vital. From Betts, et al., 2021. Licensed under CC BY 4.0.

Liver

The **liver** is the largest gland in the body, weighing about three pounds in an adult. It is also one of the most important organs. In addition to being an accessory digestive organ, it plays a number of roles in metabolism and regulation. The liver lies inferior to the diaphragm in the right upper quadrant of the abdominal cavity and receives protection from the surrounding ribs. The liver is divided into two primary lobes: a large right lobe and a much smaller left lobe.

The hepatic portal vein delivers partially deoxygenated blood containing nutrients absorbed from the small intestine and actually supplies more oxygen to the liver than do the much smaller hepatic arteries. In addition to nutrients, drugs and toxins are also absorbed. After processing the bloodborne nutrients and toxins, the liver releases nutrients needed by other cells back into the blood, which drains into the central vein and then through the hepatic vein to the inferior vena cava. With this **hepatic** portal circulation, all blood from the alimentary canal passes through the liver. This largely explains why the liver is the most common site for the metastasis of cancers that originate in the alimentary canal.

Bileproduced by the liver is a mixture secreted by the liver to accomplish the emulsification of lipids in the small intestine.

Bilirubin, the main bile pigment, is a waste product produced when the spleen removes old or damaged red blood cells from the circulation. These breakdown products, including proteins, iron, and toxic bilirubin, are transported to the liver via the splenic vein of the hepatic portal system. In the liver, proteins and iron are recycled, whereas bilirubin is excreted in the bile. It accounts for the green color of bile. Bilirubin is eventually transformed by intestinal bacteria into stercobilin, a brown pigment that gives your stool its characteristic color! In some disease states, bile does not enter the intestine, resulting in white ('acholic') stool with a high fat content, since virtually no fats are broken down or absorbed.

Between meals, bile is produced but conserved. The valve-like hepatopancreatic ampulla closes, allowing **bile** to divert to the gallbladder, where it is concentrated and stored until the next meal.

Pancreas

The soft, oblong, glandular **pancreas** lies transversely in the retroperitoneum behind the stomach. Its head is nestled into the "c-shaped" curvature of the duodenum with the body extending to the left about 15.2 cm (6 in) and ending as a tapering tail in the hilum of the spleen. It is a curious mix of exocrine (secreting digestive enzymes) and endocrine (releasing hormones into the blood) functions (Figure 13.9).

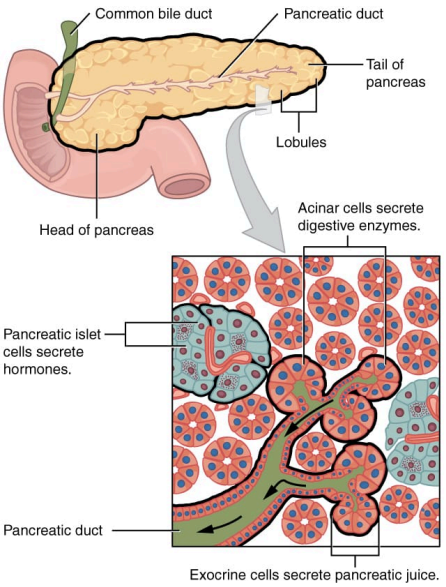


Figure 13.9 Exocrine and Endocrine Pancreas. The pancreas has a head, a body, and a tail. It delivers pancreatic juice to the duodenum through the pancreatic duct. From Betts, et al., 2021. Licensed under CC BY 4.0.

Gallbladder

The **gallbladder** is 8–10 cm (~3–4 in) long and is nested in a shallow area on the posterior aspect of the right lobe of the liver. This muscular sac stores, concentrates, and, when stimulated, propels the bile into the duodenum via the common bile duct. It is divided into three regions. The fundus is the widest portion and tapers medially into the **body**, which in turn narrows to become the **neck**.

Anatomy Labeling Activity

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Physiology (Function) of the Digestive System

The main functions of the digestive system are:

- Ingesting food
- Digesting food
- Absorbing nutrients
- Elimination of waste products

Digestive Processes

The processes of digestion include six activities: ingestion, **propulsion**, mechanical or physical digestion, chemical digestion, absorption, and **defecation**.

The first of these processes, **ingestion**, refers to the entry of food into the alimentary canal through the mouth. There, the food

is chewed and mixed with saliva, which contains enzymes that begin breaking down the carbohydrates in the food plus some lipid digestion via lingual lipase. Chewing increases the surface area of the food and allows an appropriately sized bolus to be produced.

Food leaves the mouth when the tongue and pharyngeal muscles propel it into the esophagus. This act of swallowing, the last voluntary act until defecation, is an example of **propulsion**, which refers to the movement of food through the digestive tract. It includes both the voluntary process of swallowing and the involuntary process of peristalsis. **Peristalsis** consists of sequential, alternating waves of contraction and relaxation of alimentary wall smooth muscles, which act to propel food along (see Figure 13.10). These waves also play a role in mixing food with digestive juices. Peristalsis is so powerful that foods and liquids you swallow enter your stomach even if you are standing on your head.

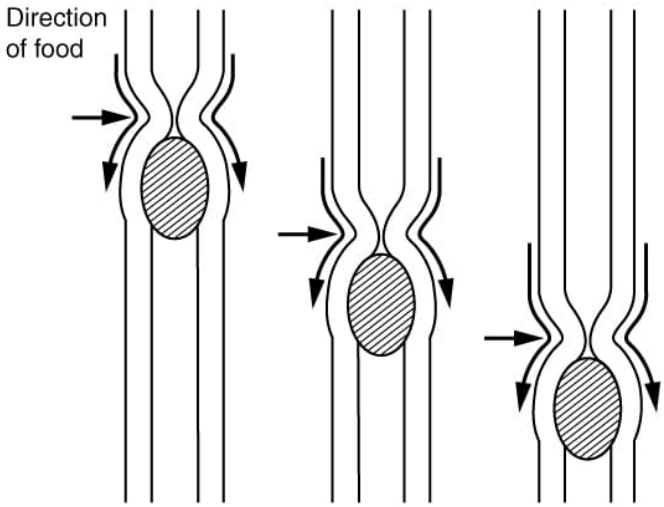


Figure 13.10. Peristalsis. Peristalsis moves food through the digestive tract with alternating waves of muscle contraction and relaxation. From Betts, et al., 2021. Licensed under CC BY 4.0.

Digestion includes both mechanical and chemical processes. **Mechanical digestion** is a purely physical process that does not change the chemical nature of the food. Instead, it makes the food smaller to increase both surface area and mobility. It includes **mastication**, or chewing, as well as tongue movements that help break food into smaller bits and mix food with saliva. Although there may be a tendency to think that mechanical digestion is limited to the first steps of the digestive process, it occurs after the food leaves the mouth, as well. The mechanical churning of food in the stomach serves to further break it apart and expose more of its surface area to digestive juices, creating an acidic “soup” called **chyme**.

In **chemical digestion**, starting in the mouth, digestive secretions break down complex food molecules into their chemical building blocks (for example, proteins into separate amino acids). These secretions vary in composition, but typically contain water, various enzymes, acids, and salts. The process is completed in the small intestine.

Food that has been broken down is of no value to the body unless it enters the bloodstream and its nutrients are put to work. This occurs through the process of **absorption**, which takes place primarily within the small intestine.

In **defecation**, the final step in digestion, undigested materials are removed from the body as feces.

Digestive System: From Appetite Suppression to Constipation

Age-related changes in the digestive system begin in the mouth and can affect virtually every aspect of the digestive system. Taste buds become less sensitive, so food isn’t as appetizing as it once was. A slice of pizza is a challenge, not a treat, when you have lost teeth, your gums are diseased, and your salivary glands aren’t producing enough saliva. Swallowing can be difficult, and ingested food moves slowly through the alimentary canal because of reduced strength and tone of muscular tissue.

Pathologies that affect the digestive organs—such as hiatal hernia, **gastritis**, and **peptic ulcer** disease—can occur at greater frequencies as you age. Problems in the small intestine may include duodenal ulcers, maldigestion, and malabsorption. Problems in the large intestine include hemorrhoids, diverticular disease, and constipation. Conditions that affect the function of accessory organs—and their abilities to deliver pancreatic enzymes and bile to the small intestine—include jaundice, acute pancreatitis,

cirrhosis, and gallstones.

In some cases, a single organ is in charge of a digestive process. For example, ingestion occurs only in the mouth and defecation only in the anus. However, most digestive processes involve the interaction of several organs and occur gradually as food moves through the alimentary canal (see Figure 13.11).

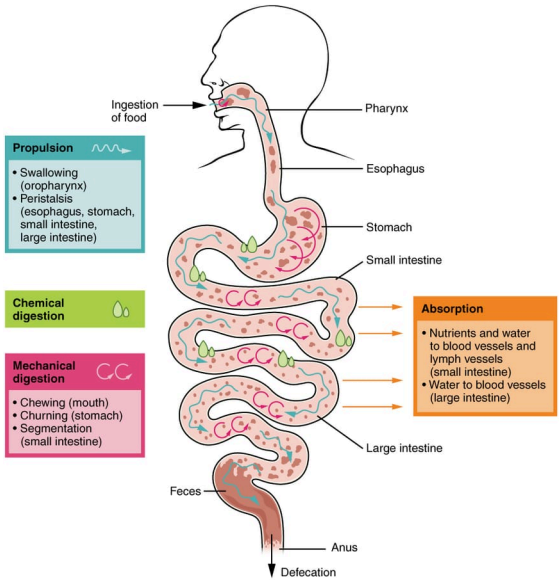


Figure 13.11. Digestive Processes. The digestive processes are ingestion, propulsion, mechanical digestion, chemical digestion, absorption, and defecation. From Betts, et al., 2021. Licensed under CC BY 4.0.

Some chemical digestion occurs in the mouth. Some absorption can occur in the mouth and stomach, for example, alcohol and aspirin.

Medical Terms not Easily Broken into Word Parts

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Common Digestive Abbreviations

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Diseases and Disorders of the Digestive System

Gastroesophageal Reflux Disease

This condition is largely caused by gastric acid flowing upwards from the stomach into the esophagus. Those suffering from the condition will often feel a burning sensation radiating near the top of the stomach. (Mayo Clinic Staff, 2020). To learn more about GERD visit the Mayo Clinic's Gastroesophageal Reflux Disease (GERD) page.

Cholecystitis

This condition is known as inflammation of the gall bladder. Gall stone development can block the gall bladder's release of bile leading to an inflammatory response. Surgical removal (cholecystectomy) or laser stone crushing known as lithotripsy are often the treatment options ("Cholecystitis", 2019). To learn more about cholecystitis visit the Radiology Info's cholecystitis web page.

Cirrhosis

Cirrhosis is condition whereby the liver scars. Advanced cirrhosis is life threatening. It generally can not be reversed. It is caused by different forms of liver disease and chronic alcoholism. (Mayo Clinic Staff, 2018).

Cirrhosis often has no signs or symptoms until liver damage is extensive and may include:

- Fatigue
- Easily bleeding or bruising
- Loss of appetite
- Nausea
- Edema
- Weight loss
- Itchy skin
- Jaundice
- Ascitis (Mayo Clinic Staff, 2018)

To learn more about Cirrhosis visit the Mayo Clinic's Cirrohsis web page .

Esophageal Cancer

This is cancer of the esophagus. The cancer can occur anywhere along the esophageal tube, and can be caused by factors including tobacco use, alcohol, and chronic acid reflux (American Cancer Society medical and editorial team, 2020a). To learn more about esophageal cancer, visit the American Cancer Society's Esophageal Cancer web page.

Hepatitis A, B and C

Inflammation of the liver is referred to as hepatitis. This condition can by caused by several factors such as viruses, alcohol consumption, toxins, and drug interactions. In some cases it can also be caused by an autoimmune response in the body. There are five types of viral hepatitis, A, B, C, D, and E (Booth, 2018). To learn more, visit Healthline's article on Hepatitis.

Celiac Sprue (Celiac Disease)

Individuals who posses celiac disease have an immune sensitivity reaction occurring in the small intestines when they consume gluten. Typically people with this condition are genetically pre-disposed to the condition. Damage to the small intestine will occur if continued consumption of gluten occurs. Individuals once diagnosed eat a gluten free diet as a best approach for management of the condition. (Celiac Disease Foundation, n.d.). To learn more, visit the Celiac Disease Foundation's *What is Celiac Disease?* article .

Crohn's Disease and Ulcerative Colitis

Crohn's disease and ulcerative colitis are chronic inflammatory bowel diseases (IBD) whereby a section or segments of the digestive tract experience inflammation. Crohn's disease can occur anywhere along the digestive tract from the mouth to the anus, although it is most often found in the small intestines. This often leads to malabsorption of nutrients from food. Ulcerative colitis is localized inflammation and ulcers in the colon (UCLA Health, n.d.). To learn more, visit UCLA Health's page about inflammatory bowel diseases.

Colon Cancer

Cancer formation in the colon portion of the digestive tract. It is typically found in older adults. Colon cancer is often diagnosed through a colonoscopy. (American Cancer Society medical and editorial team, 2020b). To learn more, visit the American Cancer Society's page on colon cancer.

Hernia

A hernia occurs when an organ or fatty tissue squeezes through a weak spot in a surrounding muscle or connective tissue. A hiatal hernia is found in the upper stomach region.

Irritable Bowel Syndrome

Irritable bowel syndrome (IBS) is a common disorder affecting the large intestines. IBS often involves abdominal pain as sensitive nerve tissue within the colon react to movement of food and waste through the digestive tract. Along with the abdominal pain individuals often experience gas and bloating. Diet and lifestyle modifications often help in the management of the condition. (American College of Gastroenterology, 2021a). To learn more about irritable bowel syndrome, visit the American College of Gastroenterology's web page on IBS.

Polyps

A polyp is a small growth of tissue protruding outward from the intestinal wall. Some cancers in the intestines start off as a polyp. Typically, they are found in people over the age of 50. Polyps start as a small collection of cells found within the colon. Most are harmless but can transition over time into a cancerous growth (Mayo Clinic Staff, 2019). To learn more about polyps review the Mayo Clinic's patient information page on polyps.

Medical Terms in Context

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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 a 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

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14: Skeletal System

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.

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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

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Skeletal System Medical Terms

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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 14.1). 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.

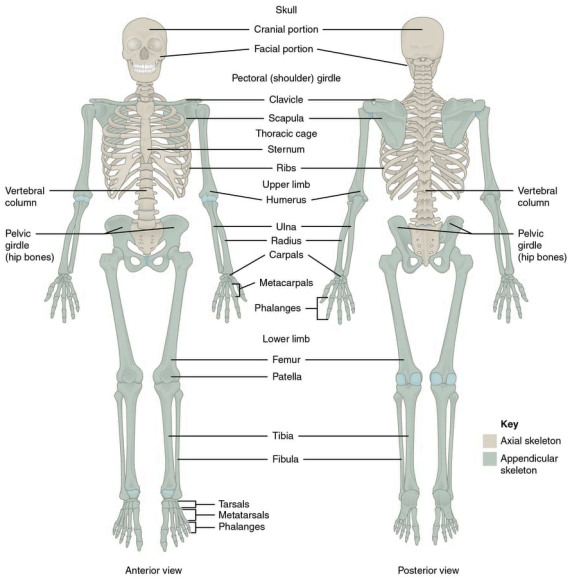


Figure 14.1 Axial and Appendicular Skeleton. The axial skeleton supports the head, neck, back, and chest and thus forms the vertical axis of the body. It consists of the skull, vertebral column (including the sacrum and coccyx), and the thoracic cage, formed by the ribs and sternum. The appendicular skeleton is made up of all bones of the upper and lower limbs. From Betts, et al., 2021. Licensed under CC BY 4.0.

Did You Know?

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

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 14.2). 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.

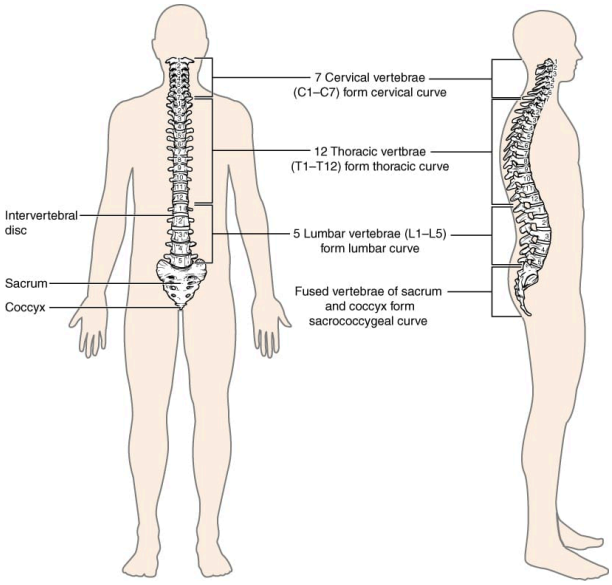


Figure 14.2 Vertebral Column. The adult vertebral column consists of 24 vertebrae, plus the sacrum and coccyx. The vertebrae are divided into three regions: cervical C1–C7 vertebrae, thoracic T1–T12 vertebrae, and lumbar L1–L5 vertebrae. The vertebral column is curved, with two primary curvatures (thoracic and sacrococcygeal curves) and two secondary curvatures (cervical and lumbar curves). From Betts, et al., 2021. Licensed under CC BY 4.0.

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 14.3). The ribs are anchored posteriorly to the 12 thoracic vertebrae (T1–T12). The thoracic cage protects the heart and lungs.

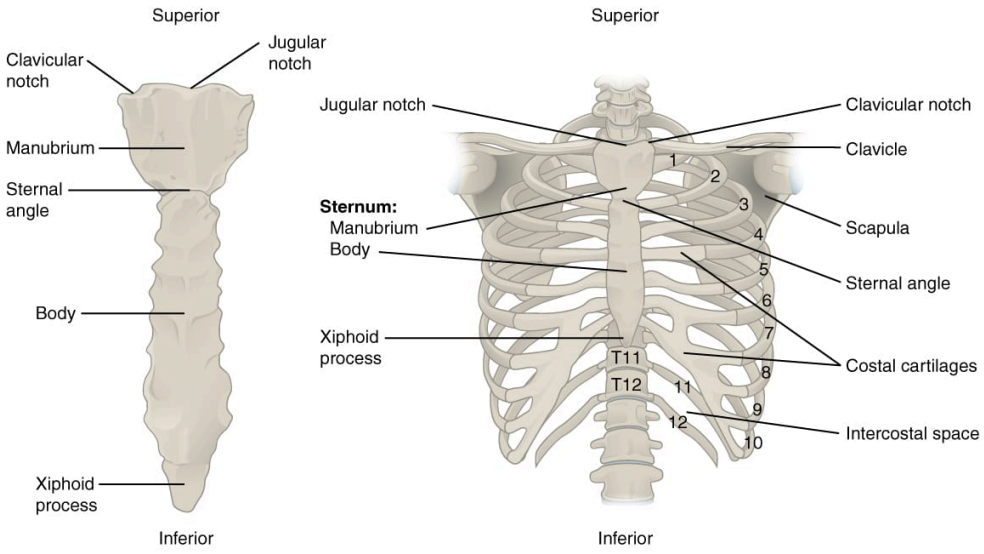


Figure 14.3 Thoracic Cage. The thoracic cage is formed by the (a) sternum and (b) 12 pairs of ribs with their costal cartilages. The ribs are anchored posteriorly to the 12 thoracic vertebrae. The sternum consists of the manubrium, body, and xiphoid process. The ribs are classified as true ribs (1–7) 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.

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 limb s 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

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Media 14.2. 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 14.4 below. There are 30 bones in each upper limb. Can you count them on your limb?

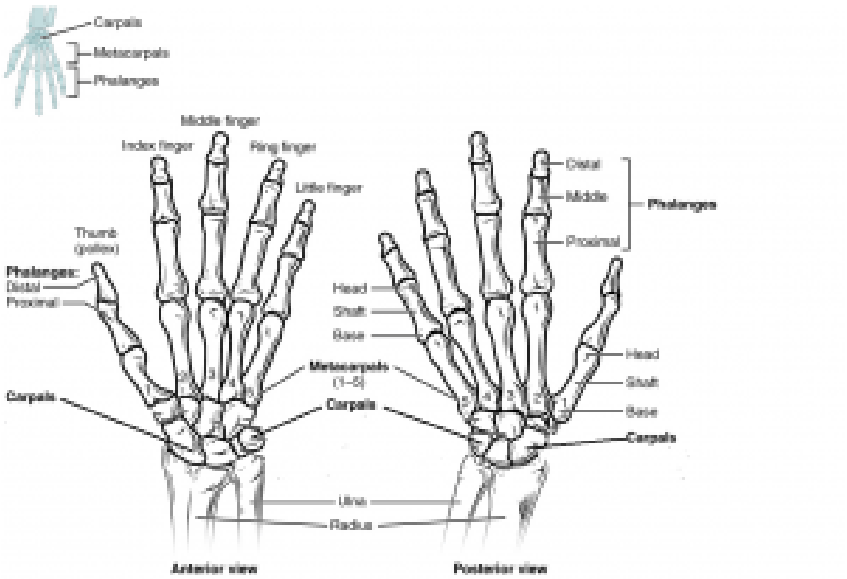


Figure 14.4 Bones of the Hands. From Betts, et al., 2021. Licensed under CC BY 4.0.

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
- **Illium** – 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 14.5).

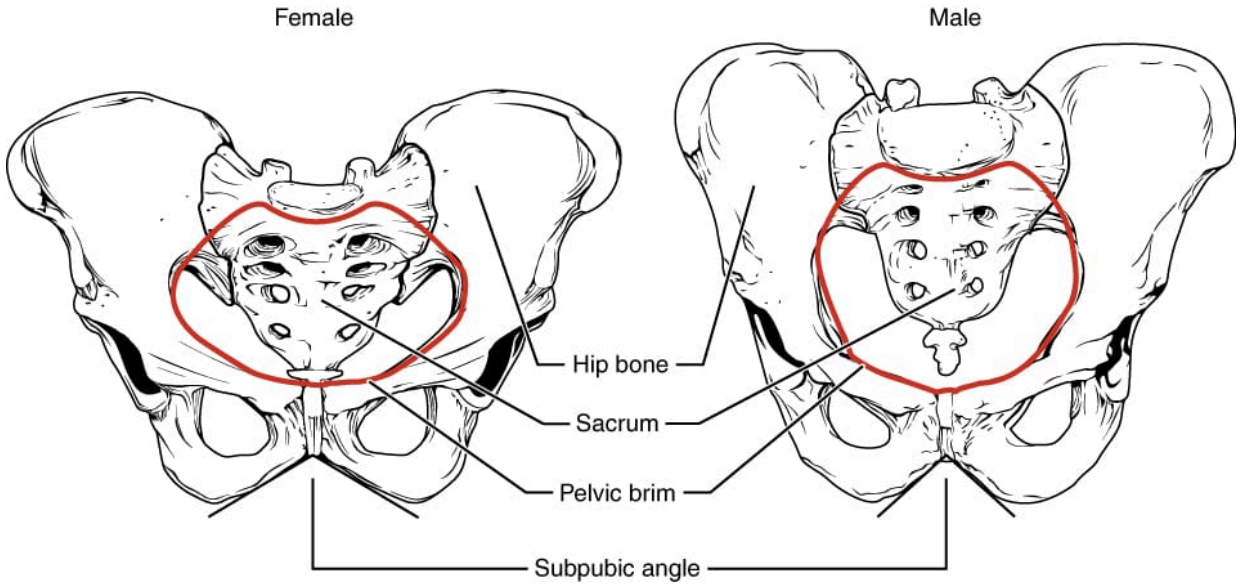


Figure 14.5 Female and male pelvis, showing the hip bone, sacrum, pelvic brim and subpubic angle. From Betts et al. 2021. Licensed under CC BY 4.0.

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).

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 14.6)

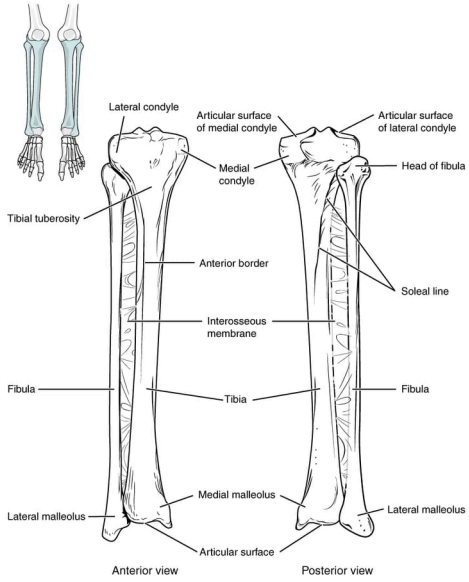


Figure 14.6 Tibia and Fibula. The tibia is the larger, weight-bearing bone located on the medial side of the leg. The fibula is the slender bone of the lateral side of the leg and does not bear weight. From Betts, et al., 2021. Licensed under CC BY 4.0.

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 14.7)

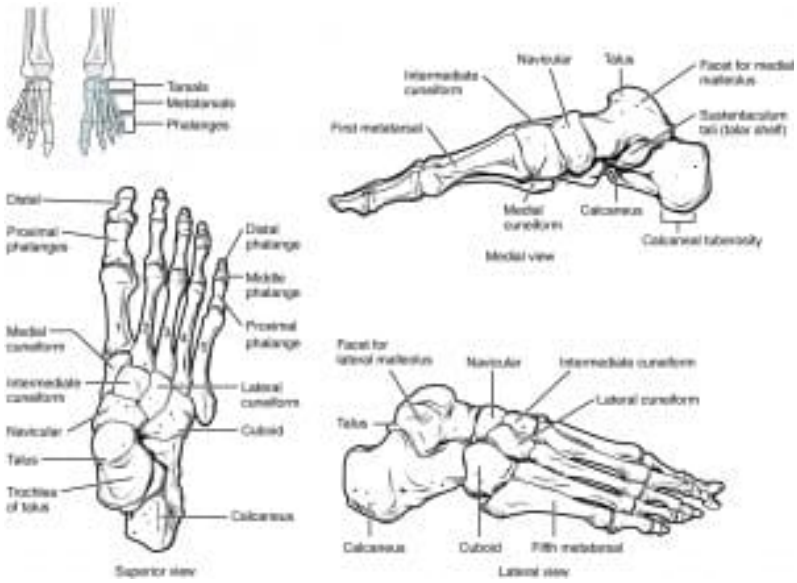


Figure 14.7 Bones of the Foot. The bones of the foot are divided into three groups. The posterior foot is formed by the seven tarsal bones. The mid-foot has the five metatarsal bones. The toes contain the phalanges. From Betts, et al., 2021. Licensed under CC BY 4.0.

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

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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

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Media 14.3. 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.

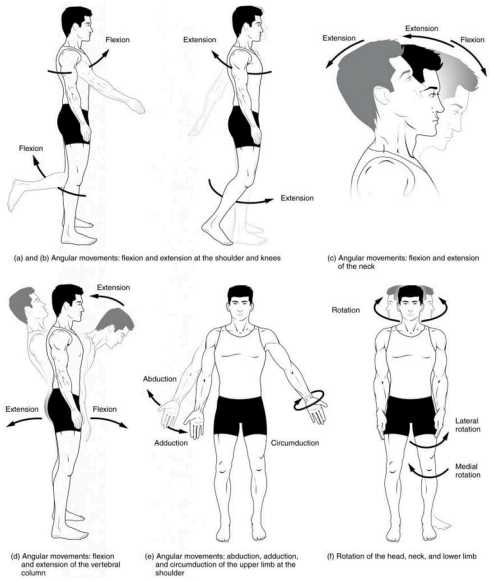


Figure 14.8 Movements of the Body, Part 1. Synovial joints give the body many ways in which to move. (a) and (b) Flexion and extension motions are in the sagittal (anterior and posterior) plane of motion. These movements take place at the shoulder, hip, elbow, knee, wrist, metacarpophalangeal, metatarsophalangeal, 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.

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 14.8(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 14.8(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 14.8(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 14.8(f)).

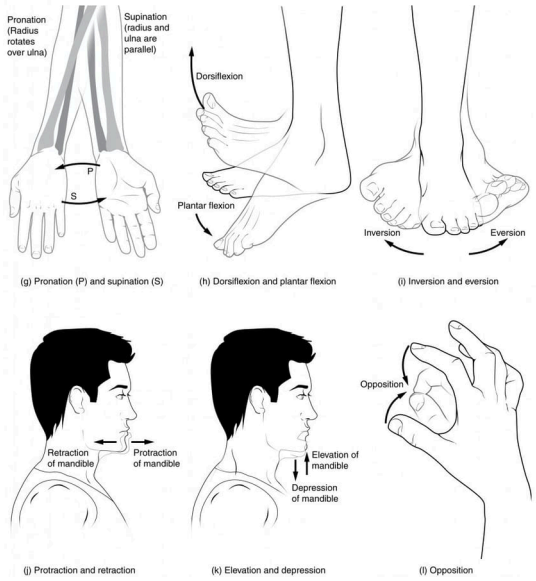


Figure 14.9 Movements of the Body, Part 2. (g) Supination of the forearm turns the hand to the palm forward position in which the radius and ulna are parallel, while forearm pronation turns the hand to the palm backward position in which the radius crosses over the ulna to form an "X." (h) Dorsiflexion 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.

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 14.9(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 14.9(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 14.9(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 14.9(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 14.9(k)).

Concept Check

- Differentiate between pronation and supination.

Skeletal System Movement Terms

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Medical Terms in Context

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Common Skeletal System Abbreviations

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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.

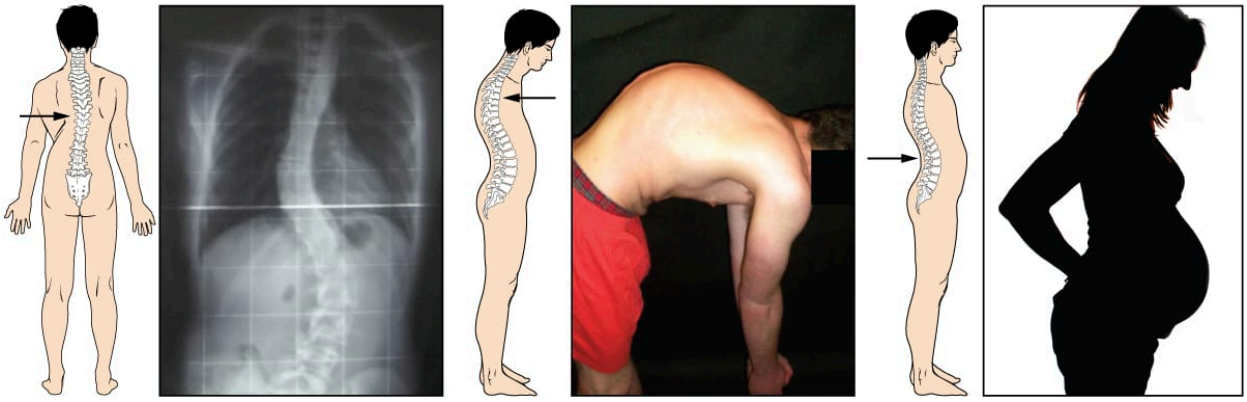
Osteomyelitis

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 14.10). 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 14.11).
- **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 14.10 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.

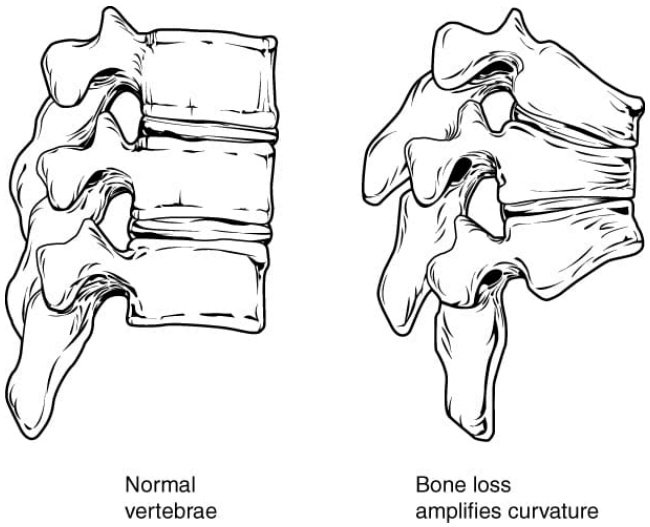


Figure 14.11. Osteoporosis. Osteoporosis is an age-related disorder that causes the gradual loss of bone density and strength. When the thoracic vertebrae are affected, there can be a gradual collapse of the vertebrae. This results in kyphosis, an excessive curvature of the thoracic region. From Betts, et al., 2021. Licensed under CC BY 4.0.

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 14.12). 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
- **Openor 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

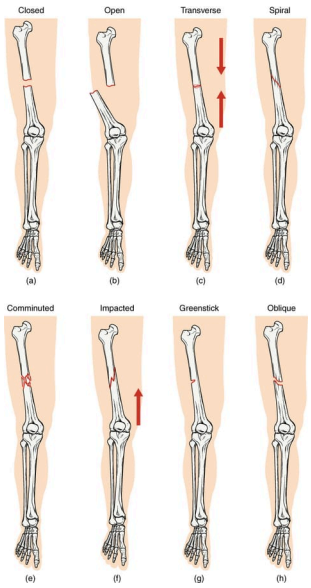


Figure 14.12. Types of Fractures. Compare healthy bone with different types of fractures: (a) closed fracture, (b) open fracture, (c) transverse fracture, (d) spiral fracture, (e) comminuted fracture, (f) impacted fracture, (g) greenstick fracture, and (h) oblique fracture. From Betts, et al., 2021. Licensed under CC BY 4.0.

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

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15: 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.

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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.

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Media 15.1 Muscles, Part 2 – Organismal Level: Crash Course A&P #22 [Online video]. Copyright 2015 by CrashCourse.

Muscular System Medical Terms

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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 15.1). 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.

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Figure 15.1 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

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 join 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), trapezious (trapezoid)
- **action** – flexor (to flex), adductor (towards midline of body)

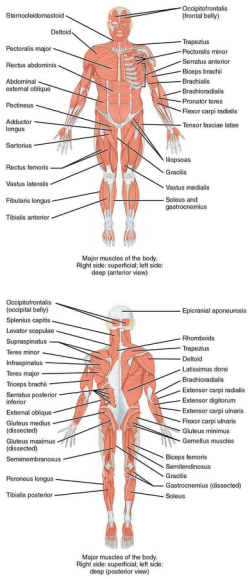


Figure 15.3. Overview of the Muscular System. On the anterior and posterior views of the muscular system above, superficial muscles (those at the surface) are shown on the right side of the body while deep muscles (those underneath the superficial muscles) are shown on the left half of the body. For 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.

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Figure 15.4. Vantage Atlas MRI scanner from Toshiba. From Mos.ru, CC BY 4.0 via Wikimedia Commons

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16: Sensory Systems

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.

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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.

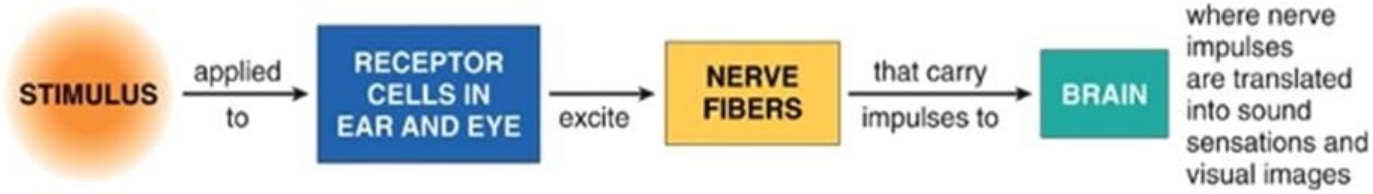


Figure 16.1. Pattern of events in the stimulation of a sense organ. From Chabner, D.E. (2017) Language of Medicine. Elsevier. p698. All Rights Reserved.

Gustation (Taste) and Olfaction (Smell)

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Sensory System Medical Terms

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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)

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Media 16.2 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 16.2).

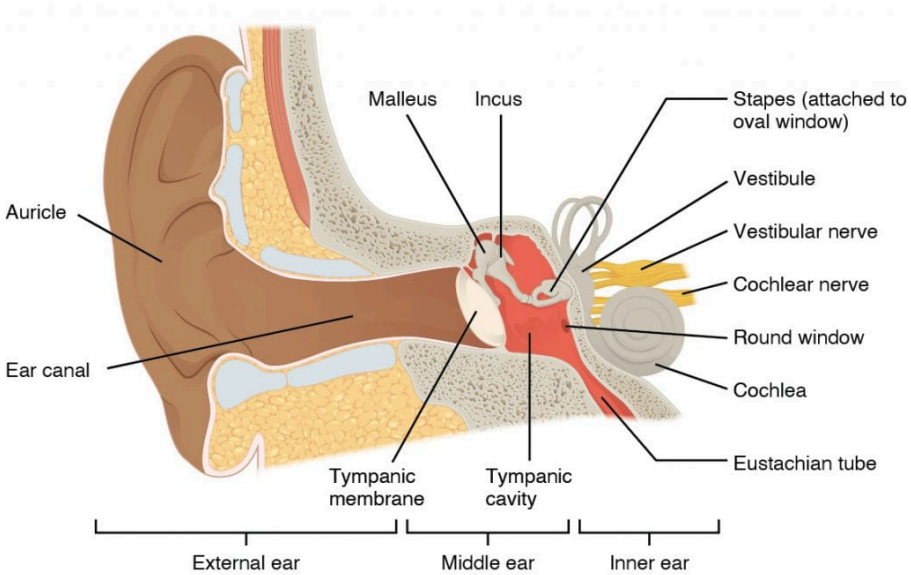


Figure 16.2 Structures of the Ear. The external ear contains the auricle, ear canal, and tympanic membrane. The middle ear contains the ossicles and is connected to the pharynx by the Eustachian tube. The inner ear contains the cochlea and vestibule, which are responsible for audition and equilibrium, respectively. From Betts, et al., 2021. Licensed under CC BY 4.0.

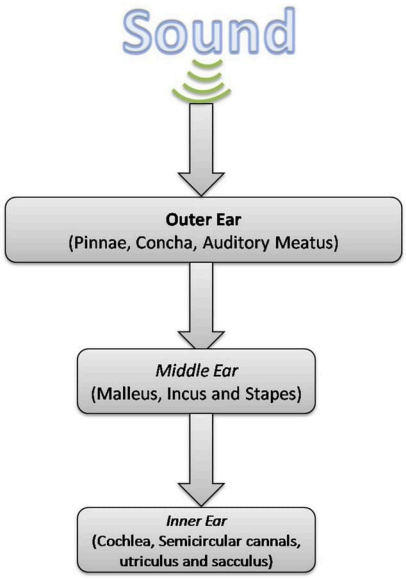


Figure 16.3 Pathway of sound vibrations from the outer ear to the bard (cerebral cortex). Modified from Nzachariah3, CC BY 3.0, via Wikimedia Commons

- 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 16.4). The cochlear duct contains several organs of Corti, which tranduce 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.

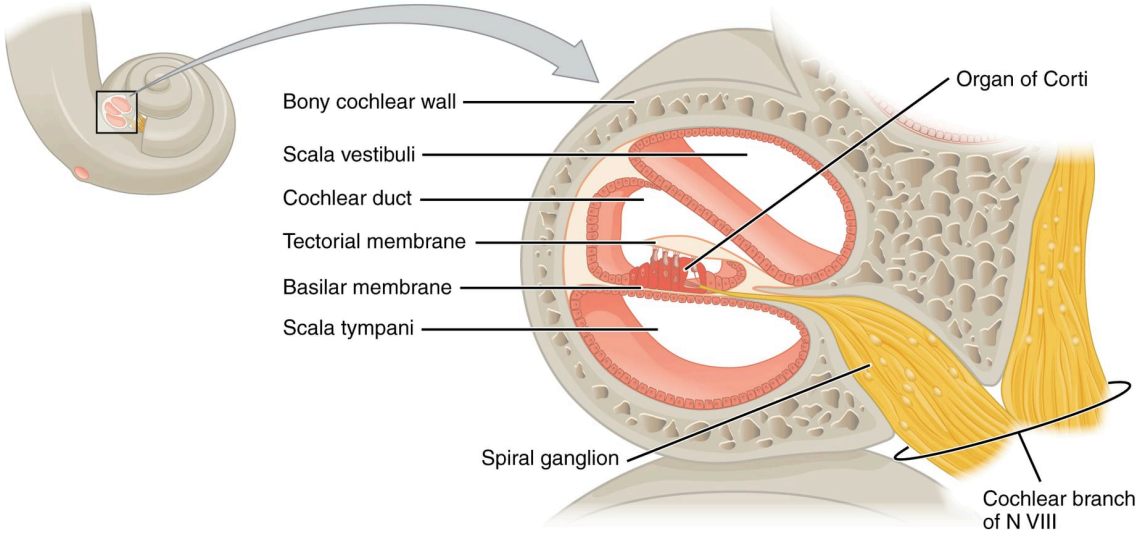


Figure 16.4 Cross Section of the Cochlea. The three major spaces within the cochlea are highlighted. The scala tympani and scala vestibuli lie on either side of the cochlear duct. The organ of Corti, containing the mechanoreceptor hair cells, is adjacent to the scala tympani, where it sits atop the basilar membrane. From Betts, et al., 2021. Licensed under CC BY 4.0.

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 16.5). The neural signals generated in the vestibular ganglion are transmitted through the vestibulocochlear nerve to the brain stem and cerebellum.

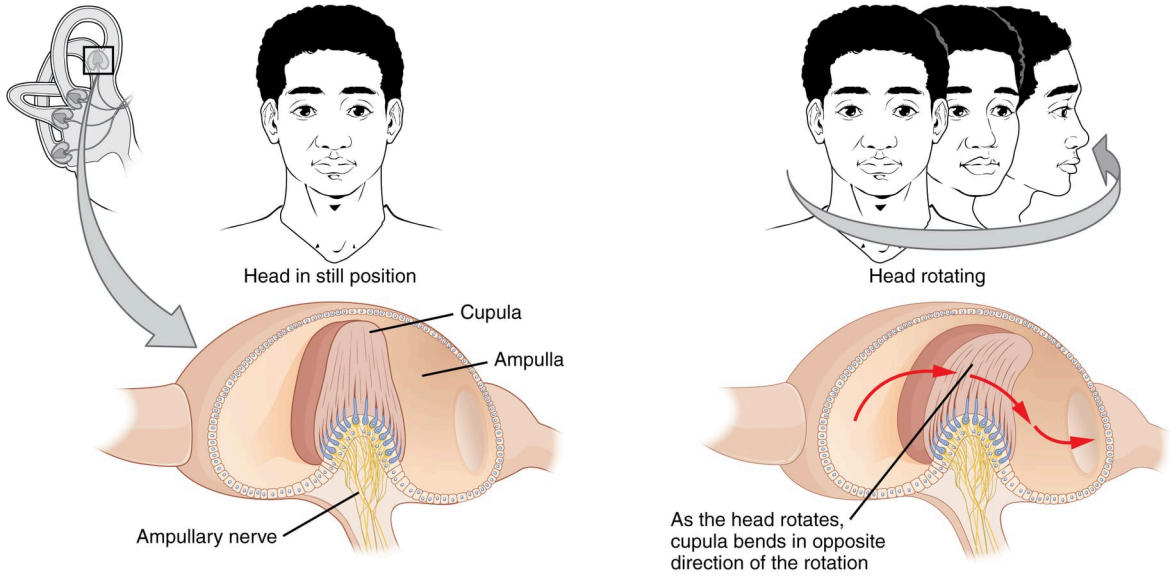


Figure 16.5 Rotational Coding by Semicircular Canals. Rotational movement of the head is encoded by the hair cells in the base of the semicircular canals. As one of the canals moves in an arc with the head, the internal fluid moves in the opposite direction, causing the cupula and stereocilia to bend. 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)

Did You Know?

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

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.

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

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Vision (Sight)

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Media 16.3 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 16.6). 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.

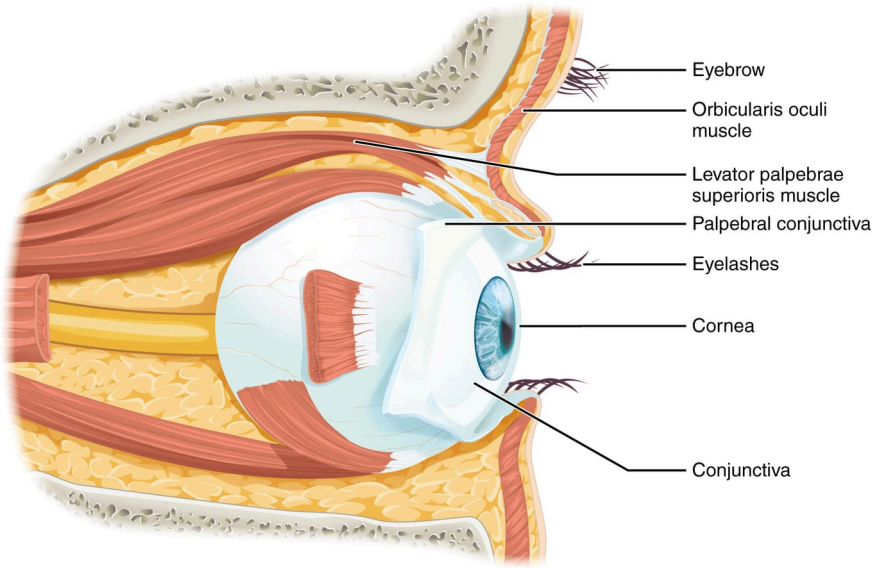


Figure 16.6 The Eye in the Orbit. The eye is located within the orbit and surrounded by soft tissues that protect and support its function. The orbit is surrounded by cranial bones of the skull. From Betts, et al., 2021. Licensed under CC BY 4.0.

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 16.7). 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.

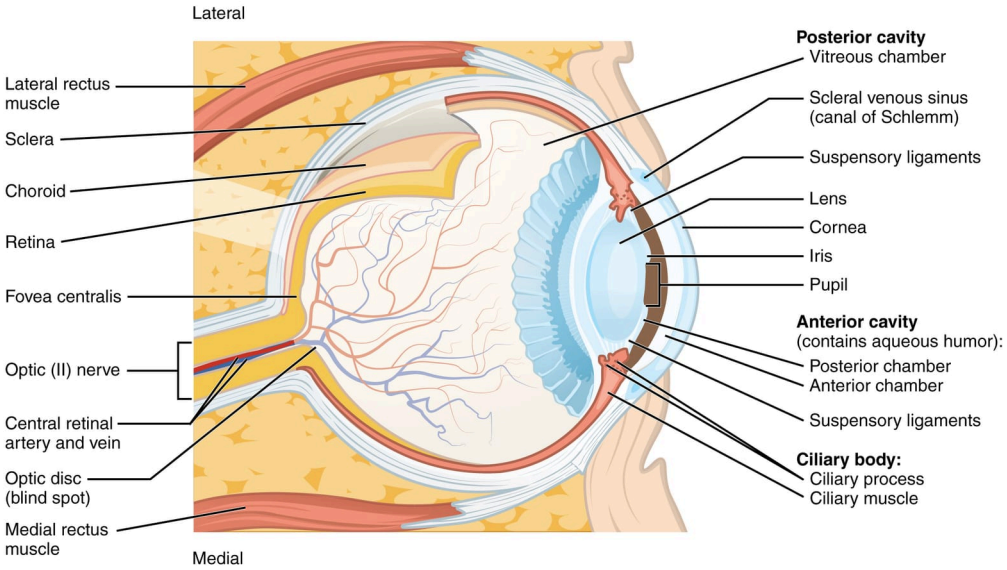


Figure 16.7 Structure of the Eye. The sphere of the eye can be divided into anterior and posterior chambers. The wall of the eye is composed of three layers: the fibrous tunic, vascular tunic, and neural tunic. Within the neural tunic is the retina, with three layers of cells and two synaptic layers 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.

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 16.7). 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 16.8). 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.

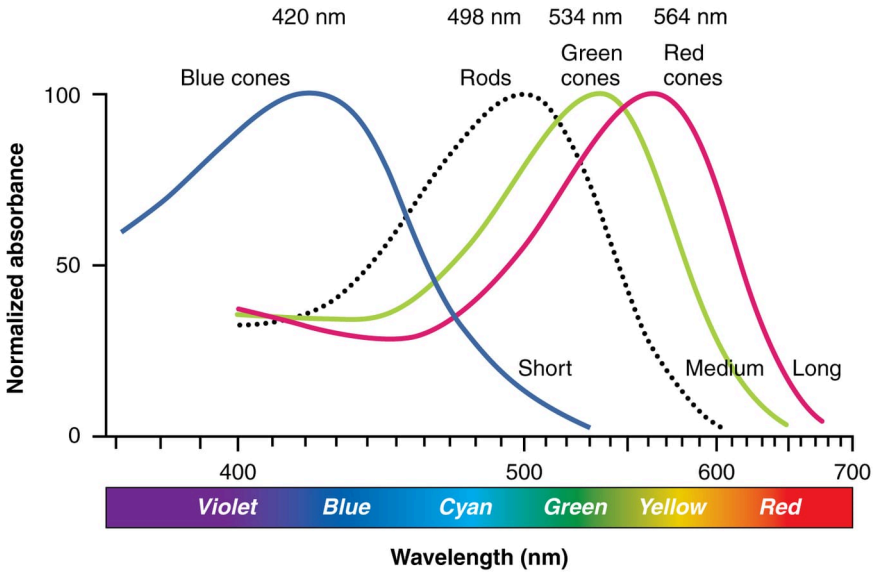


Figure 16.8 Comparison of Color Sensitivity of Photopigments. Comparing the peak sensitivity and absorbance spectra of the four photopigments suggests that they are most sensitive to particular wavelengths. From Betts, et al., 2021. Licensed under CC BY 4.0.

Sensory System Medical Terms Not Easily Broken Into Word Parts

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Anatomy Labeling Activity

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Sensory System Terms not Easily Broken into Word Parts

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Common Abbreviations for the Sensory System

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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:

- **Estropia:** the convergence of one or both eyes medially.
- **Extropia:** 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

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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

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17: Nervous System

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.

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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.

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Nervous System Medical Terms

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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 17.1). 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.

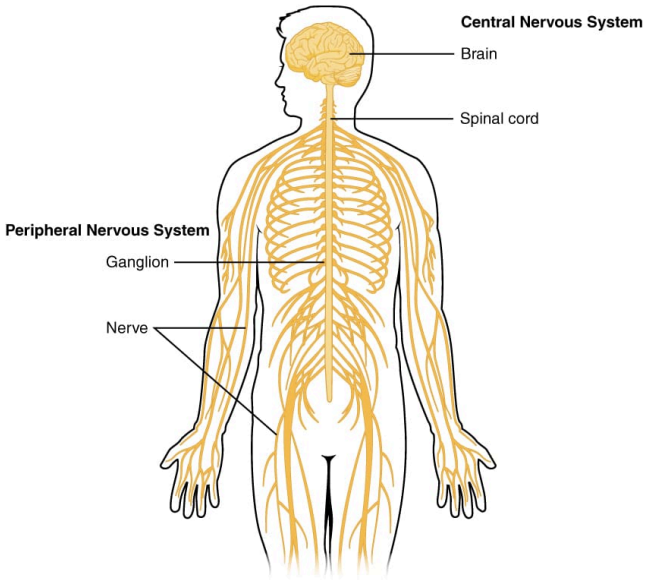


Figure 17.1 Central and Peripheral Nervous System. The structures of the PNS are referred to as ganglia and nerves, which can be seen as distinct structures. The equivalent structures in the CNS are not obvious from this overall perspective and are best examined in prepared tissue under the microscope. From Betts, et al., 2021. Licensed under CC BY 4.0.

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 17.2 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 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.

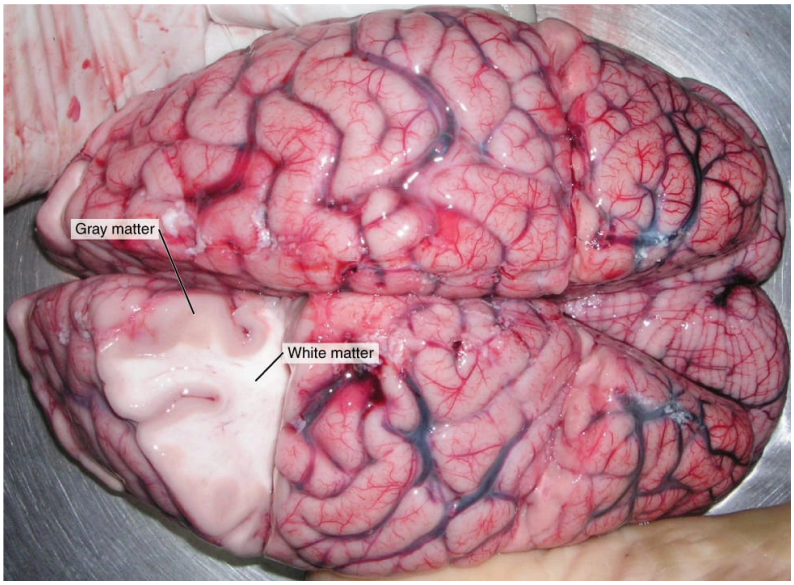


Figure 17.2 Gray Matter and White Matter. A brain removed during an autopsy, with a partial section removed, shows white matter surrounded by gray matter. Gray matter makes up the outer cortex of the brain. (credit: modification of work by "Suseno"/Wikimedia Commons). From Betts, et al., 2021. Licensed under CC BY 4.0.

Did You Know?

The brain has over 100 billion neurons.

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

17.3). 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.

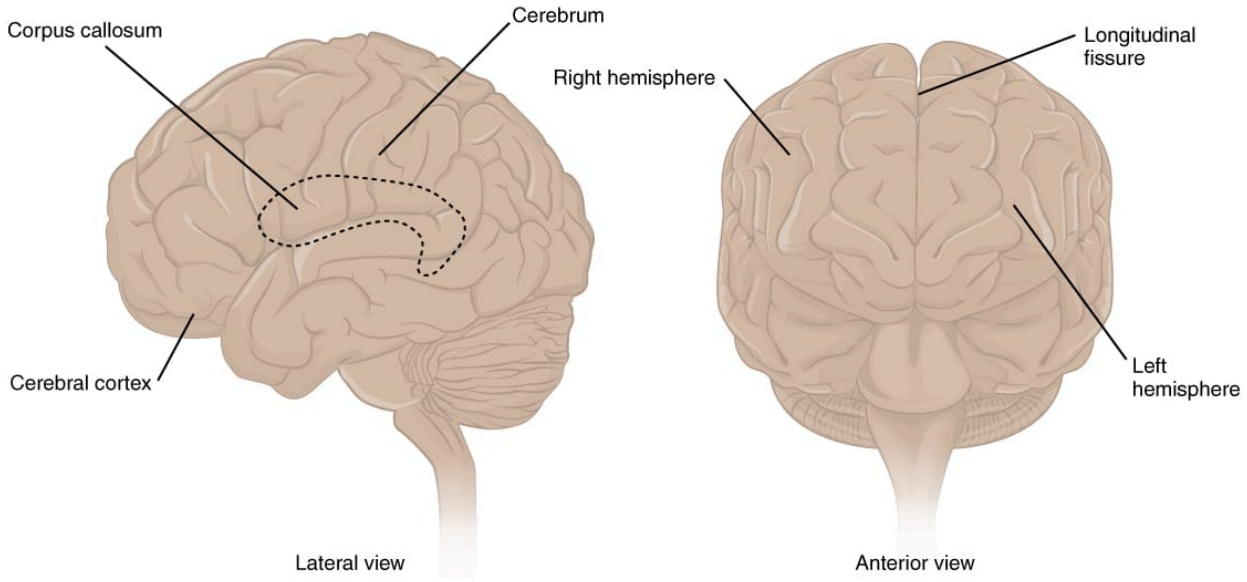


Figure 17.3 The Cerebrum. The cerebrum is a large component of the CNS in humans, and the most obvious aspect of it is the folded surface called the cerebral cortex. From Betts, et al., 2021. Licensed under CC BY 4.0.

Did You Know?

The brain is about 75% water and is the fattest organ in the body.

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.

Cerebral Cortex

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.

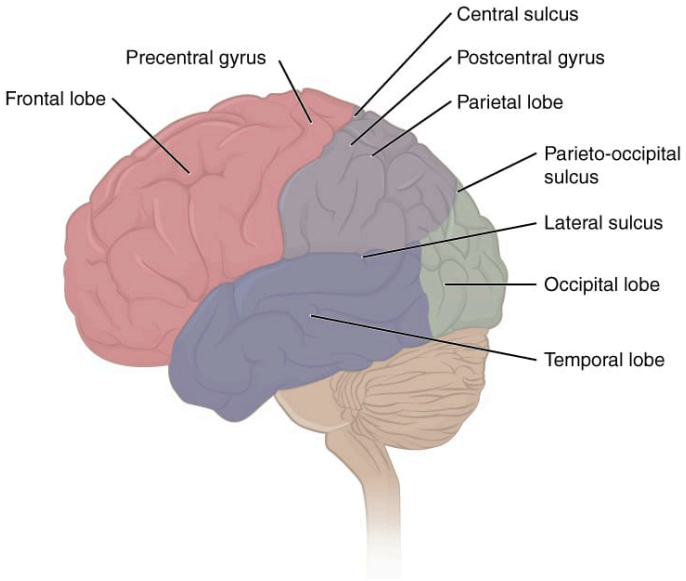


Figure 17.4 Lobes of the Cerebral Cortex. The cerebral cortex is divided into four lobes. Extensive folding increases the surface area available for cerebral functions. From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

- Identify the two major divisions of the nervous system.
- Describe the **cerebral cortex.**
- What are the halves of the cerebrum know 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 17.5). 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.

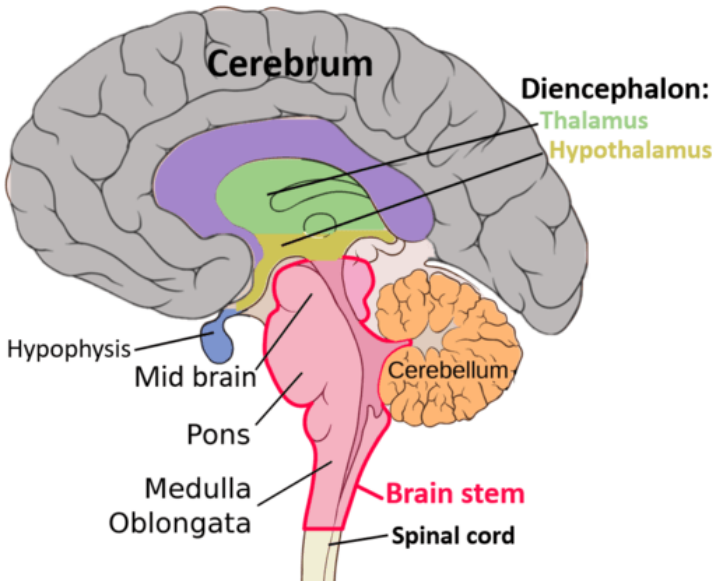


Figure 17.5 Parts of the Brain. The image highlights and names the most important structures of the brain in a sagittal(longitudinal) cross-section. Belomaad Biology Matura book, CC BY-SA 4.0, via Wikimedia Commons

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 17.6). 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.

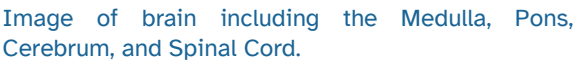


Figure 17.6 The Cerebellum. The cerebellum is situated on the posterior surface of the brain stem. Image by Patrick J. Lynch; CC BY 2.5, via Wikimedia Commons

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

Did You Know?

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

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 **formina** 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 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 17.7 shows the relationship of these parts to one another.

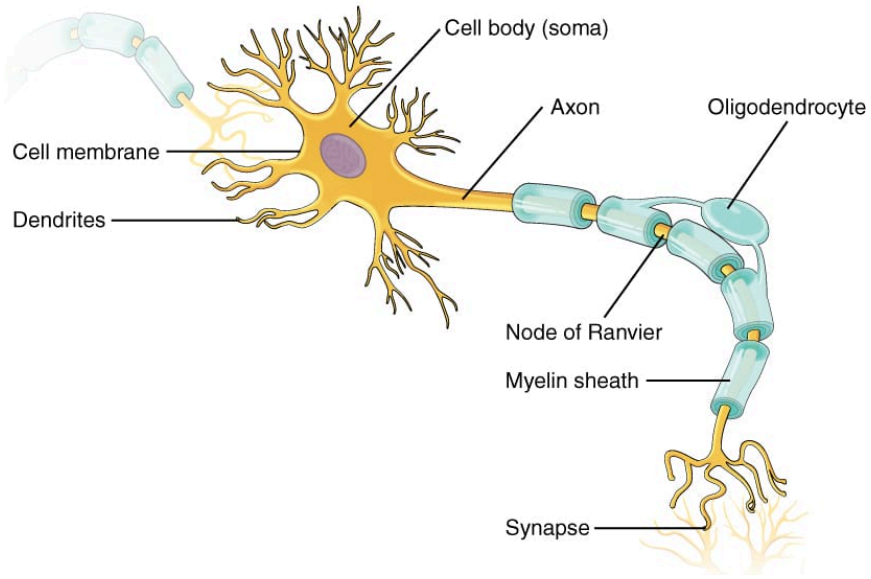


Figure 17.7 Parts of a Neuron. The major parts of the neuron are labeled on a multipolar neuron from the CNS. From Betts, et al., 2021. Licensed under CC BY 4.0.

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 17.1 outlines some common characteristics and functions.

Table 17.1: 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 17.8). 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.

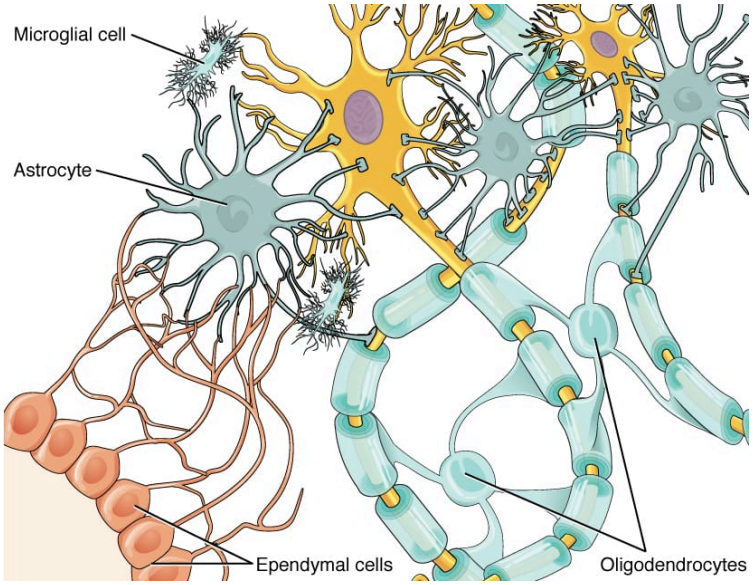


Figure 17.8 Glial Cells of the CNS. The CNS has astrocytes, oligodendrocytes, microglia, and ependymal cells that support the neurons of the CNS in several ways. From Betts, et al., 2021. Licensed under CC BY 4.0.

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 17.8.

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 17.9.

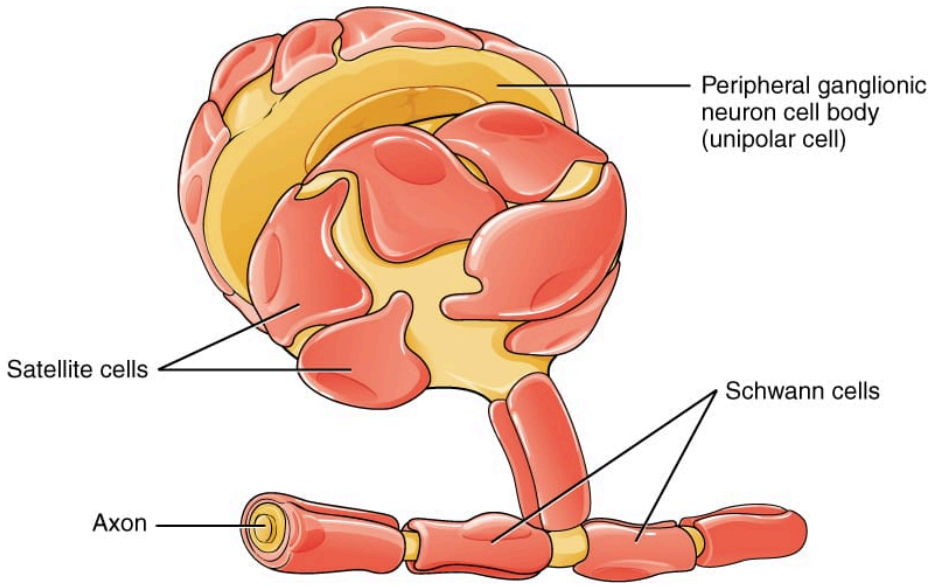


Figure 17.9 Glial Cells of the PNS. The PNS has satellite cells and Schwann cells. From Betts, et al., 2021. Licensed under CC BY 4.0.

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

Query 17.3

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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 17.10 for examples of where these divisions of the nervous system can be found.

A silhouette of a human with only the brain, spinal cord, PNS ganglia, nerves and a section of the digestive tract visible. The brain, which is part of the CNS, is the area of perception and processing of sensory stimuli (somatic/autonomic), the execution of voluntary motor responses (somatic), and the regulation of homeostatic mechanisms (autonomic). The spinal cord, which is part of the CNS, is the area where reflexes are initiated. The gray matter of the ventral horn initiates somatic reflexes while the gray matter of the lateral horn initiates autonomic reflexes. The spinal cord is also the somatic and autonomic pathway for sensory and motor functions between the PNS and the brain. The nerves, which are part of the PNS, are the fibers of sensory and motor neurons, which can be either somatic or autonomic. The ganglia, which are part of the PNS, are the areas for the reception of somatic and autonomic sensory stimuli. These are received by the dorsal root ganglia and cranial ganglia. The autonomic ganglia are also the relay for visceral motor responses. The digestive tract is part of the enteric nervous system, the ENS, which is located in the digestive tract and is responsible for autonomous function. The ENS can operate independent of the brain and spinal cord.

Figure 17.10 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.

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 17.11). 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.

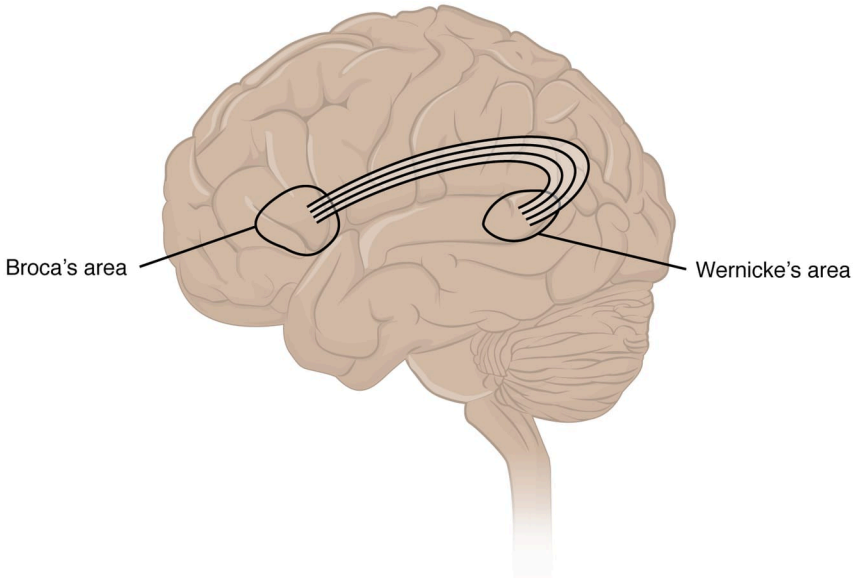


Figure 17.11 Broca's and Wernicke's Areas. Two important integration areas of the cerebral cortex associated with language function are Broca's and Wernicke's areas. The two areas are connected through the deep white matter running from the posterior temporal lobe to the frontal lobe. From Betts, et al., 2021. Licensed under CC BY 4.0.

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

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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), Creutzfeld–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).

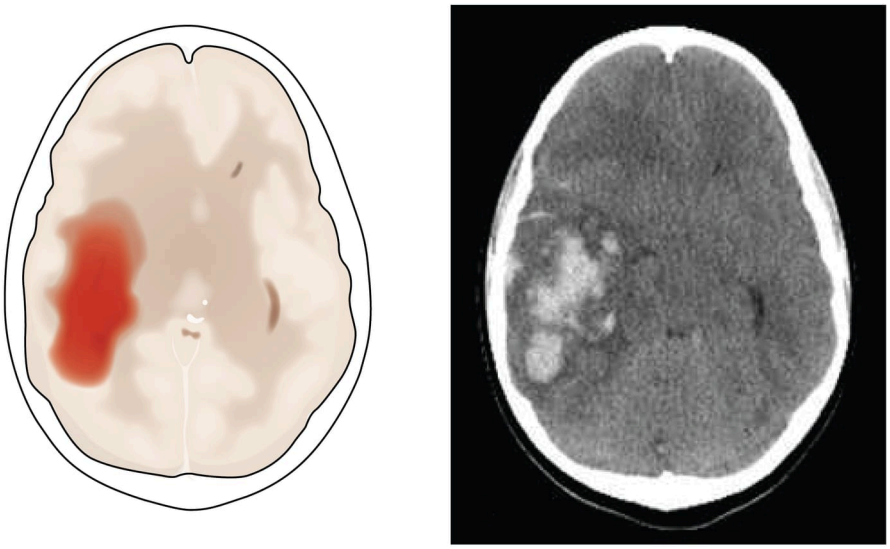
Guillain-Barre (pronounced gee-YAN bah-RAY) syndrome is an example of a demyelinating disease of the peripheral nervous system. It is also the result of an autoimmune reaction, but the inflammation is in peripheral nerves. Sensory symptoms or motor deficits are common, and autonomic failures can lead 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 17.12) (Betts, et al., 2021).



(a) (b)

Figure 17.12 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.

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.

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

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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 (Moores & 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

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18: Endocrine System

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.

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Introduction to Endocrine System

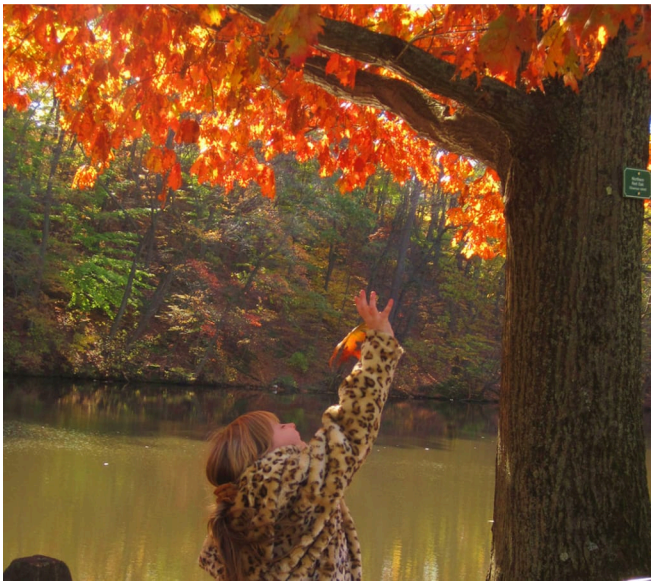


Figure 18.1 A Child Catches a Falling Leaf. Hormones of the endocrine system coordinate and control growth, metabolism, temperature regulation, the stress response, reproduction, and many other functions. (credit: “seenthroughmylense”/flickr.com). From Betts, et al., 2021. Licensed under CC BY 4.0.

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:

YouTube Video

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Media 18.1 Endocrine System, Part 1 – Glands & Hormones: Crash Course A&P #23 [Online video]. Copyright 2015 by CrashCourse.

Endocrine System Medical Terms

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Anatomy (Structure) of the Endocrine System

Did You Know?

The pancreas acts as a 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 18.2). 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.

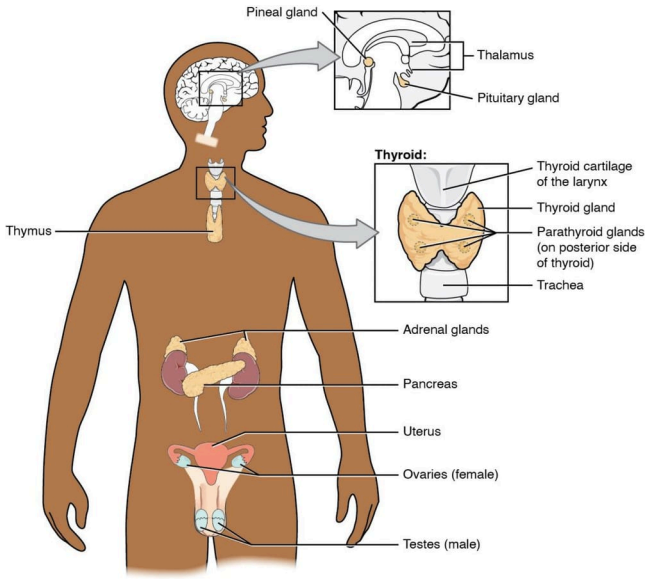


Figure 18.2 Endocrine System. Endocrine glands and cells are located throughout the body and play an important role in maintaining equilibrium (homeostasis). From Betts, et al., 2021. Licensed under CC BY 4.0.

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

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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 18.1). 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 18.2.

Table 18.2: 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

Endocrine Gland	Associated Hormones	Chemical Class	Effect
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 and synchronizes our melatonin hormones with sunrise and sunset. (Shurkin, 2013).

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.

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 18.3).

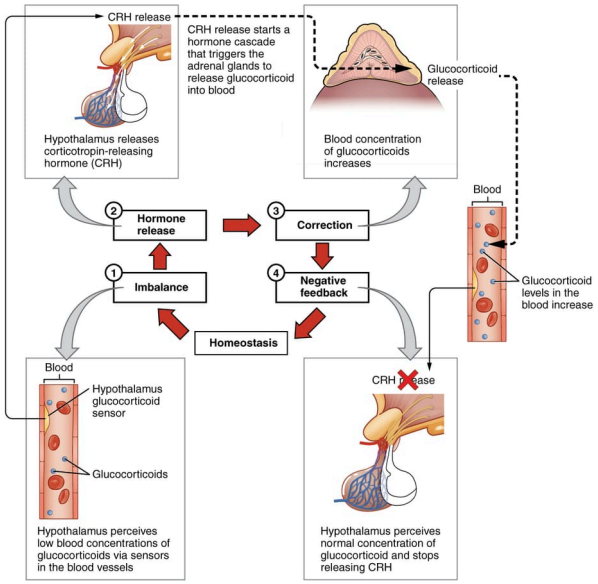


Figure 18.3 Negative Feedback Loop. The release of adrenal glucocorticoids is stimulated by the release of hormones from the hypothalamus and pituitary gland. This signaling is inhibited when glucocorticoid levels become elevated by causing negative signals to the pituitary gland and hypothalamus. From Betts, et al., 2021. Licensed under CC BY 4.0.

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.

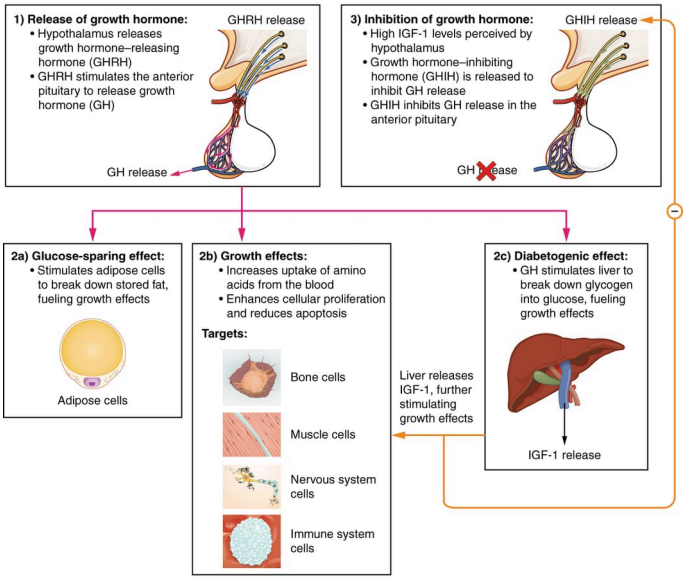


Figure 18.4 Hormonal Regulation of Growth. Growth hormone (GH) directly accelerates the rate of protein synthesis in skeletal muscle and bones. Insulin-like growth factor 1 (IGF-1) is activated by growth hormone and indirectly supports the formation of new proteins in muscle cells and bone. From Betts, et al., 2021. Licensed under CC BY 4.0.

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.

Did You Know?

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

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.

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

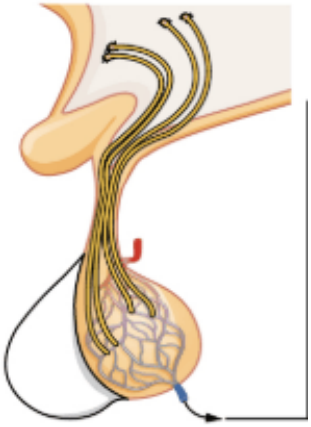
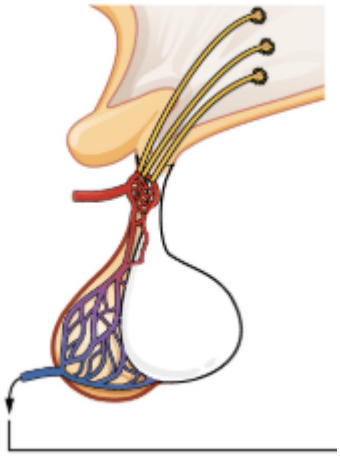
IMAGE OF GLANDS	HORMONES			
 An image displaying the posterior pituitary gland	**Posterior Pituitary Hormones**			
	Releasing hormone (hypothalamus)	**Pituitary Hormone**	**Target**	**Effects**
	ADH	Stores ADH	Kidneys, sweat glands, circulatory system	Water balance
	–	OT	Female reproductive system	Triggers uterine contractions during childbirth

IMAGE OF GLANDS	HORMONES			
 An image displaying the Anterior Pituitary Gland	**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

YouTube Video

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Figure 18.5 (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)

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.

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Media 18.3 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 18.7). 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).

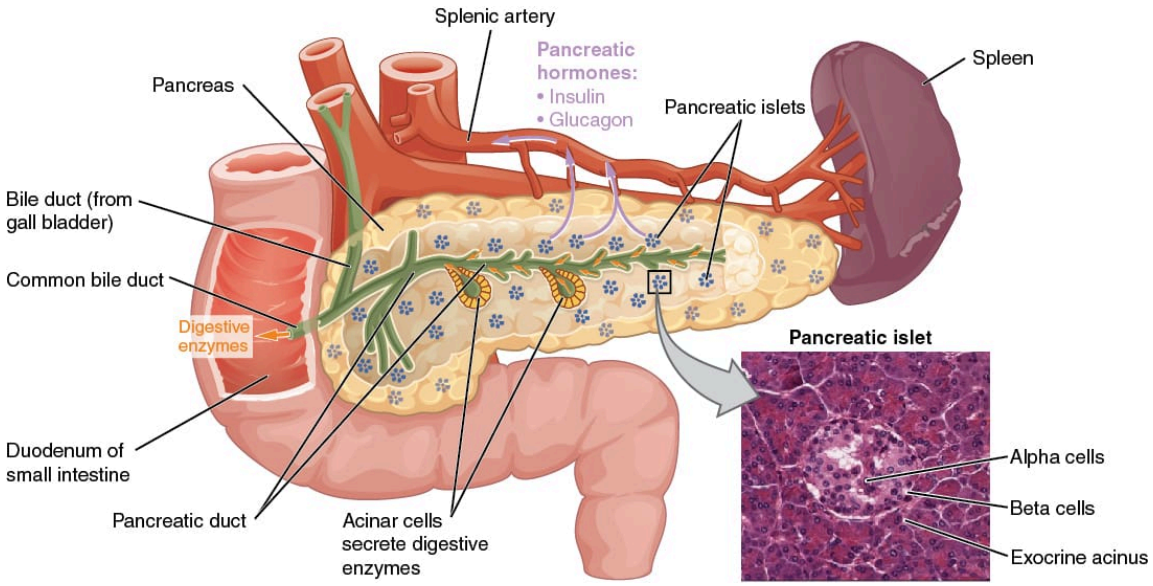


Figure 18.7 Pancreas. The pancreatic exocrine function involves the acinar cells secreting digestive enzymes that are transported into the small intestine by the pancreatic duct. Its endocrine function involves the secretion of insulin and glucagon within the pancreatic islets. These two hormones regulate 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.

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

Query 18.4

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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

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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

Query 18.7

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19: Mental Health

Mental Health Terminology

Mental health terminology helps health care workers describe emotions, thinking, behavior, and treatment accurately. In this chapter, you will build selected terms from word parts, recognize terms learned as whole words, and translate professional language into everyday language. You will also practice language that respects the person receiving care. The emphasis is on understanding and using terminology rather than diagnosing or selecting treatment.

Learning Objectives

- Identify meanings of common prefixes, combining forms, and suffixes related to mental health.
- Analyze, spell, pronounce, and define selected mental health terms.
- Describe brain structures and functions that provide a foundation for mental health terminology.
- Distinguish symptoms and assessment findings from names of disorders.
- Categorize anatomic, diagnostic, disease and disorder, and therapeutic terms.
- Interpret common mental health abbreviations in context.
- Identify health care professionals involved in mental health care.
- Use accurate, respectful terminology in short health care scenarios.

Introduction to Mental Health

Mental health includes emotional, psychological, and social well-being. It influences how people think, feel, relate to others, cope with stress, and carry out daily activities. Mental health exists along a continuum and can change over time. A person living with a mental disorder can also experience meaningful relationships, achievement, and recovery.

A mental disorder involves a clinically significant disturbance in thinking, emotional regulation, or behavior. Symptoms may cause distress or interfere with school, work, relationships, or self-care. Brief sadness, temporary worry, unusual interests, or behavior that differs from social expectations does not by itself establish a disorder. Clinicians consider symptom patterns, duration, severity, functioning, and cultural context.

Mental and physical health influence one another. Sleep loss, pain, medical illness, medications, and substance use may affect mood and thinking. Mental health symptoms can also affect appetite, energy, sleep, and participation in physical health care. For example, fatigue and difficulty concentrating may occur with depression, but also with sleep problems or medical conditions.

Psychology is the scientific study of mind and behavior. Psychiatry is a medical specialty concerned with the assessment, diagnosis, treatment, and prevention of mental disorders. The terms are related, but they describe different fields and professional training pathways.

Language Matters

Stigma involves negative stereotypes or judgments that can lead to exclusion and discrimination. Respectful communication describes a person's condition or behavior without reducing the person to a label. Ask about language preferences when possible. Describe what you observe, distinguish observations from interpretations, and use the person's words when relevant.

Language Matters

Avoid	Use instead
A schizophrenic	A person with schizophrenia
An alcoholic	A person with alcohol use disorder
The patient is crazy	The patient reports hearing a voice when no one else is present

Avoid	Use instead
The patient is manipulative	The patient requested the same medication from two staff members within ten minutes
The patient is noncompliant	The patient reports stopping the medication because of nausea

The last three examples illustrate documentation choices. A behavior description does not establish a diagnosis or explain the person's intentions.

Mental Health Terminology and Classification

The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR), describes diagnostic criteria and related information. The International Classification of Diseases (ICD), maintained by the World Health Organization, classifies health conditions across medicine. These systems support consistent communication. The DSM is a diagnostic resource; it does not provide treatment guidelines.

Classification changes as evidence and clinical understanding develop. Culture matters when interpreting experiences and functioning, but social disapproval alone does not make a behavior a mental disorder. For example, ICD-11 recognizes gaming disorder, whereas DSM-5-TR lists Internet Gaming Disorder as a condition for further study. Frequent gaming alone does not establish either condition.

Mental Health Word Parts

A prefix comes before a root. A combining form includes a root and a combining vowel, often o. A suffix appears at the end. Word parts offer clues, but a literal translation may not express a term's full clinical meaning. Many mental health terms are best learned as whole words.

Common Prefixes

Common Prefixes

Prefix	Meaning	Example
a-, an-	Without, not	Anhedonia
bi-	Two	Bipolar
dys-	Difficult, abnormal, unpleasant	Dysphoria
eu-	Good, normal, well	Euthymia
hyper-	Excessive, above normal	Hyperactivity
hypo-	Below normal, less than	Hypomania
para-	Beside, beyond, abnormal, depending on the term	Paranoia; learn its clinical meaning as a whole word
post-	After	Posttraumatic

Common Combining Forms

Common Combining Forms

Combining form	Meaning	Example
acr/o	Height, extremity	Acrophobia
agor/o	Marketplace, public gathering place	Agoraphobia
anxi/o	Anxiety, uneasiness	Anxiolytic
aut/o	Self	Autonomic

Combining form	Meaning	Example
cerebr/o	Cerebrum	Cerebral
compuls/o	Urge, compulsion	Compulsive
cycl/o	Cycle	Cyclothymia
ech/o	Echo, repeated sound	Echolalia
encephal/o	Brain	Encephalopathy
hedon/o	Pleasure	Anhedonia
iatr/o	Treatment, physician	Psychiatry
klept/o	Stealing	Kleptomania
ment/o	Mind in mental health terminology	Mental
narc/o	Sleep, stupor	Narcolepsy
neur/o	Nerve	Neurology
path/o	Disease	Psychopathology
phren/o	Mind; diaphragm in other contexts	Schizophrenia
psych/o	Mind	Psychology
pyr/o	Fire	Pyromania
schiz/o	Split, divided	Schizophrenia
soci/o	Society, social relationships	Psychosocial
somat/o	Body	Somatic
somn/o	Sleep	Somnolence
thym/o	Mood in mental health terms; thymus in other terms	Cyclothymia

Common Suffixes

Common Suffixes

Suffix	Meaning	Example
-al, -ic	Pertaining to	Mental, psychotic
-ia	Condition	Anhedonia
-iatrist	Physician specializing in treatment	Psychiatrist
-iatry	Medical treatment or specialty	Psychiatry
-ism	Condition or process, depending on the word	Learn the full term in context
-lepsy	Seizure, attack	Narcolepsy
-logist	Specialist in a field of study	Psychologist
-logy	Study of	Psychology
-lytic	Loosening, reducing, relieving	Anxiolytic
-mania	Intense preoccupation or impulse in certain terms	Kleptomania
-orexia	Appetite	Anorexia
-phobia	Fear	Acrophobia
-therapy	Treatment	Psychotherapy

Suffix	Meaning	Example
-thymia	Mood condition	Euthymia

Terminology notes: Ment/o can also refer to the chin in anatomic terminology. Thym/o does not mean mood in every word. The suffix -mania in kleptomania does not mean that the person is experiencing a bipolar manic episode. Narcolepsy is a sleep disorder rather than an epileptic seizure disorder. Schizophrenia does not mean “split personality.”

The original word-part activity credited to Connie Stevens may remain a separate chapter activity. These revised tables emphasize commonly useful forms, add examples, and clarify context-dependent meanings.

Building and Analyzing Terms

Building and Analyzing Terms

Term	Word parts	Meaning
Psychology	psych/o + -logy	Scientific study of mind and behavior
Psychiatrist	psych + -iatrist	Physician specializing in mental health care
Psychotherapy	psych/o + -therapy	Treatment using psychological methods
Anhedonia	an- + hedon + -ia	Reduced ability to experience pleasure
Acrophobia	acr/o + -phobia	Intense fear of heights
Somatic	somat + -ic	Pertaining to the body
Euthymia	eu- + -thymia	A relatively stable mood without a current depressive or manic episode

Combining vowels are commonly omitted before a suffix beginning with a vowel. Spelling patterns vary; learn the correct spelling of the whole term rather than inserting a combining vowel automatically.

Concept Check

1. Which part of anhedonia refers to pleasure?
2. Why is a literal translation of schizophrenia insufficient?
3. How do psychology and psychiatry differ?

Anatomy Related to Mental Health

Mental health is not a single organ system. Brain networks work with the nervous and endocrine systems to support thought, emotion, memory, and behavior. The structures below provide a foundation for understanding the vocabulary. A disorder cannot usually be assigned to one brain structure alone.

Anatomy Related to Mental Health

Structure	General function relevant to this chapter
Cerebrum	Supports conscious thought, perception, memory, and voluntary action
Cerebral cortex	Outer layer of the cerebrum involved in complex information processing
Prefrontal cortex	Contributes to planning, decision-making, and regulation of behavior
Amygdala	Participates in emotional learning and responses to threats
Hippocampus	Helps form and organize memories
Hypothalamus	Helps regulate appetite, temperature, autonomic activity, and hormonal responses

Structure	General function relevant to this chapter
Brainstem	Supports vital functions and contributes to alertness

The term limbic system commonly refers to interconnected structures involved in emotion, memory, and motivation. These functions also depend on connections with other brain regions. The brainstem connects with the spinal cord, allowing communication between the brain and body.

Neurons and Synapses

A neuron is a nerve cell. Dendrites receive many incoming signals, and an axon carries signals toward other cells. At a chemical synapse, a neuron releases neurotransmitters that bind to receptors on another cell. A receptor is a structure that responds to a particular chemical signal.

Terminology Connection

Encephal/o means brain; neur/o means nerve. Encephalopathy broadly refers to brain dysfunction, whereas neurology is the field concerned with nervous system disorders. Neither term is interchangeable with a psychiatric diagnosis.

Concept Check

1. Which structure contributes to memory formation?
2. How does a neurotransmitter differ from a receptor?

Physiology Related to Mental Health

Communication Between Nerve Cells

Neurotransmitters help regulate activity across brain networks. Their effects depend on the receptor and the pathway involved. Serotonin participates in mood, sleep, and other functions; dopamine participates in motivation, movement, and other processes; norepinephrine contributes to alertness and stress responses. Gamma-aminobutyric acid (GABA) generally reduces neuronal activity, while glutamate generally increases it.

Mental disorders have complex causes. A diagnosis does not establish that a person has too much or too little of one neurotransmitter. Genetics, development, physical health, experiences, and the social environment can interact. The biopsychosocial model considers biological, psychological, and social influences together.

Stress and the Body

During a perceived threat, sympathetic nervous system activity may increase heart rate, breathing, and sweating. The hypothalamus also helps coordinate hormonal responses. These responses can be helpful briefly; repeated or persistent stress can affect well-being. Physical symptoms during anxiety are real experiences. New chest pain, breathing difficulty, or sudden confusion still requires appropriate medical assessment.

Functions Described in Mental Health Assessment

Functions Described in Mental Health Assessment

Function	Meaning	Example of terminology
Mood	A person's sustained internal emotional state	Depressed, anxious, euthymic
Affect	Observable expression of emotion	Tearful, restricted, flat
Cognition	Thinking, attention, memory, and related mental processes	Impaired concentration

Function	Meaning	Example of terminology
Perception	Interpretation of sensory information	Hallucination, illusion
Thought process	How ideas are organized and connected	Linear, disorganized
Thought content	What a person is thinking about	Worries, obsessions, delusions
Insight	Awareness and understanding of one's condition	Recognizes that symptoms may reflect illness
Judgment	Ability to weigh options and consequences	Chooses a safe response to a problem

Mood is usually obtained from the person's report; affect is observed. A person may report feeling sad while showing little facial expression. Document the report and observation separately.

Common Mental Health Medical Terms

These terms describe symptoms or findings. They do not independently establish a diagnosis. Pronunciations are approximate, with the stressed syllable in capitals; accepted pronunciations may vary.

Common Mental Health Medical Terms

Term	Pronunciation	Meaning
Anhedonia	an-hee-DOH-nee-uh	Reduced ability to experience pleasure
Anxiety	ang-ZY-uh-tee	Apprehension, uneasiness, or worry
Apathy	AP-uh-thee	Reduced interest or motivation
Delusion	dih-LOO-zhun	Fixed false belief maintained despite contrary evidence and assessed in cultural context
Dysphoria	dis-FOR-ee-uh	Distress or an unpleasant emotional state
Echolalia	ek-oh-LAY-lee-uh	Repetition of another person's words
Euphoria	yoo-FOR-ee-uh	Markedly elevated feeling of well-being
Hallucination	huh-loo-sih-NAY-shun	Sensory experience without a corresponding external stimulus
Insomnia	in-SOM-nee-uh	Difficulty falling asleep, staying asleep, or obtaining satisfactory sleep
Obsession	ob-SESH-un	Intrusive, unwanted recurring thought, urge, or image
Compulsion	kum-PUL-shun	Repetitive behavior or mental act a person feels driven to perform
Psychosis	sy-KOH-sis	Symptoms involving disruption in the experience or interpretation of reality

Hallucinations may involve hearing, vision, smell, taste, or touch. An illusion differs: it is a misinterpretation of a real stimulus, such as mistaking a coat on a chair for a person. A hallucination or delusion may occur in more than one condition, including medical or substance-related conditions.

An obsession is a thought, urge, or image; a compulsion is an action or mental ritual. For example, an unwanted fear of contamination may be accompanied by repeated handwashing. Enjoying order or checking a door once does not by itself establish obsessive-compulsive disorder.

Somatic means pertaining to the body. It does not mean a symptom is imaginary. Similarly, suicidal ideation means thoughts about suicide; the term does not by itself specify intent or a plan. Statements about suicide require prompt assessment and communication according to the care setting's safety procedures.

Common Diseases and Disorders

The descriptions below introduce terminology, not complete diagnostic criteria. Qualified clinicians determine diagnoses through assessment and consideration of other possible explanations.

Depressive Disorders

Major depressive disorder involves persistent depressed mood or loss of interest or pleasure, with additional symptoms that interfere with functioning. Symptoms may include changes in sleep or appetite, low energy, difficulty concentrating, feelings of worthlessness, and thoughts of death. A major depressive episode generally includes symptoms present most of the day, nearly every day, for at least two weeks, together with other required criteria.

Persistent depressive disorder involves a longer-lasting pattern of depressive symptoms. Seasonal affective disorder refers to depression with a recurring seasonal pattern. Anhedonia describes a symptom; major depressive disorder names a disorder. Sadness alone does not establish the diagnosis.

Bipolar Disorders

Bipolar disorders involve episodes of altered mood, energy, and activity. Mania is an episode of abnormally elevated, expansive, or irritable mood accompanied by increased energy or activity and other symptoms. These may include decreased need for sleep, rapid speech, grandiosity, and risky behavior. Hypomania involves a less severe episode that differs in duration and degree of impairment.

Bipolar I disorder requires a history of at least one manic episode; a major depressive episode is not required. Bipolar II disorder involves hypomanic and major depressive episodes without a history of a manic episode. These diagnoses do not simply mean that a person's mood changes quickly.

Anxiety Disorders

Generalized anxiety disorder involves persistent, difficult-to-control anxiety and worry about multiple areas of life. Associated symptoms may include restlessness, muscle tension, sleep problems, fatigue, or difficulty concentrating. A person can feel anxious without having generalized anxiety disorder.

Panic disorder involves recurrent, unexpected panic attacks with persistent concern or behavioral changes related to the attacks. A panic attack is a sudden surge of intense fear or discomfort with physical and emotional symptoms. A single panic attack does not establish panic disorder.

A specific phobia involves marked fear or anxiety about a particular object or situation, such as heights. Agoraphobia involves fear or avoidance of situations where escape may be difficult or help unavailable if panic-like or other incapacitating symptoms occur. It is broader than "fear of open spaces."

Obsessive Compulsive and Related Disorders

Obsessive-compulsive disorder (OCD) involves obsessions, compulsions, or both that are time-consuming or cause significant distress or impairment. Body dysmorphic disorder involves preoccupation with perceived appearance flaws that are not noticeable or appear slight to others, accompanied by repetitive behaviors or mental acts. OCD belongs to its own DSM grouping rather than the anxiety disorders grouping.

Trauma and Stressor Related Disorders

Posttraumatic stress disorder (PTSD) may develop following exposure to a qualifying traumatic event. Symptoms can include intrusive memories or nightmares, avoidance, negative changes in mood or thinking, and heightened arousal or reactivity. Symptoms persist for more than one month and cause distress or impairment. Exposure to trauma does not mean that a person will develop PTSD.

Hypervigilance means heightened watchfulness for danger. A flashback is a form of re-experiencing in which the person may feel that a traumatic event is happening again. These are symptom terms rather than stand-alone diagnoses.

Schizophrenia Spectrum and Other Psychotic Disorders

Schizophrenia can affect thinking, perception, emotion, and behavior. Symptoms may include hallucinations, delusions,

disorganized speech, reduced emotional expression, reduced motivation, and cognitive difficulties. Positive symptoms are experiences or behaviors added to usual functioning; negative symptoms involve reductions in usual functioning. “Positive” and “negative” do not mean good and bad.

Psychosis is not synonymous with schizophrenia and may occur with other psychiatric disorders, substances, or medical conditions. Schizophrenia is also distinct from dissociative identity disorder. Its historical word roots should not be used as a complete clinical definition.

Feeding and Eating Disorders

Anorexia nervosa involves restricted energy intake resulting in significantly low body weight, with intense fear of weight gain or related behaviors and disturbance in the experience of weight or shape. Bulimia nervosa involves recurrent binge eating followed by compensatory behaviors, such as self-induced vomiting. Binge-eating disorder involves recurrent binge eating without regular compensatory behaviors.

Anorexia alone means loss of appetite. It is not equivalent to anorexia nervosa, and a person with anorexia nervosa may still feel hungry. Eating disorders can have serious physical effects and cannot be identified reliably by appearance alone.

Substance Related Disorders

A substance use disorder involves a problematic pattern of substance use associated with impairment or distress. Alcohol use disorder is one example. Intoxication refers to substance-specific changes that occur during or after recent substance use. Withdrawal refers to symptoms that develop after reducing or stopping a substance following repeated use and physiological adaptation.

Physical dependence means physiological adaptation and can occur with prescribed medications. It is not, by itself, equivalent to a substance use disorder. Delirium tremens is a severe form of alcohol withdrawal involving delirium and other signs; it is a medical emergency.

Personality Disorders

Personality disorders involve enduring patterns of inner experience and behavior that cause distress or impairment and are evaluated in developmental and cultural context. Borderline personality disorder can involve difficulty regulating emotions, an unstable sense of self, impulsivity, and relationship difficulties. It is distinct from bipolar disorder. A personality disorder diagnosis should never replace an objective description of a person’s current needs.

Delirium and Neurocognitive Conditions

Delirium is an acute, often fluctuating disturbance in attention and awareness, with additional cognitive changes. Potential causes include illness, medication effects, intoxication, and withdrawal. A sudden change in mental status requires prompt medical evaluation.

Major neurocognitive disorder, commonly called dementia, involves significant cognitive decline that interferes with independent daily functioning. It usually develops more gradually than delirium. Delirium can also occur in a person who already has dementia. Neither condition should be dismissed as an expected feature of aging.

Concept Check

1. Explain the difference between a panic attack and panic disorder.
2. Is anhedonia a symptom or a disorder name?
3. Why should sudden confusion receive medical assessment?

Diagnostic and Assessment Procedures

Clinical Interview and Mental Status Examination

A clinical interview gathers information about symptoms, health history, medications, substance use, functioning, and supports. A mental status examination (MSE) describes current appearance, behavior, speech, mood, affect, thought, perception, cognition, insight, and judgment. It provides a snapshot of current functioning and may change over time.

A mental status examination differs from a Mini-Mental State Examination (MMSE), which is a specific cognitive screening instrument. Do not use the abbreviations interchangeably.

Screening Tools

A screening tool helps identify people who may need further evaluation. The Patient Health Questionnaire-9 (PHQ-9) screens for depressive symptoms; the Generalized Anxiety Disorder-7 (GAD-7) screens for anxiety symptoms. Screening results are interpreted with history, functioning, and other assessment findings. A score alone does not establish a diagnosis.

Medical Evaluation and Psychological Testing

Physical examination and selected laboratory tests may help identify medical contributors to symptoms. Testing might investigate thyroid dysfunction, metabolic problems, medication effects, or substance exposure when clinically indicated. There is no routine blood test or brain scan that independently diagnoses depression or schizophrenia.

Psychological testing may examine cognition, emotional functioning, or behavior. Neuropsychological testing examines abilities such as memory, attention, and executive functioning in greater detail. Imaging or electroencephalography may be used when the history suggests a neurological or other medical condition; these are not universal mental health screening tests.

Terminology Connection

Assessment collects and interprets information. Screening identifies possible concerns. Diagnosis identifies a condition after appropriate evaluation. A differential diagnosis considers alternative explanations for the same symptoms.

Therapeutic Procedures and Treatments

Psychotherapy

Psychotherapy uses psychological methods to address distressing thoughts, emotions, and behaviors. It can be provided individually, with families, or in groups. Cognitive behavioral therapy (CBT) helps people examine patterns of thinking and behavior and develop useful skills. Exposure-based therapies help people approach feared situations or experiences in a planned therapeutic process.

Dialectical behavior therapy (DBT) teaches skills such as mindfulness, managing distress, regulating emotions, and communicating effectively. Psychoeducation helps people and families understand symptoms, treatment, and ways to support recovery. The appropriate approach depends on the person's needs and goals.

Medication Therapy

Psychotropic medications affect mental processes, emotion, or behavior. Major categories include antidepressants, antipsychotics, mood stabilizers, and anti-anxiety medications. A medication class name does not identify every possible use: an antidepressant may be used for an anxiety disorder, and some antipsychotics are used for bipolar disorder.

Antidepressants are used for depression and several other conditions. Antipsychotics may reduce psychotic symptoms. Mood stabilizers help manage mood episodes in bipolar disorder. Anxiolytic means anxiety-reducing. Medication effects, adverse effects, and monitoring needs vary; these vocabulary categories are not treatment instructions.

Brain Stimulation Therapies

Electroconvulsive therapy (ECT) uses a controlled electrical stimulus to produce a therapeutic seizure under general anesthesia with a muscle relaxant. It may be used for certain severe conditions, including severe depression. Possible adverse effects include temporary confusion and memory difficulties.

Repetitive transcranial magnetic stimulation (rTMS) uses magnetic pulses to stimulate targeted brain regions. It generally does not require anesthesia and differs from ECT. These are therapeutic procedures, not diagnostic tests.

Recovery and Rehabilitation

Recovery is a personal process of improving well-being and pursuing a meaningful life. Services may include support with daily routines, housing, education, employment, relationships, and management of physical health. Peer support involves assistance from people who draw on relevant lived experience. Recovery goals are developed with the person receiving care.

Mental Health Medical Abbreviations

Spell out an abbreviation on first use and follow the care setting's approved terminology. Several abbreviations have more than one meaning.

Mental Health Medical Abbreviations

Abbreviation	Meaning or caution
ADLs	Activities of daily living
ADHD	Attention-deficit/hyperactivity disorder
AUD	Alcohol use disorder
BD	Bipolar disorder; confirm context
BDD	Body dysmorphic disorder
BPD	Often borderline personality disorder; avoid confusing it with bipolar disorder
CBT	Cognitive behavioral therapy
DBT	Dialectical behavior therapy
DSM-5-TR	Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision
DTs	Delirium tremens
ECT	Electroconvulsive therapy
GAD	Generalized anxiety disorder
GAD-7	Generalized Anxiety Disorder-7 screening tool
ICD	International Classification of Diseases
ID	Intellectual disability in this context; may have other meanings
MDD	Major depressive disorder
MSE	Mental status examination
OCD	Obsessive-compulsive disorder
ODD	Oppositional defiant disorder
PD	May mean panic disorder, personality disorder, or Parkinson disease; clarify
PHQ-9	Patient Health Questionnaire-9
PTSD	Posttraumatic stress disorder

Abbreviation	Meaning or caution
SAD	May mean seasonal affective disorder or social anxiety disorder; clarify
SUD	Substance use disorder
rTMS	Repetitive transcranial magnetic stimulation

Avoid BP for bipolar disorder because it commonly means blood pressure. In plain language, name a disorder in full when an abbreviation might confuse the reader.

Health Care Professionals Related to Mental Health

Mental health care often involves a team. Titles, licensing requirements, and authorized services vary by jurisdiction.

Health Care Professionals Related to Mental Health

Professional	General role
Psychiatrist	Physician who evaluates mental health conditions and may provide psychotherapy, prescribe medication, and arrange other medical treatments
Psychologist	Professional trained in psychology; clinical services may include assessment, testing, and psychotherapy; prescribing authority depends on jurisdiction and additional training
Psychiatric mental health nurse practitioner	Advanced practice registered nurse who may assess, diagnose, provide treatment, and prescribe within applicable law
Psychiatric mental health registered nurse	Provides nursing assessment, therapeutic communication, medication administration, education, and coordination of care
Clinical social worker	May provide psychotherapy, assess psychosocial needs, and connect people with services
Licensed professional counselor	Provides counseling and related services within the professional license
Occupational therapist	Supports participation in meaningful activities, routines, and daily living
Peer support specialist	Uses relevant lived experience and training to support recovery and connection

Medical Terminology in Context

These fictional scenarios are for terminology practice. They do not provide enough information to make a diagnosis.

Scenario One

Jordan reports, “I used to enjoy cooking, but nothing feels enjoyable anymore.” Jordan also reports difficulty falling asleep and feeling sad most days. During the interview, Jordan speaks quietly and has limited facial expression.

1. Which term describes reduced pleasure?
2. Which term describes the sleep complaint?
3. Which findings describe mood and which describe affect?
4. Why should a learner avoid diagnosing major depressive disorder from this paragraph alone?

Scenario Two

Riley repeatedly experiences an unwanted fear of contamination. Riley washes their hands for extended periods and misses the bus because of the washing routine. A clinician recommends CBT that includes exposure and response prevention.

1. Identify the obsession and the compulsion.
2. Expand CBT.

3. Classify CBT as an anatomic, diagnostic, disease and disorder, or therapeutic term.

Scenario Three

An older adult admitted with pneumonia becomes newly disoriented, has trouble sustaining attention, and fluctuates between drowsiness and restlessness. Family members report that this behavior began today.

1. Which term may describe this acute change?
2. Why should the change be reported promptly?
3. Rewrite “The patient is acting crazy” using the observations in the scenario.

Scenario Four

A referral says “PD; evaluate for CBT.” The record also mentions tremor and several neurological appointments.

1. Why is PD unclear?
2. What should the health care worker do before interpreting or expanding it?

Test Yourself

1. Define psychology in one sentence.
2. What is the main purpose of the DSM-5-TR?
3. Which describes a sensory experience without an external stimulus: delusion, hallucination, or compulsion?
4. Explain the difference between mood and affect.
5. Define withdrawal in the context of substance use.
6. Is a screening result the same as a confirmed diagnosis? Explain.
7. Categorize each term as anatomic, diagnostic or assessment, disease and disorder, or therapeutic: hippocampus; mental status examination; bipolar I disorder; ECT.
8. Build a term meaning study of the mind using psych/o and a suffix.
9. Why can anorexia and anorexia nervosa not be used interchangeably?
10. Replace “an alcoholic” with respectful clinical language.
11. Explain why schizophrenia should not be defined as split personality.
12. Say anhedonia, psychosis, and dysphoria aloud. Define each in everyday language.

Suggested Media and Further Learning

The following resources support the chapter. Videos are supplementary.

- YouTube Video

  This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

  View this YouTube Video online

  Intro to Psychology — Crash Course Psychology 1: https://youtu.be/vo4pMVb0R6M.

- After viewing, explain how psychology differs from psychiatry. This link was supplied in the existing chapter.

YouTube Video

- *This interactive element is not available in this format. Visit the link or scan the QR code to access it online.*

  View this YouTube Video online

Emotion Stress and Health — Crash Course Psychology 26: https://youtu.be/4KbSRXP0wik.

- After viewing, identify two physical responses to stress. This link was supplied in the existing chapter.
- NIMH Brain Stimulation Therapies: https://www.nimh.nih.gov/health/topics/brain-stimulation-therapies/brain-stimulation-therapies. Includes an overview video; compare ECT and rTMS.
- NIMH Health Topics: https://www.nimh.nih.gov/health/topics. Choose one condition and identify a symptom term, a disorder name, and a treatment term.

Attributions

The instructor supplied the original chapter text and muscular system chapter used to guide scope and organization. This expanded chapter includes newly written explanations, revised terminology tables, and original practice scenarios.

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20: Oncology

Oncology Terminology

Oncology terminology helps health care workers describe abnormal cell growth, cancer diagnosis, treatment, and follow-up accurately. This chapter connects word parts with the behavior of cells and tissues, introduces common cancer names, and explains terms used in imaging, pathology, and treatment reports. You will practice translating professional language into clear, respectful explanations for a person receiving care.

Learning Objectives

- Apply medical language rules to build, analyze, spell, pronounce, and define selected oncology terms.
- Identify meanings of common oncology prefixes, combining forms, and suffixes.
- Describe normal cell growth and selected changes associated with neoplasia.
- Distinguish benign growths, in situ lesions, invasive cancer, and metastatic cancer.
- Differentiate tumor grade from cancer stage and interpret the components of TNM terminology.
- Categorize anatomic, diagnostic, disease and disorder, and therapeutic terms related to oncology.
- Interpret common oncology abbreviations in context.
- Identify professionals involved in cancer care and use accurate terminology in short health care scenarios.

Introduction to Oncology

Oncology is the branch of medicine concerned with cancer. An oncologist is a physician who diagnoses or treats cancer. Cancer includes many diseases in which abnormal cells grow without normal regulation and may invade nearby tissues or spread to distant sites. Many cancers form solid tumors, but cancers such as leukemia generally do not.

A neoplasm is an abnormal growth of tissue. Neoplasms may be benign, meaning noncancerous, or malignant, meaning cancerous. Benign does not mean harmless: a benign growth can press on an organ, obstruct a passageway, or produce excess hormones. A mass or nodule is a finding that needs interpretation; neither word automatically means cancer.

Cancer names often describe the tissue or organ where the cancer began. A carcinoma arises from epithelial tissue, while a sarcoma arises from connective or supportive tissues. Not all malignant tumors are carcinomas, and not all words ending in -oma name benign tumors. Melanoma, lymphoma, and myeloma are important malignant examples.

Language Matters

Use “person with cancer” or the person’s preferred wording. Avoid describing a person as a diagnosis. Explain unfamiliar words before using abbreviations, and avoid assuming that a cancer name alone predicts the outcome. Prognosis depends on multiple factors, and an individual’s experience cannot be determined from a population statistic alone.

For example, “The biopsy showed cancer cells in the tissue sample” is clearer than “Your Bx is positive for CA.” When explaining benign, say “The growth is not cancerous,” rather than promising that it cannot cause any problems.

Oncology Word Parts

A prefix appears before a root. A combining form includes a root and a combining vowel, often o. A suffix appears at the end. Word parts provide useful clues, but students must also learn the clinical meaning of the whole term.

Common Prefixes

Common Prefixes

Prefix	Meaning	Example
ana-	Up, back, again; meaning depends on the term	Anaplasia
anti-	Against	Antineoplastic
apo-	Away from	Apoptosis
dys-	Abnormal, difficult	Dysplasia
ecto-	Outside, outer	Ectoderm
endo-	Within	Endoscopy
hyper-	Excessive, increased	Hyperplasia
hypo-	Below normal, decreased	Hypoplasia
meta-	Beyond, change	Metastasis
neo-	New	Neoplasm
peri-	Around	Peritumoral

Common Combining Forms

Common Combining Forms

Combining form	Meaning	Example
aden/o	Gland	Adenocarcinoma
angi/o	Vessel	Angiogenesis
capsul/o	Capsule, enclosing structure	Encapsulated
carcin/o	Cancer	Carcinogen
cyt/o	Cell	Cytology
hemat/o	Blood	Hematology
hist/o	Tissue	Histology
immun/o	Immune protection	Immunotherapy
leiomy/o	Smooth muscle	Leiomyoma
lip/o	Fat	Lipoma
lymph/o	Lymph, lymphatic tissue	Lymphoma
melan/o	Dark pigment, black	Melanoma
mutat/o	Change	Mutation
myel/o	Bone marrow or spinal cord, depending on context	Myeloma
nephr/o	Kidney	Nephroblastoma
nod/o	Node, knot	Nodal
onc/o	Tumor	Oncology
oste/o	Bone	Osteosarcoma
path/o	Disease	Pathology
radi/o	Radiation	Radiotherapy

Combining form	Meaning	Example
sarc/o	Flesh, connective tissue	Sarcoma

Common Suffixes

Common Suffixes

Suffix or ending	Meaning	Example
-blastoma	Tumor associated with immature or developing cells	Nephroblastoma
-carcinoma	Malignant epithelial tumor	Adenocarcinoma
-ectomy	Surgical removal	Mastectomy
-gen	Producing, causing	Carcinogen
-genesis	Formation, origin, production	Angiogenesis
-logist	Specialist	Oncologist
-logy	Study of	Oncology
-oma	Tumor or mass; does not establish whether benign or malignant	Lipoma, melanoma
-penia	Deficiency, reduced number	Neutropenia
-plasia	Formation, development, growth	Hyperplasia
-plasm	Formation, growth	Neoplasm
-sarcoma	Malignant connective or supportive tissue tumor	Osteosarcoma
-scopy	Visual examination with an instrument	Colonoscopy
-stasis	Standing, stopping; whole-word meaning varies	Metastasis
-therapy	Treatment	Chemotherapy

Terminology Connection

Mutat/o is a combining form, not a prefix. The complete ending is -carcinoma, rather than -carcinom. Metastasis means spread of cancer to another site; it should not be defined by translating -stasis alone. Likewise, apoptosis and anaplasia require whole-word definitions. Myel/o refers to bone marrow in myeloma but to the spinal cord in some other terms.

The original word-part activity credited to Connie Stevens can remain a separate activity. These tables revise categories, clarify meanings, and add forms used throughout this chapter.

Building and Analyzing Terms

Building and Analyzing Terms

Term	Word parts	Meaning
Oncology	onc/o + -logy	Field concerned with tumors and cancer
Carcinogen	carcin/o + -gen	Agent capable of causing cancer
Adenocarcinoma	aden/o + -carcinoma	Cancer with glandular epithelial features
Osteosarcoma	oste/o + -sarcoma	Malignant tumor in which cancer cells produce bone
Hyperplasia	hyper- + -plasia	Increased number of cells in a tissue
Neoplasm	neo- + -plasm	Abnormal new growth of tissue
Angiogenesis	angi/o + -genesis	Formation of blood vessels

Concept Check

1. Why does the ending -oma not establish that a tumor is benign?
2. Which combining form refers to tissue, and which refers to cells?
3. Build a term for a malignant tumor with glandular epithelial features.

Anatomy Related to Oncology

Cancer may arise in almost any part of the body. Because oncology is not one organ system, this anatomy review focuses on structures that appear repeatedly in cancer terminology.

Anatomy Related to Oncology

Structure	Relevance to oncology
Epithelial tissue	Covers surfaces and lines organs and glands; carcinomas arise here
Connective and supportive tissues	Include bone, cartilage, fat, and muscle; sarcomas arise in these tissue families
Bone marrow	Produces blood cells; involved in leukemias and several other hematologic cancers
Lymphatic tissue	Includes lymphocytes in lymph nodes and other sites; lymphomas arise from lymphocytes
Blood and lymph vessels	Can provide routes for cancer cells to travel
Basement membrane	A thin supporting layer beneath epithelium; its relationship to tumor cells helps distinguish in situ from invasive disease

A lymph node is an immune system structure that filters lymph. Enlarged lymph nodes may reflect infection, inflammation, or cancer. Lymphadenopathy means abnormal or enlarged lymph nodes; it is a finding, not a synonym for lymphoma.

Physiology of Normal and Abnormal Cell Growth

Cell Division and Cell Death

Normal tissues balance cell division, specialization, and cell death. Mitosis is cell division that produces two daughter cells. Differentiation is the development of specialized cell features and functions. Apoptosis is a regulated process of programmed cell death. Cancer can develop when genetic changes disrupt the controls governing growth, division, DNA repair, or cell death.

Cancer is a genetic disease because it involves changes in genes; that does not mean every cancer is inherited. Somatic changes arise in cells during a person's lifetime. Germline changes are present in egg or sperm cells and may be inherited. A hereditary cancer predisposition increases risk but does not guarantee cancer will develop.

Describing Changes in Tissue

Describing Changes in Tissue

Term	Meaning	Important distinction
Hyperplasia	Increase in the number of cells	May be a response to normal signals or a pathologic process; not automatically cancer
Hypertrophy	Increase in cell size	Differs from an increase in cell number
Metaplasia	Replacement of one mature cell type by another	Not itself synonymous with malignancy

Term	Meaning	Important distinction
Dysplasia	Abnormal cellular appearance and tissue organization	May be precancerous in some settings; not every dysplastic lesion becomes cancer
Anaplasia	Marked loss of normal cellular differentiation	Often associated with aggressive malignant features
Neoplasia	Abnormal new tissue growth	May be benign or malignant

These terms do not describe an inevitable sequence that every tissue follows. A hyperplastic tissue does not necessarily progress to dysplasia or cancer. Clinical meaning depends on the organ, findings, and diagnosis.

Invasion and Metastasis

Local invasion means extension into neighboring tissues. Metastasis means spread from the primary site to another part of the body, producing secondary disease. Cancer cells may travel through lymphatic or blood vessels. Angiogenesis, the formation of new blood vessels, can help supply a growing tumor.

The primary site is where the cancer began. If breast cancer spreads to the liver, the disease in the liver is metastatic breast cancer, not a new primary liver cancer. The plural of metastasis is metastases.

Concept Check

1. How does hyperplasia differ from hypertrophy?
2. Why does genetic not always mean inherited?
3. How should colon cancer that spreads to the lung be named?

Cancer Risk and Prevention Terminology

A risk factor increases the chance of developing a condition. A carcinogen is an agent capable of causing cancer. Tobacco smoke, ultraviolet radiation, and certain infections are examples of exposures associated with cancer. Other influences include age, inherited predisposition, alcohol use, and selected environmental or occupational exposures. Not all bacteria, viruses, chemicals, or radiation exposures have the same effects.

A risk factor does not prove why an individual developed cancer. Likewise, a person without a recognized risk factor can develop cancer. Prevention means reducing risk where possible; it does not guarantee that cancer will never occur. Use factual language that avoids blame.

Screening looks for cancer or precancerous changes before symptoms appear. Diagnostic testing investigates a symptom, abnormal finding, or positive screening result. A positive screening result is not the same as a confirmed cancer diagnosis. Screening methods and eligibility depend on the cancer, age, risk, and current guidance.

Benign and Malignant Growths

Benign and Malignant Growths

Feature	Benign growth	Malignant growth
Cancer status	Noncancerous	Cancerous
Local behavior	May enlarge or compress surrounding structures	May invade nearby tissues
Distant spread	Does not metastasize	May metastasize
Growth rate	Variable	Variable; not all cancers grow rapidly

Feature	Benign growth	Malignant growth
Clinical effects	May cause serious problems because of location or function	Effects vary with type, location, extent, and other features

An adenoma is a benign epithelial tumor with glandular features. A lipoma is a benign tumor of fat. A leiomyoma is a benign smooth muscle tumor; uterine fibroids are common examples. By contrast, leiomyosarcoma is malignant. The full term matters more than the last few letters alone.

Carcinoma in situ describes abnormal epithelial cells that remain confined to their original compartment without invasion into underlying tissue. In situ means “in its original place.” Invasive carcinoma has grown beyond that boundary. A lesion can be noninvasive and still require treatment or monitoring; noninvasive and benign are not interchangeable terms.

Common Cancer Families and Body Sites

Carcinomas and Sarcomas

Carcinomas include adenocarcinoma and squamous cell carcinoma. They occur in organs such as the breast, colon, lung, prostate, and skin. Sarcomas include osteosarcoma, liposarcoma, and leiomyosarcoma. A sarcoma is not named by simply adding -oma to any tissue root; learn the complete tumor name.

Leukemia Lymphoma and Myeloma

Leukemia involves blood-forming tissues and abnormal blood cells. Lymphoma arises in lymphocytes and may involve lymph nodes or other organs; it does not mean any lump in a lymph node. Hodgkin lymphoma and non-Hodgkin lymphomas are major lymphoma groupings. Myeloma is a malignancy of plasma cells, which are antibody-producing immune cells commonly found in bone marrow.

Breast and Reproductive Organs

Invasive ductal carcinoma begins in breast duct cells and extends into surrounding tissue. Invasive lobular carcinoma begins in milk-producing lobules. Ductal carcinoma in situ (DCIS) remains within ducts without invasion into surrounding breast tissue. Paget disease of the breast affects the nipple and areola and is distinct from Paget disease of bone. Breast cancer can occur in men as well as women.

Other reproductive cancer names include cervical, endometrial, ovarian, testicular, and prostate cancer. Endometrial refers to the lining of the uterus. Orchiectomy, also called orchidectomy, means surgical removal of a testicle. An inguinal orchiectomy is commonly part of testicular cancer diagnosis and treatment; additional care depends on type and stage. Fertility preservation may be discussed before treatment.

Benign prostatic hyperplasia (BPH) is noncancerous enlargement of the prostate. Urinary symptoms or an enlarged prostate do not automatically require a biopsy. Assessment may include history, examination, laboratory testing, and other investigations based on the findings. Prostate cancers vary: some grow slowly, while others behave aggressively.

Gastrointestinal and Pancreatic Cancers

Cancer may arise in the esophagus, stomach, colon, rectum, liver, or pancreas. Colorectal means pertaining to the colon and rectum. The pancreas contains exocrine tissue that produces digestive secretions and endocrine tissue that produces hormones. Most pancreatic cancers arise from exocrine tissue; pancreatic neuroendocrine tumors are a different group.

Pancreatic cancer is often difficult to treat, but effective treatments are available. Depending on the disease and the person’s situation, options may include surgery, chemotherapy, radiation, or selected targeted or immune treatments. Prognosis varies with the cancer type, stage, and response to treatment.

Skin Cancers

Basal cell carcinoma and squamous cell carcinoma are common skin cancers. Melanoma arises from melanocytes, the pigment-producing cells. Although melanoma can spread and become life-threatening, outcomes depend on stage and other features; the name should not be defined simply as “a deadly skin cancer.” Skin cancer can occur in any skin tone.

The ABCDE features help describe suspicious pigmented lesions. They are recognition clues rather than a diagnosis.

Skin Cancers

Letter	Feature	Description
A	Asymmetry	One half differs from the other
B	Border	Irregular, notched, blurred, or poorly defined edges
C	Color	Uneven or varied color
D	Diameter	Often greater than 6 mm, but melanoma may be smaller
E	Evolving	Change in size, shape, color, symptoms, or other features

An irregular border does not establish that cancer has spread. Evolving is broader than elevation: a lesion does not need to be raised to be concerning. A new or changing lesion warrants clinical assessment.

Urinary and Endocrine Cancers

Renal cell carcinoma arises in kidney tissue. Urothelial carcinoma commonly involves the bladder lining and may occur elsewhere in the urinary tract. Wilms tumor, also called nephroblastoma, is a childhood kidney cancer. It is not accurate to assume every affected child was born with a detectable tumor. Treatment commonly combines surgery and chemotherapy, with radiation in selected cases; many children can be cured.

Thyroid cancers differ in behavior and treatment. Thyroidectomy means removal of part or all of the thyroid gland. After total thyroidectomy, thyroid hormone replacement is needed. Some thyroid cancers may also be treated with radioactive iodine or other therapies; treatment is not identical for every thyroid tumor.

Diagnostic Tools and Pathology

Biopsy and Tissue Examination

A biopsy removes cells or tissue for examination. An incisional biopsy samples part of a lesion; an excisional biopsy removes the entire lesion for evaluation. A needle biopsy obtains a sample through a needle. Cytology examines cells, while histology examines tissue structure. A pathologist interprets laboratory and tissue findings.

A pathology report may identify the tumor type, grade, invasion, margin status, and other features. A surgical margin is the edge of removed tissue. A negative margin means cancer cells were not identified at the examined edge; a positive margin means cancer cells were found there. Margin status alone does not describe the extent of disease elsewhere in the body.

Imaging and Endoscopy

Computed tomography (CT) uses x-rays to create detailed cross-sectional images. Magnetic resonance imaging (MRI) uses magnetic fields and radio waves. Ultrasound uses sound waves. Positron emission tomography (PET) uses a radioactive tracer to show selected metabolic activity. Imaging can locate abnormalities and help assess disease extent, but an imaging finding does not always establish its cause.

Endoscopy uses an instrument to view an internal structure. Colonoscopy examines the colon and may allow removal of a polyp or collection of a biopsy. Some procedures can be used for screening or diagnosis, depending on why they are performed.

Laboratory Tests and Biomarkers

A complete blood count (CBC) measures blood cells. A fecal occult blood test (FOBT) looks for hidden blood in stool; a fecal immunochemical test (FIT) detects human blood using antibodies. A positive stool screening test requires follow-up and does not itself confirm colorectal cancer.

A tumor marker or biomarker is a measurable characteristic that can provide information about disease. Examples include prostate-specific antigen (PSA), estrogen receptor (ER), progesterone receptor (PR), and human epidermal growth factor receptor 2 (HER2). The role of a marker depends on the cancer and test: it may help assess risk, guide treatment, monitor response, or detect recurrence.

Biomarker testing of a tumor may identify changes that help guide treatment. A liquid biopsy looks for tumor-related material in a body fluid, often blood. Tumor testing and testing for inherited cancer susceptibility answer different questions. A marker result alone may not confirm or exclude cancer, and finding a target does not guarantee a response to treatment.

Screening and Symptom Awareness

Knowing usual breast or testicular appearance and reporting a new change can support timely evaluation. Breast self-examination is not a substitute for recommended screening mammography. There is no standard routine testicular cancer screening test for everyone. Neither BSE nor TSE should be presented as a universal requirement that determines whether a person has cancer.

Tumor Grade and Cancer Stage

Grade

Grade describes microscopic tumor features, including how abnormal cells look and how differentiated they are. In general, higher-grade tumors tend to behave more aggressively. Grading systems vary; some use numbers, others low and high categories, and some use specialized scores. Grade is not a universal I-to-IV measurement of cancer severity.

Stage

Stage describes the extent of disease. Clinical staging uses information such as examination, imaging, and biopsies before definitive treatment. Pathologic staging adds findings from surgery and examination of removed tissue when applicable. Grade and stage answer different questions; a high-grade tumor is not automatically stage IV.

TNM Terminology

TNM is used for many solid tumors, with definitions specific to each cancer.

TNM Terminology

Component	What it describes
T	Size or local extent of the primary tumor
N	Involvement of regional lymph nodes
M	Presence or absence of distant metastasis

In many TNM systems, M0 indicates no evidence of distant metastasis and M1 indicates distant metastasis. Nodal involvement does not automatically mean distant metastasis. A designation such as T2 must be interpreted using the rules for that cancer; it does not always mean a tumor is 2 cm.

Many cancers use overall stages 0 through IV. Stage 0 commonly describes carcinoma in situ; stages I through III describe increasing local or regional extent, with cancer-specific differences; stage IV commonly indicates distant spread. Blood cancers and some other tumors use different systems, and some cancers do not use every stage.

Concept Check

1. Which describes microscopic cellular features: grade or stage?
2. What does the N in TNM describe?
3. Does a negative surgical margin prove that no cancer exists elsewhere?

Cancer Treatments and Therapeutic Terminology

Treatment may aim to cure disease, control its growth, reduce the chance of recurrence, or relieve symptoms. Plans depend on cancer type, extent, biomarkers, health status, and the person's goals. Local treatments act mainly on a defined area; systemic treatments travel through the body. A person may receive several treatment types.

Surgery and Radiation Therapy

Surgery may remove a tumor, obtain diagnostic tissue, or relieve symptoms. Resection means removal of tissue or part or all of an organ. Debulking removes part of a tumor mass when complete removal is not possible or appropriate. Lumpectomy removes a breast lesion with surrounding tissue; mastectomy removes breast tissue.

Radiation therapy uses radiation to damage cancer cells. External beam radiation comes from a machine outside the body. Brachytherapy places a radiation source in or near the treatment area. Some radiopharmaceutical treatments are systemic. Radiation used to create a diagnostic image and radiation delivered as treatment have different purposes.

Chemotherapy and Other Drug Treatments

Cytotoxic chemotherapy kills cells or interferes with cell division. It may also affect healthy rapidly dividing cells. A regimen is a planned treatment schedule, and a cycle includes treatment and an interval before the next treatment. Antineoplastic means acting against neoplastic growth.

Chemotherapy and Other Drug Treatments

Drug category	General action or purpose
Alkylating agents	Damage DNA and interfere with cell replication
Antimetabolites	Interfere with processes needed to make DNA or RNA
Microtubule inhibitors	Disrupt structures needed for cell division
Targeted therapies	Act on selected molecular features involved in cancer growth or survival
Immunotherapies	Help the immune system recognize or attack cancer
Hormone therapies	Reduce hormone production or block hormone effects in hormone-sensitive cancers

These categories do not mean every drug has the same risks or works for every cancer. Some treatments overlap categories; for example, certain monoclonal antibodies can be described as targeted therapy and immunotherapy. Targeted therapy can still cause serious adverse effects.

Stem Cell Transplantation

Hematopoietic stem cell transplantation restores blood-forming cells after certain intensive treatments. Autologous transplantation uses the person's own cells; allogeneic transplantation uses donor cells. Stem cells may come from peripheral blood, bone marrow, or cord blood. Bone marrow transplant is one form of this treatment, not a routine therapy for every bone or muscle cancer.

Timing and Goals of Treatment

Timing and Goals of Treatment

Term	Meaning
Neoadjuvant therapy	Treatment given before the main treatment, often to reduce tumor size
Adjuvant therapy	Additional treatment after the primary treatment to reduce recurrence risk
Maintenance therapy	Treatment continued to help sustain disease control in selected conditions
Active surveillance	Planned monitoring, with treatment considered if defined changes occur
Palliative care	Care addressing symptoms, distress, and quality of life alongside other appropriate care

Palliative care can begin at diagnosis and may accompany treatment intended to cure cancer. It is not synonymous with hospice. Hospice generally emphasizes comfort when care is directed toward the end of life; eligibility and services depend on the care system.

Treatment Effects and Supportive Care Vocabulary

Side effects vary by therapy and person. Understanding these terms supports accurate reporting and patient education.

Treatment Effects and Supportive Care Vocabulary

Term	Meaning
Alopecia	Hair loss
Anemia	Reduced red blood cells or hemoglobin, affecting oxygen-carrying capacity
Neutropenia	Low neutrophil count, which can increase infection risk
Thrombocytopenia	Low platelet count, which can increase bleeding risk
Mucositis	Inflammation or injury of a mucous membrane, often involving the mouth or digestive tract
Peripheral neuropathy	Nerve dysfunction that may cause numbness, tingling, pain, or weakness
Lymphedema	Swelling related to impaired lymph drainage
Extravasation	Leakage of an infused substance from a vessel into surrounding tissue
Antiemetic	Medication used to prevent or relieve nausea and vomiting

Fever or other signs of infection during treatment, especially with neutropenia, require prompt contact with the treating team. The team provides instructions about when and how to seek urgent assessment. A terminology learner should recognize the concern without assuming the cause or selecting treatment independently.

Remission Recurrence and Survivorship

Remission means a reduction or disappearance of signs and symptoms of cancer. Complete remission means all detectable signs of cancer have disappeared; partial remission means disease has decreased but remains detectable. Complete remission is not a guarantee that cancer will never return. Recurrence means cancer has returned after a period when it was not detected. Progression means the disease is growing or spreading.

No evidence of disease (NED) describes current test findings. Prognosis is an estimate of the likely course or outcome. Survivorship includes health and quality-of-life concerns following a cancer diagnosis, including during and after treatment. Follow-up may address recurrence, late effects, daily function, emotional well-being, and other health needs.

Oncology Medical Abbreviations

Interpret abbreviations in context and follow the care setting's approved usage. CA can mean cancer, while Ca commonly denotes

calcium; confirm the intended meaning rather than relying only on capitalization.

Oncology Medical Abbreviations

Abbreviation	Meaning
ANC	Absolute neutrophil count
BCC	Basal cell carcinoma
BMT	Bone marrow transplant
BPH	Benign prostatic hyperplasia
BSE	Breast self-examination; not a replacement for recommended screening
Bx	Biopsy
CBC	Complete blood count
CIS	Carcinoma in situ
CT	Computed tomography
DCIS	Ductal carcinoma in situ
ER and PR	Estrogen receptor and progesterone receptor
FIT	Fecal immunochemical test
FOBT	Fecal occult blood test
HER2	Human epidermal growth factor receptor 2
HSCT	Hematopoietic stem cell transplantation
mets	Informal shorthand for metastases; spell out in patient education
MRI	Magnetic resonance imaging
NED	No evidence of disease
PET	Positron emission tomography
PSA	Prostate-specific antigen
SCC	Squamous cell carcinoma in this context; may have other meanings
TNM	Tumor, regional nodes, distant metastasis
TSE	Testicular self-examination; not a universal routine screening requirement

Pronouncing Selected Oncology Terms

Pronunciations are approximate. Capital letters identify the stressed syllable; accepted pronunciations may vary.

Pronouncing Selected Oncology Terms

Term	Pronunciation	Everyday meaning
Oncology	on-KOL-uh-jee	Field of cancer medicine
Neoplasm	NEE-oh-plaz-um	Abnormal tissue growth
Benign	bih-NINE	Not cancerous
Malignant	muh-LIG-nunt	Cancerous
Carcinoma	kar-sih-NOH-muh	Cancer arising from epithelial cells
Sarcoma	sar-KOH-muh	Cancer arising from connective or supportive tissues

Term	Pronunciation	Everyday meaning
Metastasis	meh-TAS-tuh-sis	Spread of cancer to another site
Metastases	meh-TAS-tuh-seez	Plural of metastasis
Biopsy	BY-op-see	Removal of a sample for examination
Neutropenia	noo-troh-PEE-nee-uh	Low neutrophil count
Thrombocytopenia	throm-boh-sy-toh-PEE-nee-uh	Low platelet count
Angiogenesis	an-jee-oh-JEN-eh-sis	Formation of blood vessels

Health Care Professionals in Oncology

Cancer care is often provided by a team. Professional responsibilities depend on training, credentials, and the setting.

Health Care Professionals in Oncology

Professional	General role
Medical oncologist	Manages cancer using medications and coordinates care
Surgical oncologist	Uses surgery to diagnose or treat cancer
Radiation oncologist	Plans and oversees radiation treatment
Hematologist oncologist	Treats blood disorders and blood-related cancers
Pathologist	Interprets tissue, cell, and laboratory findings
Radiologist	Interprets medical images and may perform image-guided procedures
Oncology nurse	Assesses symptoms, provides treatment and education, and coordinates care
Oncology pharmacist	Helps evaluate regimens, medication safety, interactions, and supportive medicines
Genetic counselor	Explains inherited risk, testing options, and implications for individuals and families
Dietitian and oncology social worker	Support nutrition and practical, emotional, or resource needs within their respective professions

Medical Terminology in Context

These fictional scenarios are for vocabulary practice and do not supply enough information to make treatment decisions.

Scenario One

A pathology report identifies invasive ductal carcinoma of the breast. The report describes a high-grade tumor, while the oncology assessment notes no evidence of distant metastasis on the completed evaluation.

1. Which words describe the tissue of origin and invasion?
2. Does high-grade automatically mean stage IV? Explain.
3. Translate “no evidence of distant metastasis” into everyday language.

Scenario Two

Biopsy of a liver lesion shows cells consistent with the person’s previously diagnosed colon adenocarcinoma. The clinician documents metastatic colorectal cancer.

1. Which organ is the primary site?
2. Why is the liver lesion not automatically called primary liver cancer?

3. Identify the word parts in adenocarcinoma.

Scenario Three

After chemotherapy, Morgan's CBC shows a reduced neutrophil count. Morgan reports a fever. The nurse contacts the oncology team promptly and documents concern for infection during neutropenia.

1. Expand CBC.
2. Define neutropenia and identify its suffix.
3. Why does the fever require prompt communication?

Scenario Four

A person has surgery to remove a tumor, followed by chemotherapy to lower the risk of recurrence. The treatment plan also includes palliative care for pain and distress. The person asks, "Does palliative care mean treatment has stopped?"

1. What term describes chemotherapy given after the primary treatment?
2. Write a plain-language response about palliative care.
3. Define recurrence.

Test Yourself

1. Define oncology and oncologist.
2. Explain why benign does not mean harmless.
3. Distinguish carcinoma from sarcoma.
4. Classify each as anatomic, diagnostic, disease and disorder, or therapeutic: lymph node; biopsy; melanoma; brachytherapy.
5. Explain the difference between grade and stage.
6. Expand TNM and state what each component describes.
7. Is a positive FOBT a confirmed diagnosis of colorectal cancer? Explain.
8. Distinguish screening from diagnostic evaluation.
9. What does the E in the melanoma ABCDE features mean?
10. Explain the difference between adjuvant and neoadjuvant therapy.
11. Why is complete remission not necessarily the same as cure?
12. Say metastasis and metastases aloud and explain the difference.

Suggested Media and Further Learning

- What Is Cancer? National Cancer Institute: https://www.cancer.gov/about-cancer/understanding/what-is-cancer. Identify one difference between benign and malignant growth.
- Cancer Staging. National Cancer Institute: https://www.cancer.gov/about-cancer/diagnosis-staging/staging. Explain grade and stage to a partner using different words for each.
- YouTube Video

  This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

  View this YouTube Video online

  How Do Cancer Cells Behave Differently from Healthy Ones? TED-Ed: https://youtu.be/BmFEoCFDi-w.

- Identify two terms from this chapter used or illustrated in the video.
- NCI Dictionary of Cancer Terms: https://www.cancer.gov/publications/dictionaries/cancer-terms.

- Look up one unfamiliar term, practice its pronunciation, and write an everyday-language definition.

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Sources were consulted October 29, 2026. The chapter provides introductory terminology; cancer-specific systems and treatment recommendations require their own current clinical resources.

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