of the occipital lobe has been shaved to reveal the white and gray matter beneath the surface blood vessels. The white matter branches through the shaved section like the limbs of a tree. The gray matter branches and curves on the outside of the white matter, creating a buffer between the outer edges of the occipital lobe and the internal white matter. [Return to Figure 8.2].

Figure 8.3 image description: This figure shows the lateral view on the left panel and the anterior view on the right panel of the brain. The major parts including the cerebrum are labeled. Lateral view labels (clockwise from top) read: cerebrum, cerebral cortex, corpus callosum (located on the interior of the brain). Anterior view labels indicate the right and left hemispheres and the longitudinal fissure between them. [Return to Figure 8.3].

Figure 8.4 image description: This figure shows the lateral view of the brain and the major lobes are labeled. From the front of the brain (left) labels read: frontal lobe, precentral gyrus, central sulcus, postcentral gyrus, parietal lobe, lateral sulcus, occipital lobe, temporal lobe. [Return to Figure 8.4].

Figure 8.5 image description: This figure shows the location of the thalamus, hypothalamus, and pituitary gland in the brain. Each part is labeled respectively. The thalamus is located in the midsection of the brain. The hypothalamus is located below the thalamus and the pituitary gland below that. [Return to Figure 8.5].

Figure 8.6 image description: This figure shows the location of the midbrain, pons, and the medulla in the brain that make up the brainstem. The midbrain is located at the top, the pons is located beneath that, and the medulla is the lowest most point of the brain stem. [Return to Figure 8.6].

Figure 8.7 image description: This figure shows the location of the cerebellum in the brain which is located on the posterior surface of the brain stem. Labels read (top, left): pons, inferior olive, (top, right) cerebellum, deep cerebellar white matter (arbor vitae). In the top panel, a lateral view labels the location of the cerebellum and the deep cerebellar white matter. In the bottom panel, a photograph of a brain, with the cerebellum in pink is shown. [Return to Figure 8.7].

Figure 8.8 image description: This illustration shows the anatomy of a neuron. The neuron has a very irregular cell body (soma) containing a purple nucleus. There are six projections protruding from the top, bottom, and left sides of the cell body. Each of the projections branches many times, forming small, tree-shaped structures protruding from the cell body. The right side of the cell body tapers into a long cord called the axon. The axon is insulated by segments of myelin sheath, which resemble a semitransparent toilet paper roll wound around the axon. The myelin sheath is not continuous but is separated into equally spaced segments. The bare axon segments between the sheath segments are called nodes of Ranvier. An oligodendrocyte is reaching its two arm-like projections onto two myelin sheath segments. The axon branches many times at its end, where it connects to the dendrites of another neuron. Each connection between an axon branch and a dendrite is called a synapse. The cell membrane completely surrounds the cell body, dendrites, and axon. The axon of another nerve is seen in the upper left of the diagram connecting with the dendrites of the central neuron. [Return to Figure 8.8].

Figure 8.9 image description: Three illustrations show some of the possible shapes that neurons can take. In the unipolar neuron, the dendrite enters from the left and merges with the axon into a common pathway, which is connected to the cell body. The axon leaves the cell body through the common pathway, the branches off to the right, in the opposite direction as the dendrite. Therefore, this neuron is T-shaped. In the bipolar neuron, the dendrite enters into the left side of the cell body while the axon emerges from the opposite (right) side. In a multipolar neuron, multiple dendrites enter the cell body. The only part of the cell body that does not have dendrites is the part that elongates into the axon. [Return to Figure 8.9].

Figure 8.10 image description: This diagram contains three black and white drawings of more specialized nerve cells. Part A shows a pyramidal cell of the cerebral cortex, which has two, long, nerve tracts attached to the top and bottom of the cell body. However, the cell body also has many short dendrites projecting out a short distance from the cell body. Part B shows a Purkinje cell of the cerebellar cortex. This cell has a single, long, nerve tract entering the bottom of the cell body. Two large nerve tracts leave the top of the cell body but immediately branch many times to form a large web of nerve fibers. Therefore, the Purkinje cell somewhat resembles a shrub or coral in shape. Part C shows the olfactory cells in the olfactory epithelium and olfactory bulbs. It contains several cell groups linked together. At the bottom, there is a row of olfactory epithelial cells that are tightly packed, side-by-side, somewhat resembling the slats on a fence. There are six neurons embedded in this epithelium. Each neuron connects to the epithelium through

branching nerve fibers projecting from the bottom of their cell bodies. A single nerve fiber projects from the top of each neuron and synapses with nerve fibers from the neurons above. These upper neurons are cross-shaped, with one nerve fiber projecting from the bottom, top, right and left sides. The upper cells synapse with the epithelial nerve cells using the nerve tract projecting from the bottom of their cell body. The nerve tract projecting from the top continues the pathway, making a ninety-degree turn to the right and continuing to the right border of the image. [Return to Figure 8.10].

Figure 8.11 image description: This diagram shows several types of nervous system cells associated with two multipolar neurons. Astrocytes are star shaped-cells with many dendrite-like projections but no axon. They are connected with the multipolar neurons and other cells in the diagram through their dendrite-like projections. Ependymal cells have a teardrop-shaped cell body and a long tail that branches several times before connecting with astrocytes and the multipolar neuron. Microglial cells are small cells with rectangular bodies and many dendrite-like projections stemming from their shorter sides. The projections are so extensive that they give the microglial cell a fuzzy appearance. The oligodendrocytes have circular cell bodies with four dendrite-like projections. Each projection is connected to a segment of myelin sheath on the axons of the multipolar neurons. The oligodendrocytes are the same color as the myelin sheath segment and are adding layers to the sheath using their projections. [Return to Figure 8.11].

Figure 8.12 image description: This diagram shows a collection of PNS glial cells. The largest cell is a unipolar peripheral ganglionic neuron which has a common nerve tract projecting from the bottom of its cell body. The common nerve tract then splits into the axon, going off to the left, and the dendrite, going off to the right. The cell body of the neuron is covered with several satellite cells that are irregular, flattened, and take on the appearance of fried eggs. Schwann cells wrap around each myelin sheath segment on the axon, with their nucleus creating a small bump on each segment. [Return to Figure 8.12].

Figure 8.13 image description: 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 the autonomous function. The ENS can operate independently of the brain and spinal cord. [Return to Figure 8.13].

Figure 8.14 image description: An illustration of the brain with Broca's area and Wernicke's area identified. Broca's area is located in the lateral aspect of the frontal lobe. Wernicke's area is found at the end of the lateral sulcus just anterior to the visual cortex. The two are connected by white matter tracts between the posterior temporal love and lateral aspect of the frontal lobe. Both areas are associated with the loss of speech and language. Expressive aphasia is associated with Broca's area. Receptive aphasia is associated with Wernicke's area. [Return to Figure 8.14].

Figure 8.15 image description: The left panel of this figure shows an image of the brain with a region in red. This red region indicates a hemorrhage associated with a stroke. The right panel shows a hemorrhage as it might appear on a CT scan. [Return to Figure 8.15].

9. Cardiovascular System

Learning Objectives

- Examine the anatomy of the heart
- Determine the main functions of the cardiovascular system
- Differentiate cardiovascular system medical terms and common abbreviations
- Recognize the medical specialties associated with the cardiovascular system
- Discover common diseases, disorders, and procedures related to the cardiovascular system

Cardiovascular System Word Parts

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

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https://pressbooks.uwf.edu/medicalterminology/?p=92#h5p-55

Introduction to the Cardiovascular System

The cardiovascular system is made of three components: the heart, vessels, and blood. 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 of 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.

Watch this video:

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Media 9.1. The Heart, Part 1 – Under Pressure: Crash Course A&P #25 [Online video]. Copyright 2015 by CrashCourse.

Practice Medical Terms Related to the Cardiovascular System

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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 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, the **superior vena cava**.

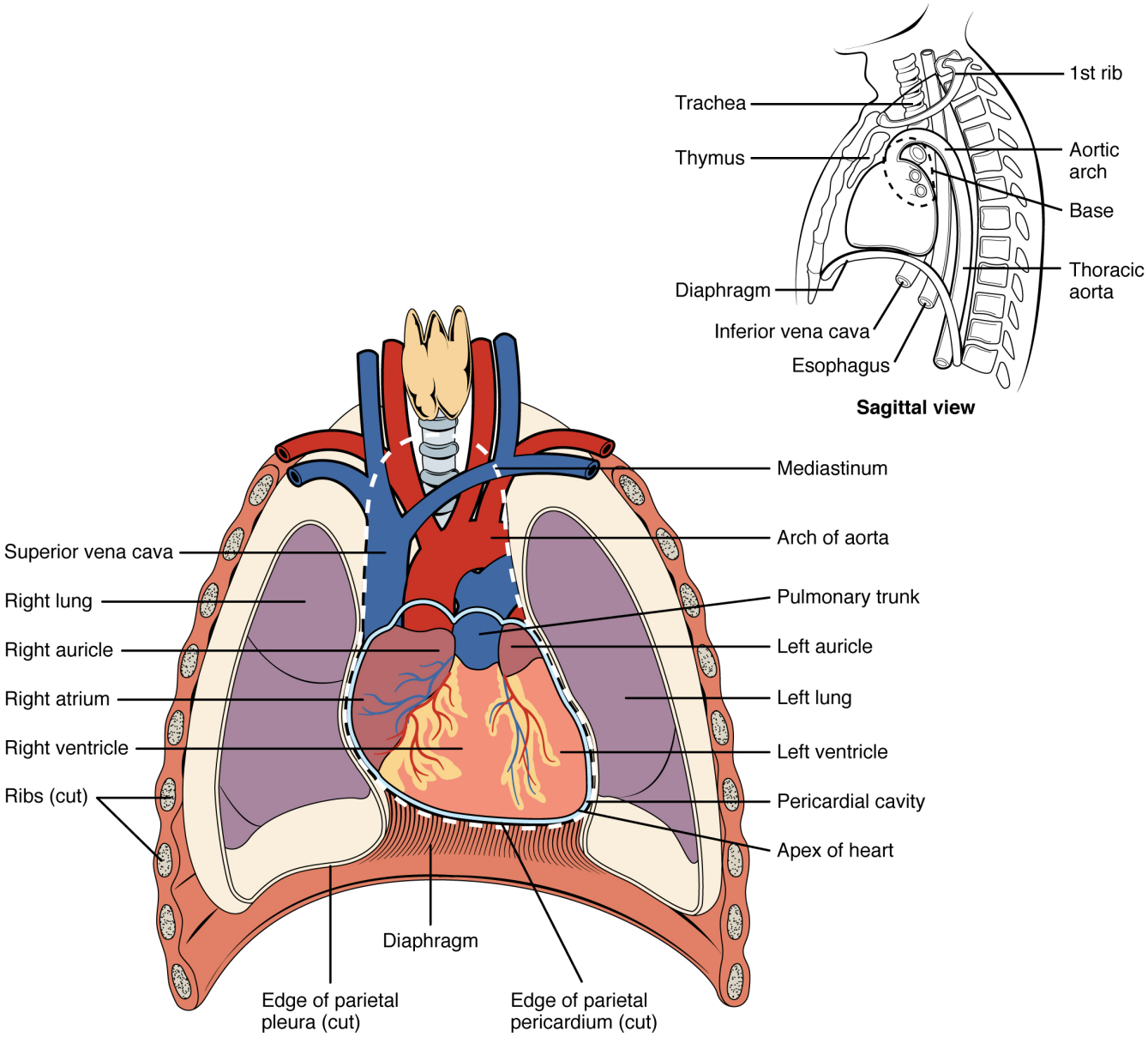

Figure 9.1. Position of the Heart in the Thorax. The heart is located within the thoracic cavity, medially between the lungs in the mediastinum. It is about the size of a fist, is broad at the top, and tapers toward the base. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 **pericardial cavity** 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 the **myocardium** layer is thicker than the **endocardium** layer.

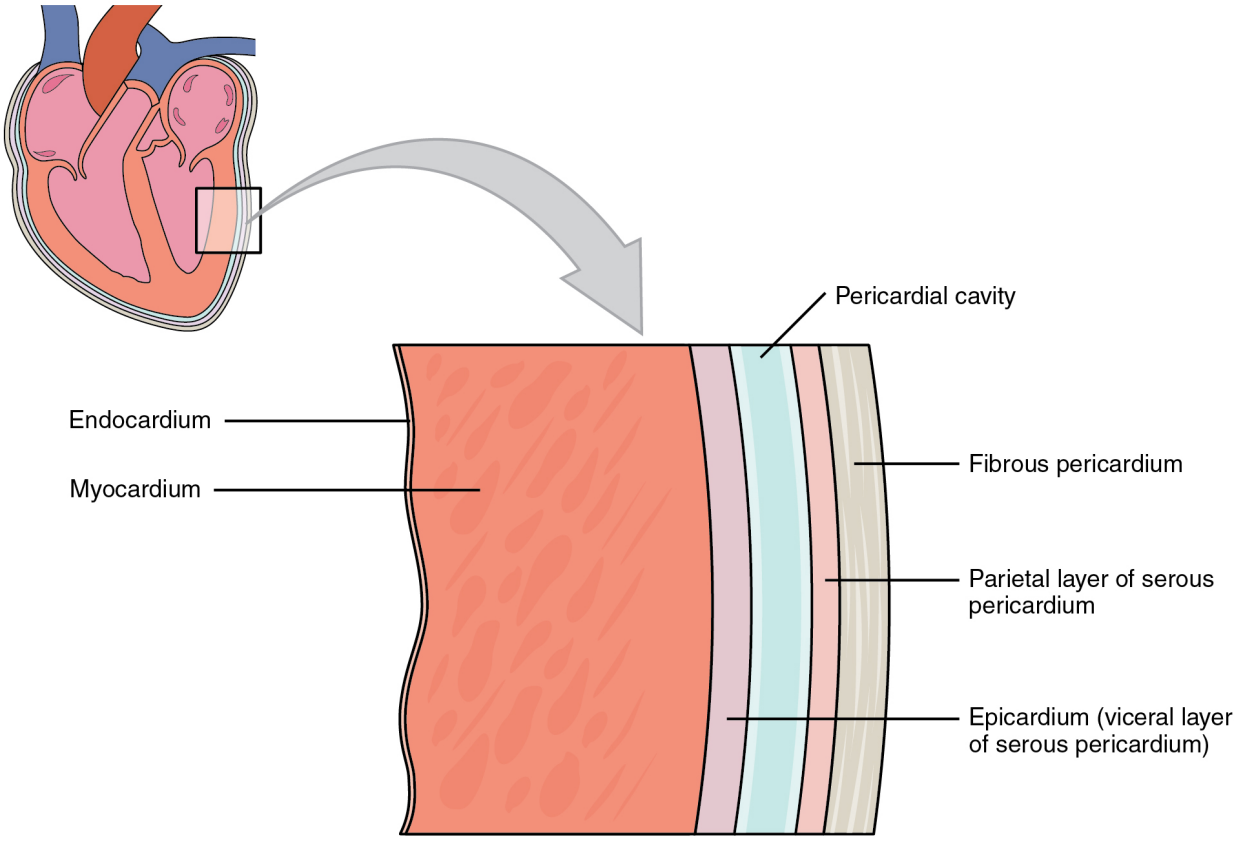

Figure 9.2. Pericardial Membranes and Layers of the Heart Wall. The pericardial membrane that surrounds the heart consists of three layers and the pericardial cavity. The heart wall also consists of three layers. The pericardial membrane and the heart wall share the epicardium From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 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.

1. 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.

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 carries 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 postnatal 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.

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.

Concept Check

- On Figure 9.3 below, use your finger to trace the pathway of blood flowing through the right side of the heart, naming each of the following structures as you encounter them: Superior and inferior venae cavae, right atrium, tricuspid valve, right ventricle, pulmonary valve, right and left pulmonary arteries.
- Suggest what would happen if the **aorta** experienced a blockage or constriction.

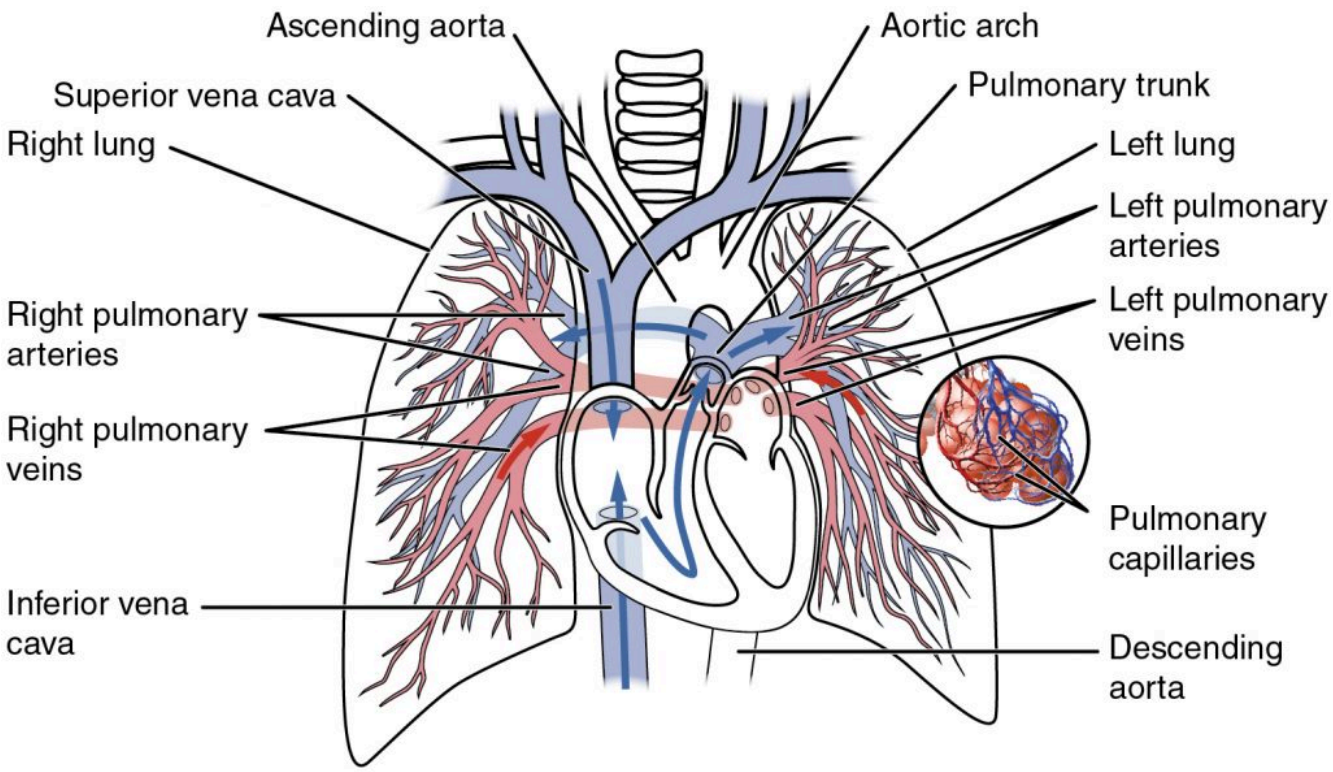

Figure 9.3. Pulmonary Circuit Blood exiting from the right ventricle flows into the pulmonary trunk, which bifurcates into the two pulmonary arteries. These vessels branch to supply blood to the pulmonary capillaries, where gas exchange occurs within the lung alveoli. Blood returns via the pulmonary veins to the left atrium. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 9.4 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.

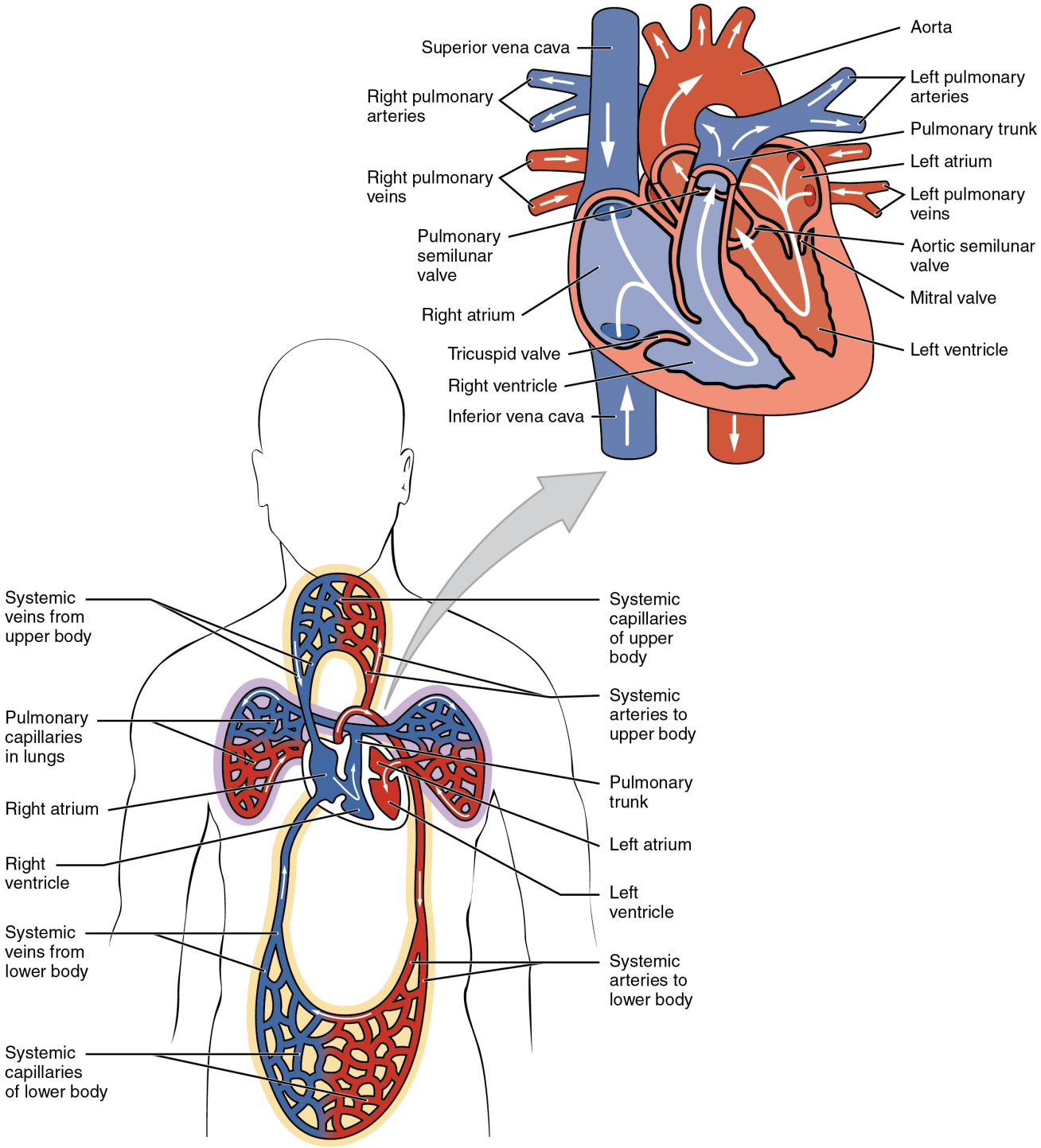

Figure 9.4. Dual System of the Human Blood Circulation. Blood flows from the right atrium to the right ventricle, where it is pumped into the pulmonary circuit. The blood in the pulmonary artery branches is low in oxygen but relatively high in carbon dioxide. Gas exchange occurs in the pulmonary capillaries (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 the 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., 2013. Licensed under CC BY 4.0. [Image description.]

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 the body through the open semilunar valves. Once this phase ends, the semilunar valves close, in preparation for another filling phase.

2. The Heart as an Organ: The Coronary Blood Supply

Myocardial cells require their own blood supply to carry out their function of contracting and relaxing the heart in order to pump blood. Their own blood supply provides nutrients and oxygen and carries away carbon dioxide and waste. These functions are provided by the coronary arteries and coronary veins.

Concept Check

On the image below, locate the three main coronary arteries:

- **Anterior interventricular artery** (more commonly known as the **left anterior descending artery, or LAD**)
- **Circumflex artery (Cx)**
- **Right coronary artery (RCA)**

Follow the path of each of these three arteries to try to determine which parts of the myocardium each artery (along with its many smaller branches) supplies with blood.

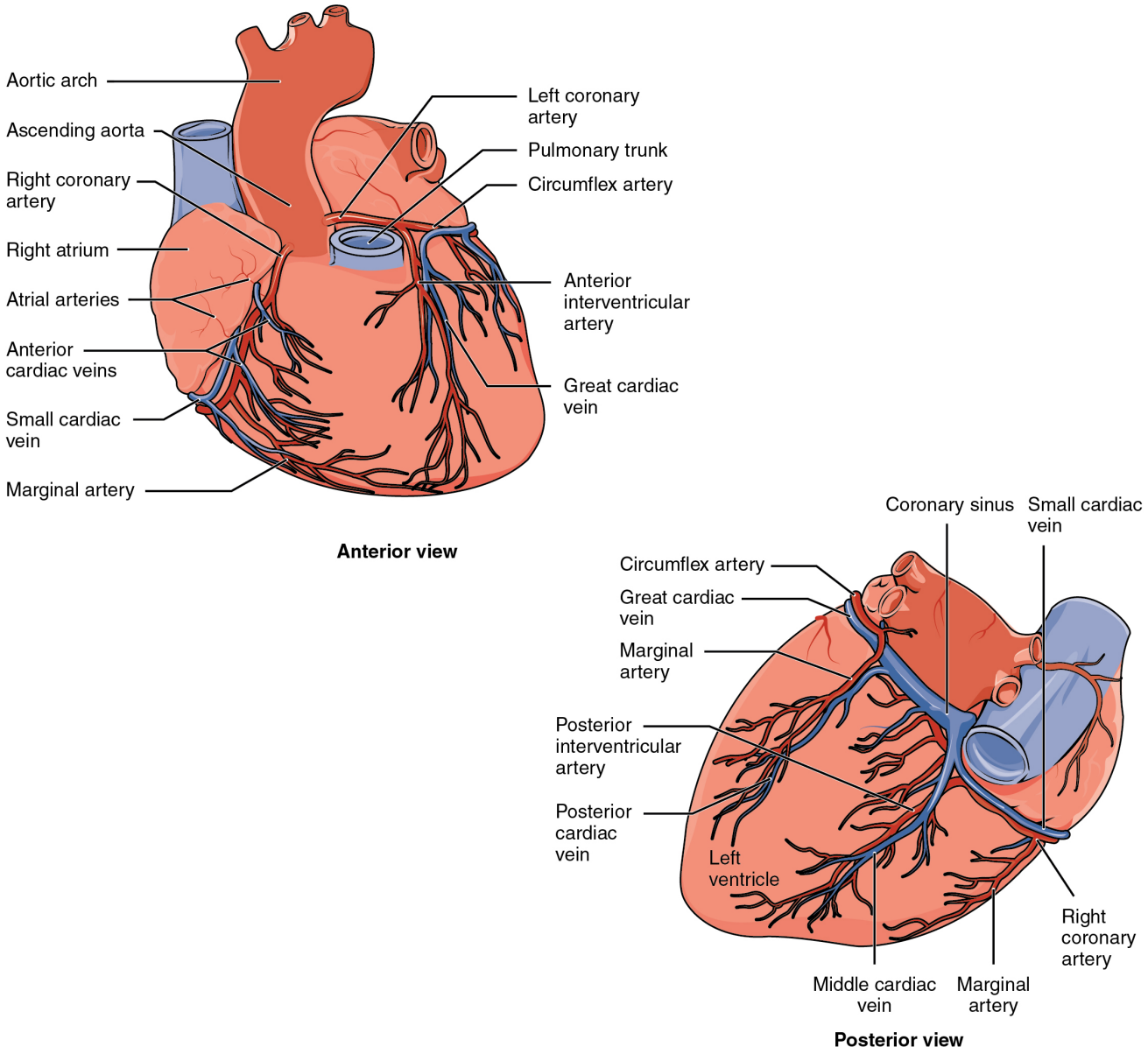

Figure 9.5 Coronary Circulation. The anterior view of the heart shows the prominent coronary surface vessels. The posterior view of the heart shows the prominent coronary surface vessels. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

3. The Heart's Electrical Conduction System

In order for all parts of the heart to work together to beat regularly and effectively, the heart has its own electrical system, which initiates and conducts each heartbeat through the entire myocardium. Specialized groups of heart cells perform this function all on their own, without requiring messages from the central nervous system.

Watch this video:

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Media 9.2. The Heart, Part 2 – Heart Throbs: Crash Course A&P #26 [Online video]. Copyright 2015 by CrashCourse.

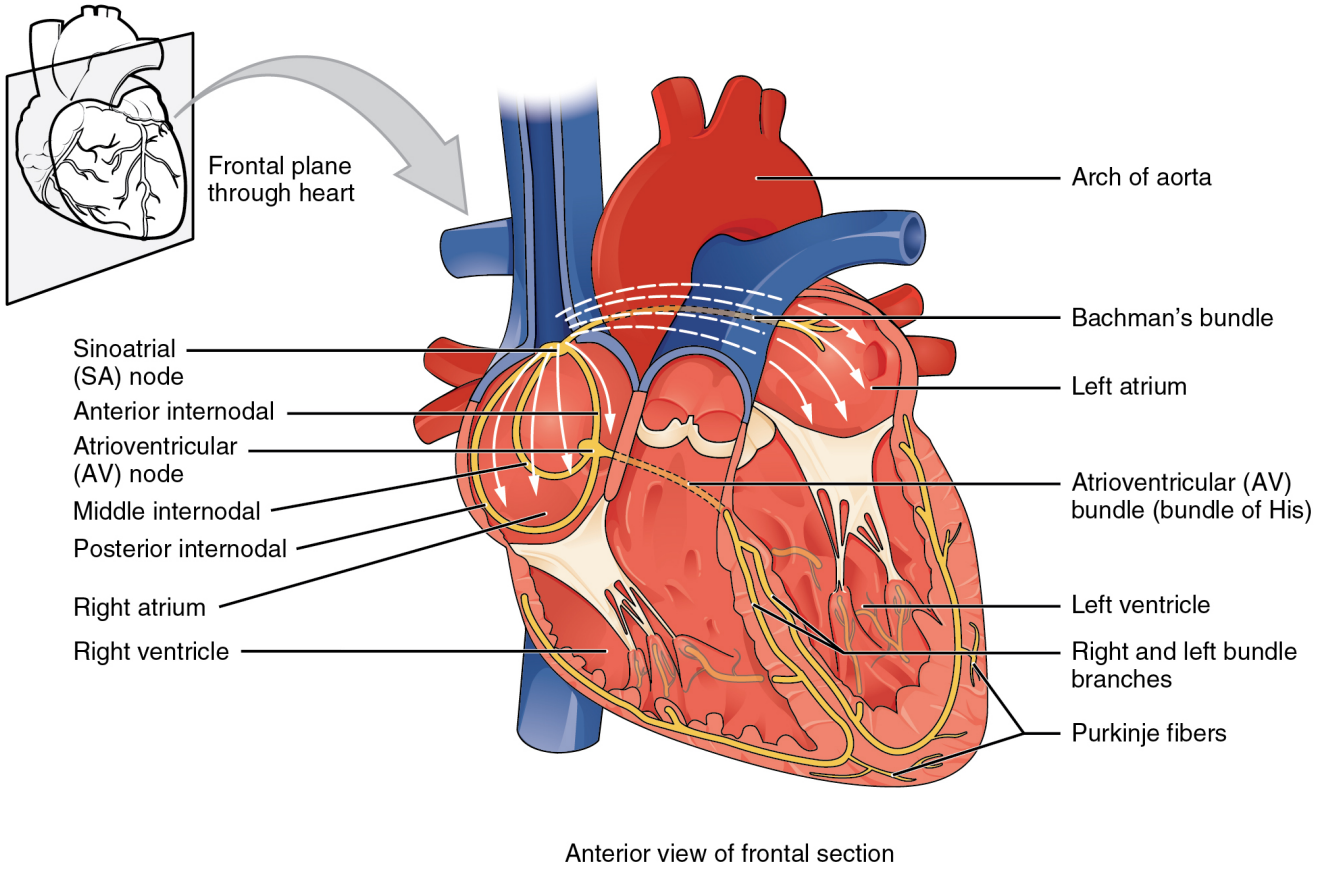

Figure 9.6. Conduction System of the Heart. Specialized conducting components of the heart include the sinoatrial node, the internodal pathways, the atrioventricular node, the atrioventricular bundle, the right and left bundle branches, and the Purkinje fibers. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Concept Check

On the image above, trace the electrical impulse generated by the heart's pacemaker (the **sinoatrial node**, or **SA node**) through the rest of the conduction system, including the **atrioventricular (AV) node**, the **atrioventricular bundle (bundle of His)**, the **right and left bundle branches**, and the **Purkinje fibers**.

We can detect and record the electrical activity of the heart's conduction system using an electrocardiogram (ECG or EKG). Figure 9.7 shows the electrical impulse originating in the SA node (step 2) and traveling through the heart's conduction system, allowing the heart to complete one cardiac cycle. Each waveform on the ECG tracing represents electricity moving through and affecting a different part of the heart. Did you notice that the **AV valves** close when the electrical impulse reaches the ventricles, just before systole occurs?

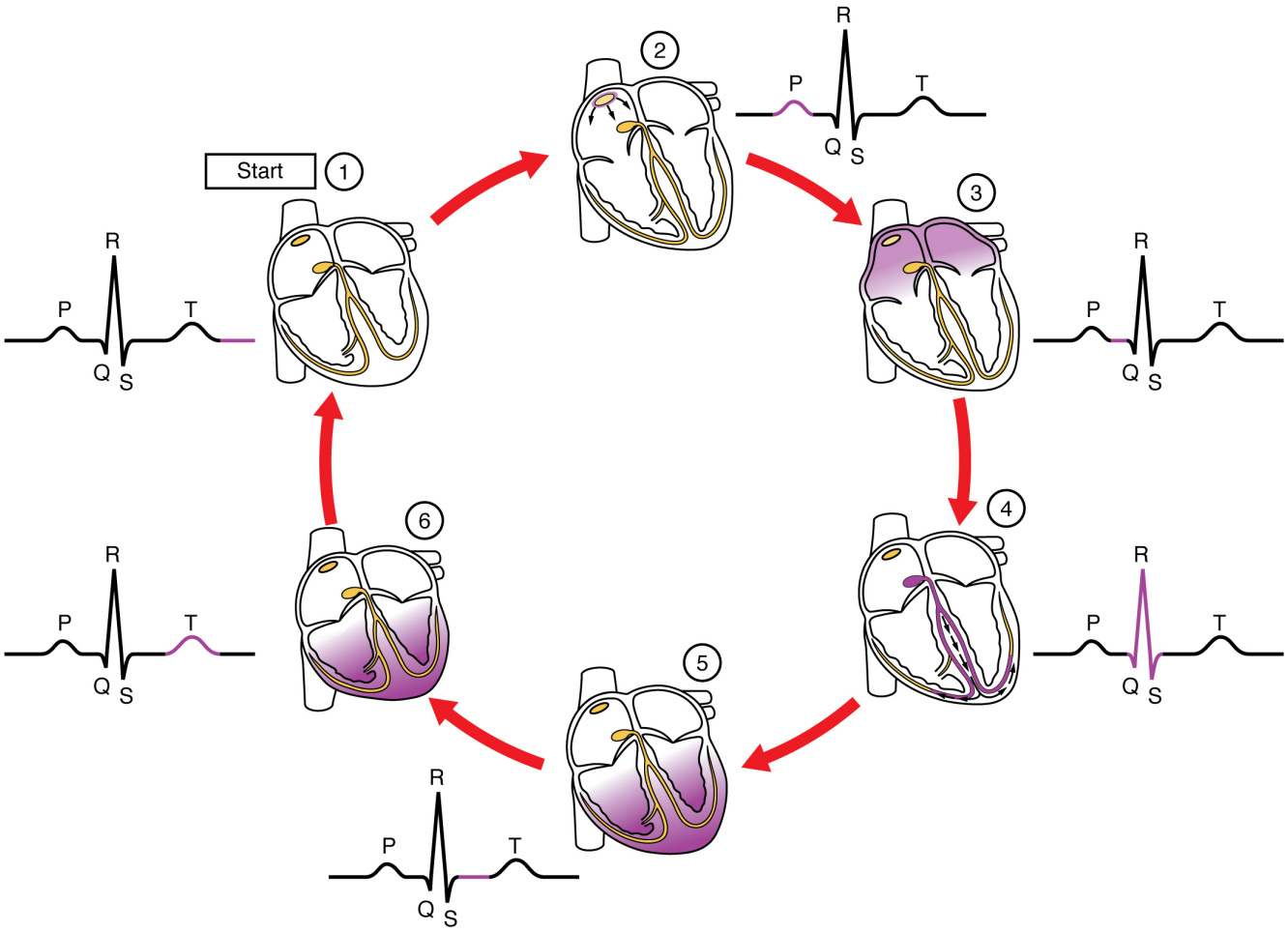

Figure 9.7. ECG Tracing Correlated to the Cardiac Cycle. This diagram correlates an ECG tracing with the electrical and mechanical events of a heart contraction. Each segment of an ECG tracing corresponds to one event in the cardiac cycle. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Practice Terms Related to the Cardiovascular System

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Common Abbreviations for the Cardiovascular System

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

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https://pressbooks.uwf.edu/medicalterminology/?p=92#h5p-59

Diseases and Disorders of the Heart

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.

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 that 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, n.d.-a). To learn more, visit the Centers for Disease Control and Prevention's web page on cardiomyopathy.

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 American Heart Association's web page on heart failure.

Valvular Heart Disease

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, n.d.-b).

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, n.d.-b).

- **Mitral Valve Prolapse**
  - 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, n.d.-b).
- **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, n.d.-b).

Visit the Center for Disease Control and Prevention's web 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 9.8). 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, n.d.-c).

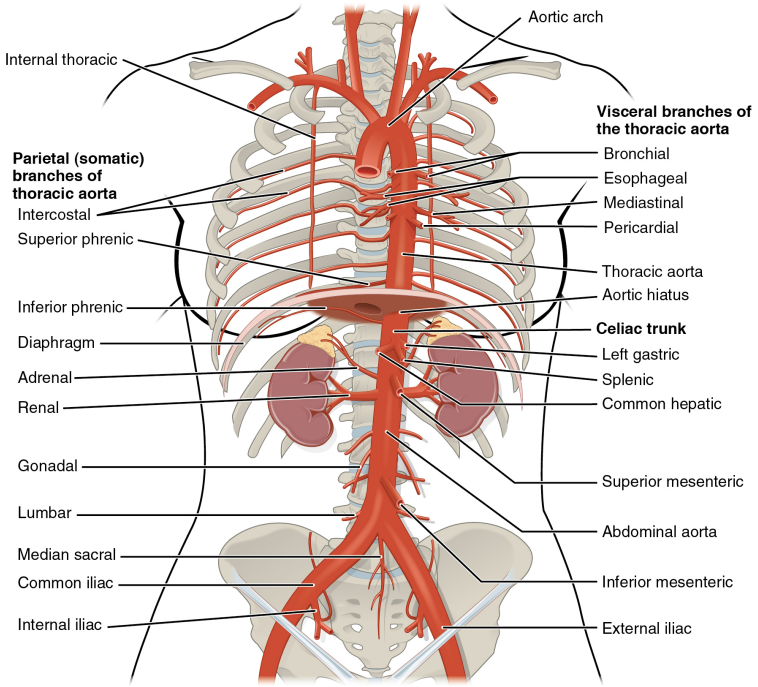


Figure 9.8. Arteries of the Thoracic and Abdominal Regions The thoracic aorta gives rise to the arteries of the visceral and parietal branches. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

People who smoke or 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 can be asymptomatic and may be detected during diagnostic tests that are done for other reasons. They are sometimes repaired surgically and sometimes treated with medications such as **antihypertensives** (Centers for Disease Control and Prevention, n.d.-c; National Heart, Lung, and Blood Institute, n.d.). Visit the National Heart, Lung, and Blood Institute's web page on aortic aneurysms to learn more.

Heart Defects

Fetal circulation is different from **postnatal** circulation. There are two 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.

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 to 25% 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.
  - Signs and 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.

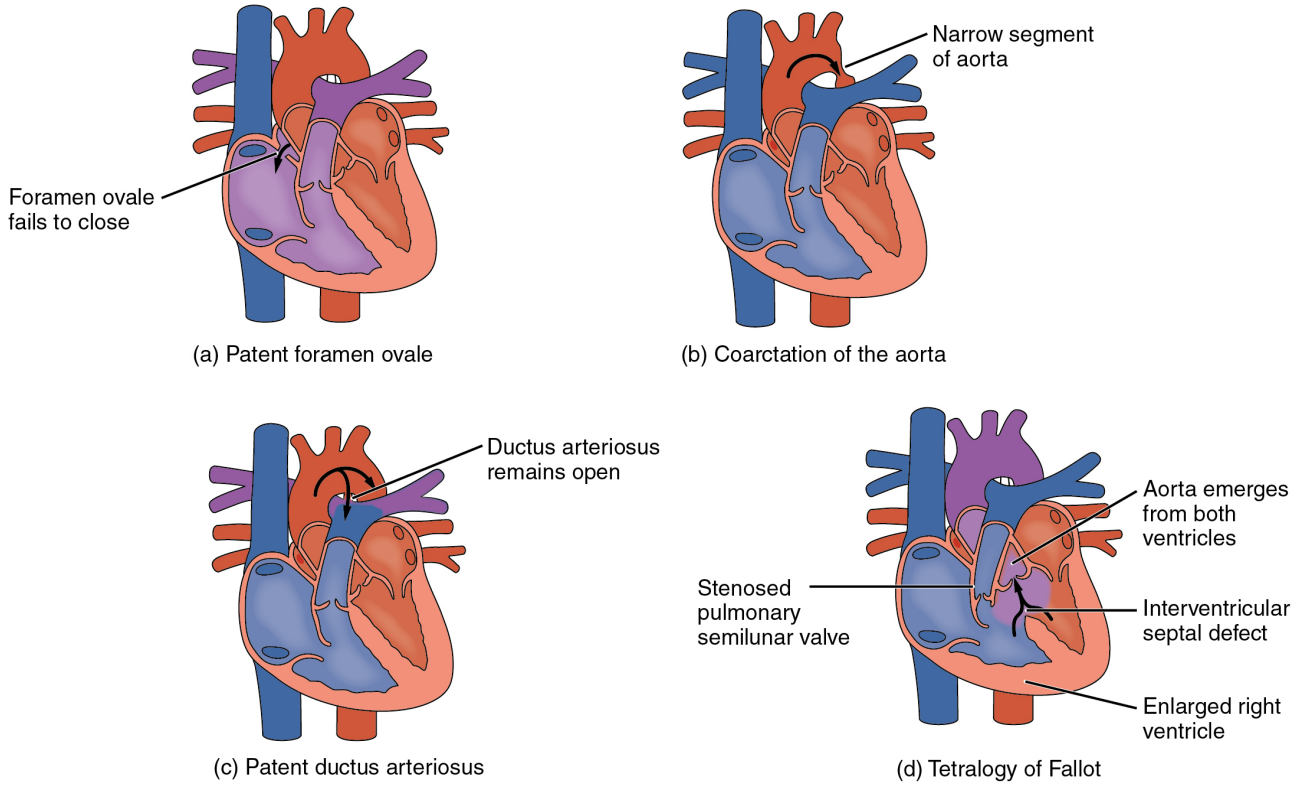


Figure 9.9. Congenital Heart Defects. (a) A patent foramen ovale defect is an abnormal opening in the interatrial septum, or more commonly, a failure of the foramen ovale to close. (b) Coarctation of the aorta is an abnormal narrowing of the aorta. (c) A patent ductus arteriosus is the failure of the ductus arteriosus to close. (d) Tetralogy of Fallot includes an abnormal opening in the interventricular septum. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Diseases Related to 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 myocardial infarction (MI).

The image below shows the blockage of coronary arteries on an **angiogram**.

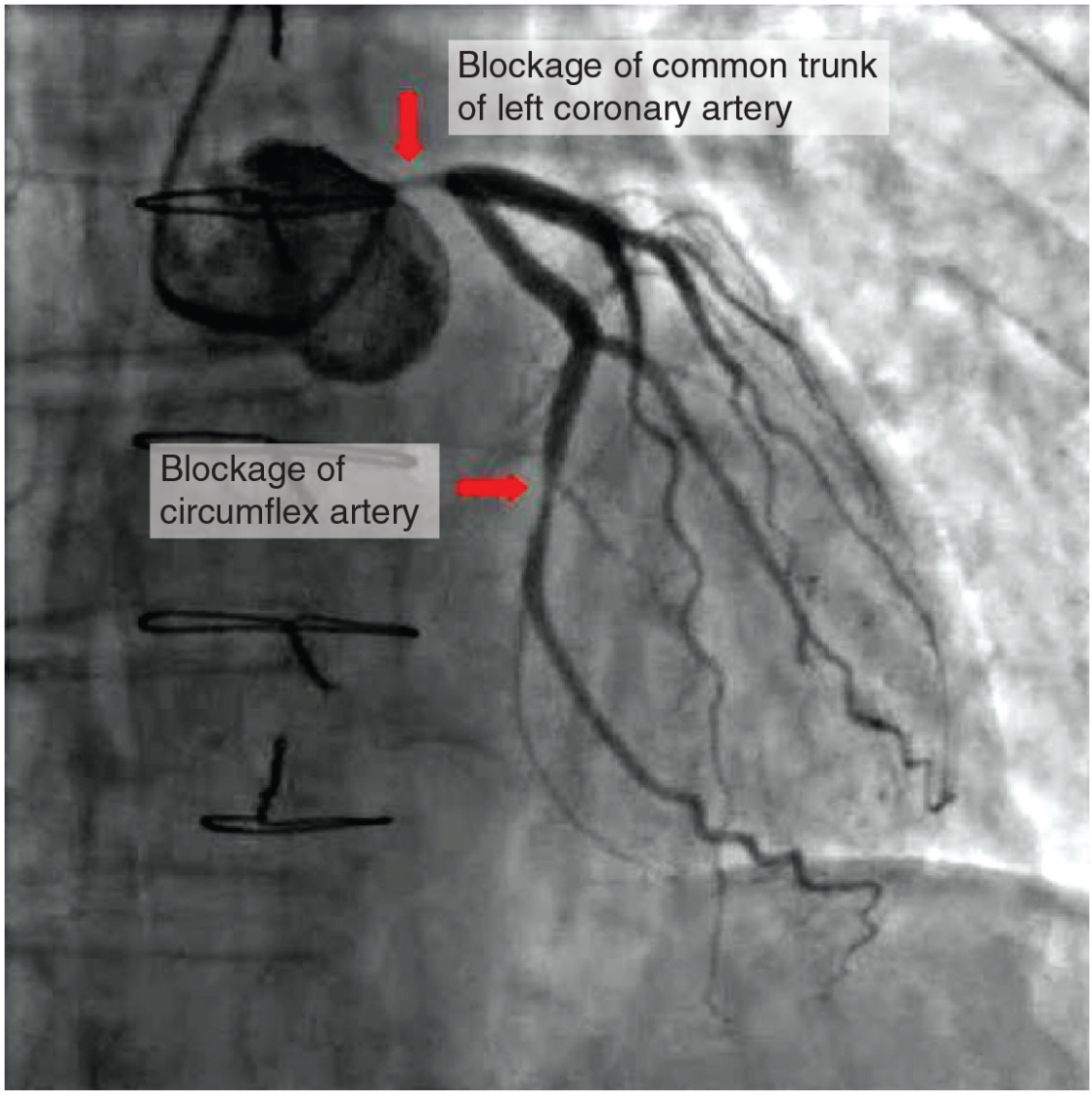


Figure 9.10. Angiogram of Atherosclerotic Coronary Arteries. In this coronary angiogram (X-ray), the dye makes visible two occluded coronary arteries. Such blockages can lead to decreased blood flow (ischemia) and insufficient oxygen (hypoxia) delivered to the cardiac tissues. If uncorrected, this can lead to cardiac muscle death (myocardial infarction). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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).

- **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.
- **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.

Myocardial Infarction

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

A MI normally results from a lack of blood flow to a region of the heart, resulting in death of the cardiac muscle cells. A 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.

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 signs and 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.

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.

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.

Did you know?

It is estimated that between 22 and 64% of myocardial infarctions present without any symptoms.

Diseases of the (Electrical) Conduction System

Arrhythmia

The heart's natural pacemaker, the sinoatrial (SA) node initiates an electrical impulse 60 to 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**. **Arrhythmias** 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.
- **Ventricular 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.

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.

Abnormal Heart Rates

Bradycardia is the condition in which resting adult heart rate drops below 60 beats per minute (bpm). A client exhibiting signs and 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 heart rate in the normal range but is still suffering from these symptoms. Most patients remain asymptomatic as long as the heart rate remains above 50 bpm.

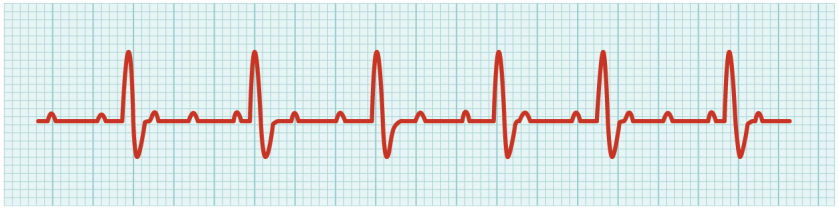
Tachycardia is the condition in which the resting rate is above 100 bpm. Tachycardia is not normal in a resting patient and may be detected in pregnant women or individuals experiencing extreme stress. Some individuals may remain **asymptomatic**, but when present, signs and symptoms may include dizziness,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

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.

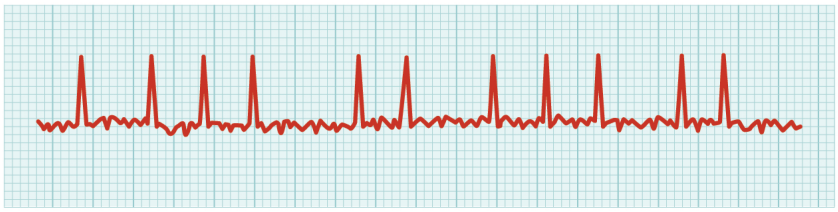
AV blocks are often described by degrees. A **first-degree or partial block** indicates a delay in conduction between the SA and AV nodes. A **second-degree or incomplete block** occurs when some impulses from the SA node reach the AV node and continue, while others do not. In the **third-degree or complete block**, there is no correlation between atrial activity and ventricular activity. This means that none of the impulses generated by the SA node get transmitted to the rest of the heart and the AV node must take over as the primary pacemaker, initiating contractions at 40 to 60 bpm, which is adequate to maintain consciousness.

In order to speed up the heart rate and restore full **sinus rhythm**, a cardiologist can implant an **artificial pacemaker**, which delivers electrical impulses to the heart muscle to ensure that the heart continues to contract and pump blood effectively. These artificial pacemakers are programmable by the cardiologists and can either provide stimulation temporarily upon demand or on a continuous basis. Some devices also contain built-in defibrillators.



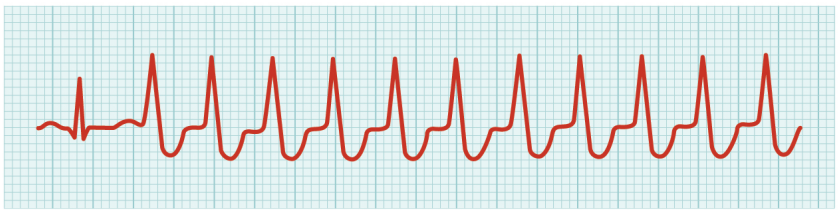
(a) Second-degree (partial) block

Note how half of the P waves are not followed by the QRS complex and T waves while the other half are.
Question: What would you expect to happen to heart rate (pulse)?



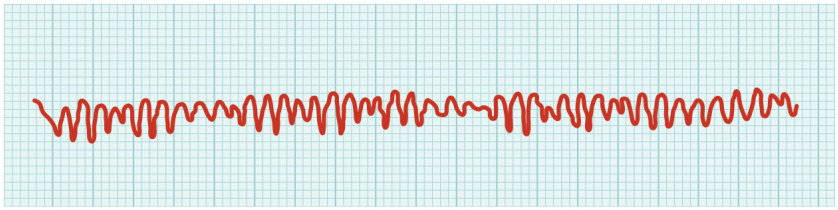
(b) Atrial fibrillation

Note the abnormal electrical pattern prior to the QRS complexes. Also note how the frequency between the QRS complexes has increased.
Question: What would you expect to happen to heart rate (pulse)?



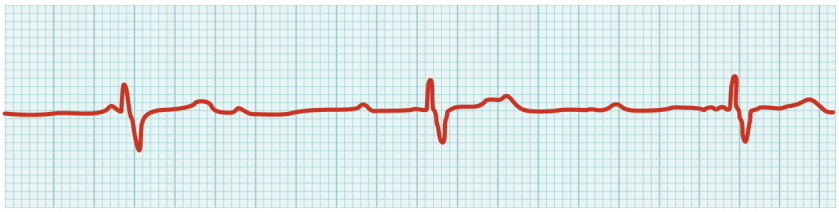
(c) Ventricular tachycardia

Note the unusual shape of the QRS complex, focusing on the "S" component.
Question: What would you expect to happen to heart rate (pulse)?



(d) Ventricular fibrillation

Note the total lack of normal electrical activity.
Question: What would you expect to happen to heart rate (pulse)?



(e) Third-degree block

Note that in a third-degree block some of the impulses initiated by the SA node do not reach the AV node while others do. Also note that the P waves are not followed by the QRS complex.
Question: What would you expect to happen to heart rate (pulse)?

Figure 9.11. Common ECG Abnormalities. (a) In a second-degree or partial block, one-half of the P waves are not followed by the QRS complex and T waves while the other half are. (b) In atrial fibrillation, the electrical pattern is abnormal prior to the QRS complex, and the frequency between the QRS complexes has increased. (c) In ventricular tachycardia, the shape of the QRS complex is abnormal. (d) In ventricular fibrillation, there is no normal electrical activity. (e) In a third-degree block, there is no correlation between atrial activity (the P wave) and ventricular activity (the QRS complex). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Medical Terms in Context

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https://pressbooks.uwf.edu/medicalterminology/?p=92#h5p-60

Medical Specialties Related to the Cardiovascular System

Cardiologists and Thoracic Surgeons

Cardiologists are medical doctors that specialize in diagnosing and treating heart diseases. After completing medical school, cardiologists must complete at least six more years of training (Betts et al., 2013). Thoracic surgeons provide surgical treatments on the heart and other thoracic organs (National Cancer Institute, n.d.). For more information, visit the American College of Cardiology Foundation's web page on cardiologists.

Cardiology Technologists

Cardiology technologists complete a college training program and perform diagnostic tests such as **electrocardiography** and stress testing, as well as **pacemaker** monitoring (Bureau of Labor Statistics, 2021). Please visit the Bureau of Labor Statistics' web page on cardiology technologists 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 and administer medications (New York State Education Department, 2020). For more information, please read this job description from the American Board of Cardiovascular Perfusion (PDF).

Cardiovascular System Vocabulary

Ablation

The removal or destruction of a body part or tissue or its function. Ablation may be performed by surgery, hormones, drugs, radiofrequency, heat, or other methods.

Aneurysm

Weakening of the wall of a blood vessel, causing it to thin and balloon out, and possibly eventually burst, resulting in internal bleeding.

Angina pectoris

Chest pain. It may be a symptom of coronary artery disease and myocardial infarction.

Angiogram

An x-ray or computer image (CT scan or MRI) of the blood vessels and blood flow in the body. A dye may be injected through a catheter (small tube) into an artery or vein to make the blood vessels easier to see.

Antihypertensives

A class of medications used to treat high blood pressure.

Arrhythmia

A deviation from the normal pattern of impulse conduction and contraction of the heart.

Asymptomatic

Having no signs or symptoms of disease.

Atherosclerosis

A hardening of the arteries that involves the accumulation of plaque.

Auscultation

Listening to the heart using a stethoscope.

Atrioventricular (AV)

The area of the heart where the atria and ventricles meet.

Atrioventricular (AV) valves

Mitral (bicuspid) valve that allows blood to flow from left atrium to left ventricle and tricuspid valve that allows blood to flow from right atrium to right ventricle.

Bradycardia

A condition in which the heart beats slower than 50 beats per minute.

Cardiac

Having to do with the heart.

Cardiac troponin

The regulatory protein for muscle contraction.

Cardiogenic

Originating from the heart.

Cardiologist

A physician who studies and treats diseases of the heart.

Cardiology

The study of the heart.

Cardiomegaly

Enlarged heart.

Cardiomyopathy

Disease of the heart muscle.

Compliance

The ability of the blood vessels to dilate and constrict as needed.

Computerized tomography (CT)

A noninvasive imaging technique that uses computers to analyze several cross-sectional X-rays in order to reveal minute details about structures in the body.

Congenital

Present at birth.

Creatine kinase MB

An enzyme that catalyzes the conversion of creatine to phosphocreatine, consuming ATP.

Cyanosis

A condition in which the oxygen supply is restricted, causing the skin to look blue.

Diabetes mellitus

A disease in which the body does not control the amount of glucose (a type of sugar) in the blood and the kidneys make a large amount of urine. This disease occurs when the body does not make enough insulin or does not use it the way it should.

Diaphoresis

Sweating.

Diastole

Period of time when the heart muscle is relaxed and the chambers fill with blood.

Ductus arteriosus

A temporary connection between pulmonary trunk and aorta in the fetal heart.

Dyspnea

Difficulty breathing.

Echocardiogram

A computer picture of the heart created by bouncing high-energy sound waves (ultrasound) off internal tissues or organs of the chest.

Echocardiography

A procedure that uses high-energy sound waves (ultrasound) to look at tissues and organs inside the chest.

Electrocardiogram (ECG/EKG)

The record of the heart's function produced by the electrocardiograph.

Electrocardiograph

The instrument that generates an electrocardiogram (ECG); 10 electrodes are placed in standard locations on the patient's skin to record heart function.

Electrocardiography

The science of recording the electrical activity of the heart.

Endocarditis

A condition in which the tissues lining the inside of the heart and the heart valves become inflamed.

Foramen ovale

An opening between right and left atria, which is normal in the fetal heart.

Great vessels

Include the superior vena cava, inferior vena cava, aorta and pulmonary trunk.

Heart murmur

An abnormal heart sound.

Heart rate

The number of times the heart beats within a certain time period, usually a minute.

High-density lipoprotein (HDL)

Often referred to as "good" cholesterol.

Hypercholesterolemia

Higher than normal levels of cholesterol in the blood.

Hyperlipidemia

Excessive fat in the blood.

Hypertension

Abnormally high blood pressure.

Implantable cardioverter defibrillators (ICD)

A small device placed by surgery in the chest or abdomen that is used to correct a heartbeat that is abnormal. Wires are passed through a vein to connect the device to the heart. When it detects abnormal heartbeats, it sends an electrical shock to the heart to restore the heartbeat to normal.

Inferior vena cava

One of the two largest veins in the body. It carries deoxygenated blood from the torso and legs back to the heart.

Interatrial septum

The wall separating the right and left atria.

Interventricular septum

The wall of myocardium that separates the right and left ventricles.

Ischemia

Lack of blood flow to body tissues.

Low-density lipoprotein (LDL)

Often referred to as 'bad' cholesterol.

Magnetic Resonance Imaging (MRI)

A procedure in which radio waves and a powerful magnet linked to a computer are used to create detailed pictures of areas inside the body.

Mitral valve

Located at the opening between the left atrium and left ventricle; also known as the bicuspid valve.

Myocardial infarction (MI)

Heart attack, caused by lack of blood flow and oxygen to the heart.

Myocarditis

A rare condition in which the heart muscle becomes thick and inflamed and may also become weak.

Occlusion

A blockage.

Pacemaker

An electronic device that is implanted in the body to monitor heart rate and rhythm. It gives the heart electrical stimulation when it does not beat normally.

Palpitations

A rapid or irregular heartbeat that a person can feel.

Pericardial fluid

Watery fluid produced in the serous and visceral pericardium surrounding the surface of the heart.

Pericarditis

Inflammation of the (sac) surrounding the heart.

Pericardiocentesis

Surgical puncture to aspirate fluid from the (sac) surrounding the heart.

Plaque

A fatty material including cholesterol, connective tissue, white blood cells, and some smooth muscle cells.

Polycythemia

A rare disorder in which the bone marrow produces an abnormally large amount of blood cells.

Pulmonary trunk

The very large artery referred to as a trunk, a term indicating that the vessel gives rise to several smaller arteries.

Roots of the great vessels

The part of each great vessel (aorta, pulmonary trunk, inferior vena cava, superior vena cava) that connects to the base of the heart.

Serous membrane

One of the thin membranes that cover the walls and organs in the thoracic and abdominopelvic cavities.

Sinus rhythm

The normal electrical pattern followed by contraction of the heart.

Sphygmomanometer

A blood pressure cuff attached to a measuring device.

Stethoscope

An instrument used to hear sounds produced by the heart, lungs, or other parts of the body.

Superior vena cava

One of two large veins in the body, which carries deoxygenated blood from the head and upper extremities back to the heart.

Syncope

Fainting.

Systole

Period of time when the heart muscle is contracting.

Tachycardia

A condition in which the resting rate is above 100 bpm.

Valvuloplasty

The widening of a stenosed heart valve using a balloon catheter.

Test Yourself

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.uwf.edu/medicalterminology/?p=92#h5p-61

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Image Descriptions

Figure 9.1 image description: This diagram shows the location of the heart in the thorax (sagittal and anterior views). The sagittal view labels read (from top, clockwise): first rib, aortic arch, thoracic arch, esophagus, inferior vena cava, diaphragm, thymus, trachea. The anterior view labels read (from top, clockwise): mediastinum, arch of aorta, pulmonary trunk, left auricle, left lung, left ventricle, pericardial cavity, apex of heart, edge of parietal pericardium, diaphragm, edge of parietal pleura, ribs, right ventricle, right atrium, right auricle, right lung, superior vena cava. [Return to Figure 9.1].

Figure 9.2 image description: This image shows a magnified view of the structure of the heart wall. Labels read (from top, clockwise): pericardial cavity, fibrous pericardium, parietal layer of serous pericardium, epicardium (visceral layer of serous pericardium), myocardium, endocardium. [Return to Figure 9.2].

Figure 9.3 image description: This diagram shows the network of blood vessels in the lungs. Labels read (from top, clockwise (left-side of the body): aortic arch, pulmonary trunk, left lung, left pulmonary arteries, left pulmonary vein, pulmonary capillaries, descending aorta, (right side of body) inferior vena cava, right pulmonary veins, right pulmonary arteries, right lung, superior vena cava, ascending aorta. [Return to Figure 9.3].

Figure 9.4 image description: The top panel shows the human heart with the arteries and veins labeled (from top, clockwise): aorta, left pulmonary arteries, pulmonary trunk, left atrium, left pulmonary veins, aortic semilunar valve, mitral valve, left ventricle, inferior vena cava, right ventricle, tricuspid valve, right atrium, pulmonary semilunar valve, right pulmonary veins, right pulmonary arteries, superior vena cava. The bottom panel shows a rough map of the human circulatory system. Labels read (from top, clockwise): systemic capillaries of upper body, systemic arteries to upper body, pulmonary trunk, left atrium, left ventricle, systemic arteries to lower body, systemic capillaries of lower body, systemic veins from lower body, right ventricle, right atrium, pulmonary capillaries in lungs, systemic veins from upper body. [Return to Figure 9.4].

Figure 9.5 image description: The top panel of this figure shows the anterior view of the heart while the bottom panel shows the posterior view of the heart. The different blood vessels are labeled. Anterior view labels (from top of diagram, clockwise): left coronary artery, pulmonary trunk, circumflex artery, anterior interventricular artery, great cardiac vein, small cardiac vein, anterior cardiac veins, atrial arteries, right atrium, right coronary artery, ascending aorta, aortic arch. Posterior view labels (from top of diagram, clockwise): coronary sinus, small cardiac vein, right coronary artery, marginal artery, middle cardiac vein, posterior cardiac vein, posterior interventricular artery, marginal artery, great cardiac vein, circumflex artery. [Return to Figure 9.5].

Figure 9.6 image description: This image shows the anterior view of the frontal section of the heart with the major parts labeled. Labels read (from top of diagram, clockwise) arch of aorta, Bachman's bundle, atrioventricular bundle (bundle of His), left ventricle, right and left bundle branches, Purkinje fibers, right ventricle, right atrium, posterior intermodal, middle intermodal, atrioventricular node, anterior intermodal, Sinoatrial node. [Return to Figure 9.6].

Figure 9.7 image description: This diagram shows the six different stages of heart contraction and relaxation along with the stages in the QT cycle. [Return to Figure 9.7].

Figure 9.8 image description: This diagram shows the arteries in the thoracic and abdominal cavity. Visceral branches of the thoracic aorta labels (from top): bronchial, esophageal, mediastinal, pericardial, thoracic aorta, aortic hiatus, celiac trunk, left gastric, splenic, common hepatic, superior mesenteric, abdominal aorta, inferior mesenteric, external iliac. Parietal (somatic) branches of thoracic aorta labels (from top): intercostal, superior phrenic, inferior phrenic, diaphragm, adrenal, renal, gonadal, lumbar, medial sacral, common iliac, internal iliac. [Return to Figure 9.8].

Figure 9.9 image description: This diagram shows the structure of the heart with different congenital defects. The top left panel shows patent foramen ovale (label reads foramen ovale fails to close), the top right panel shows coarctation of the aorta (label reads narrow segment of aorta), the bottom left panel shows patent ductus arteriosus (label reads Ductus arteriosus remains open) and the bottom right shows tetralogy of fallot (labels read aorta emerges from both ventricles, interventricular septal defect, enlarged right ventricle, stenosed pulmonary semilunar valve). [Return to Figure 9.9].

Figure 9.10 image description: An angiogram of atherosclerotic coronary arteries. The image shows blockages in the

common trunk of the left coronary artery and circumflex artery. Blockages can cause ischemia, hypoxia, and myocardial infarction. [Return to Figure 9.10].

Figure 9.11 image description: In this image the QT cycle for different heart conditions are shown. From top to bottom, the arrhythmias shown are second-degree partial blocks (text reads: Note how half of the P waves are not followed by the QRS complex and T waves while the other half are. Question: what would you expect to happen to heart rate?), atrial fibrillation (text reads: Note the abnormal electric pattern prior to the QRS complexes. Also note how the frequency between the QRS complexes has increased. Question: What would you expect to happen to heart rate?), ventricular tachycardia (text reads: Note the unusual shape of the QRS complex, focusing on the S component. Question: What would you expect to happen to heart rate?), ventricular fibrillation (text reads: Note the total lack of normal electrical activity. Question: What would you expect to happen to heart rate?), and third degree block (text reads: Note that in a third-degree block some of the impulses initiated by the SA node do not reach the AV node while others do. Also note that the P waves are not followed by the QRS complex. Question: What would you expect to happen to heart rate?). [Return to Figure 9.11].

10. Blood Vessels and Blood

Learning Objectives

- Examine the anatomy of the blood vessels and the composition of blood
- Determine the main functions of the blood vessels and of the components of blood
- Differentiate medical terms of the blood vessels and blood and common abbreviations
- Recognize the medical specialties associated with the blood vessels and blood
- Discover common diseases, disorders, and procedures related to the blood vessels and blood

Blood Vessels and Blood Word Parts

Click on prefixes, combining forms, and suffixes to reveal a list of word parts to memorize for blood vessels and blood.

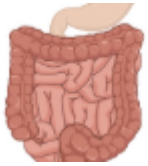
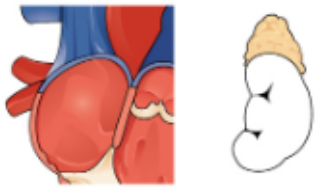
An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.uwf.edu/medicalterminology/?p=111#h5p-62

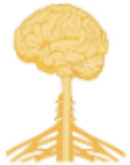
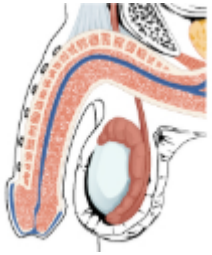
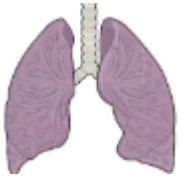
Introduction to the Blood Vessels and Blood

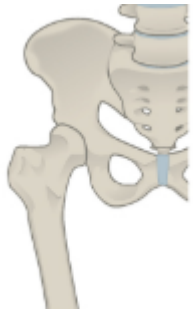
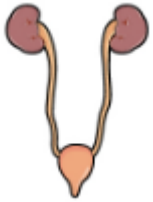
Our large, complex bodies need blood to deliver nutrients to and remove wastes from our trillions of cells. The heart, as discussed in the previous chapter, pumps blood throughout the body in a network of blood vessels. Together, these three components—blood, heart, and vessels—make up the cardiovascular 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., 2013. Licensed under CC BY 4.0.

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Digestive 	Absorbs nutrients and water; delivers nutrients (except most lipids) to the liver for processing by hepatic portal vein; provides nutrients essential for hematopoiesis and building hemoglobin.
Endocrine 	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 	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 	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 	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 	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 	Aids in the erection of genitalia in both sexes during sexual arousal; transports gonadotropic hormones that regulate reproductive functions.
Respiratory 	Provides blood for a 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 	Provides calcium, phosphate, and other minerals critical for bone matrix; transports hormones regulating buildup and absorption of matrix including growth hormone (somatotropin), thyroid hormone, calcitonin, and parathyroid hormones; erythropoietin stimulates myeloid cell hematopoiesis; some level of protection for select vessels by bony structures.
Urinary 	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.

Watch this video:

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.uwf.edu/medicalterminology/?p=111#oembed-1

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

Practice Medical Terms Related to the Blood Vessels and Blood

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.uwf.edu/medicalterminology/?p=111#h5p-63

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.

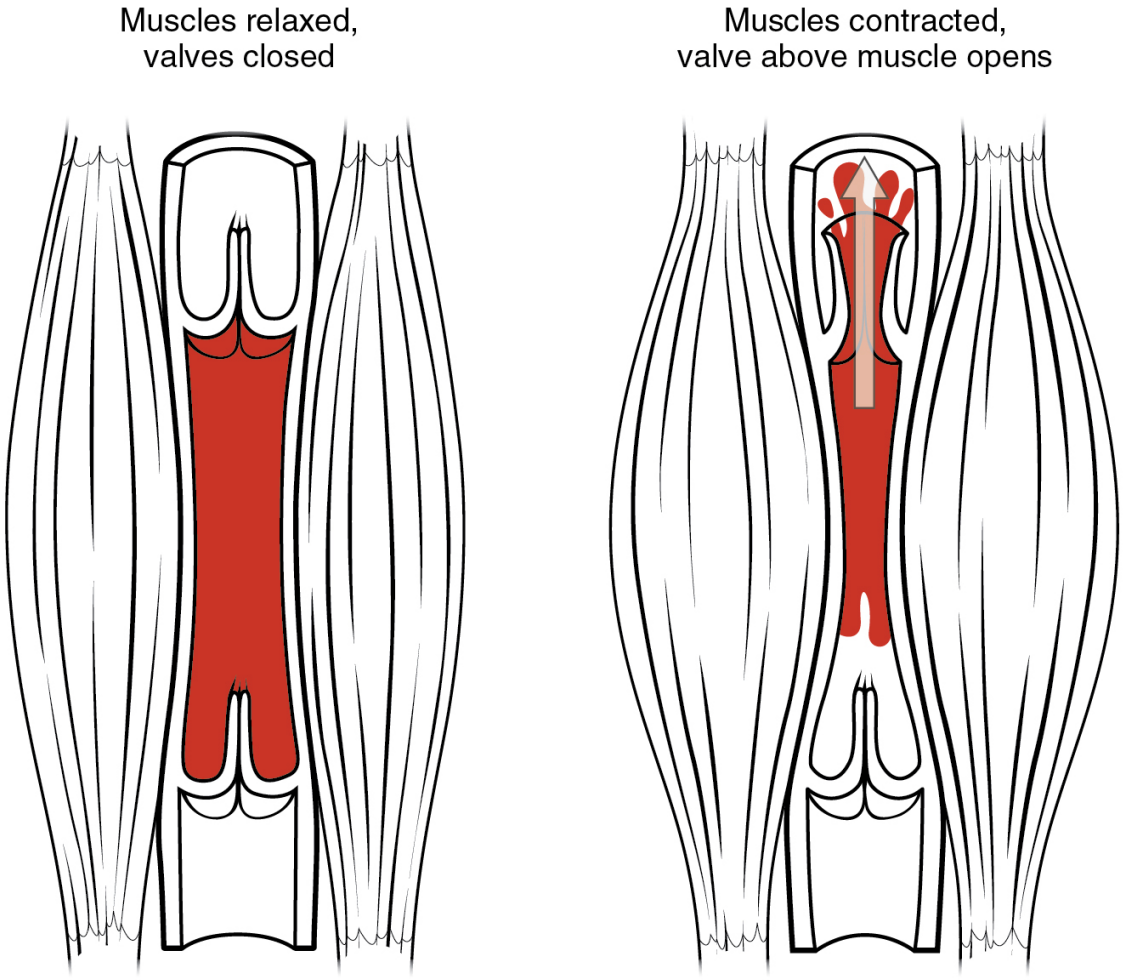
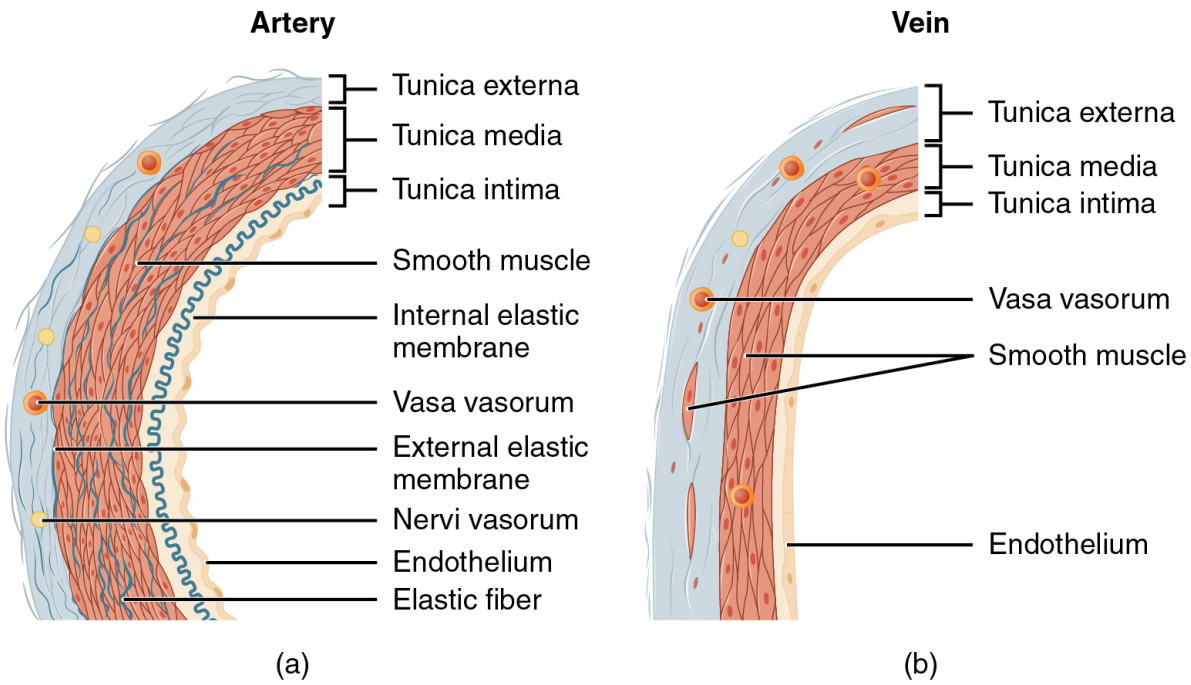


Figure 10.1 Skeletal Muscle Pump. The contraction of skeletal muscles surrounding a vein compresses the blood and increases the pressure in that area. This action forces blood closer to the heart where venous pressure is lower. Note the importance of the one-way valves to assure that blood flows only in the proper direction. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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** (see Figure 10.3). 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.



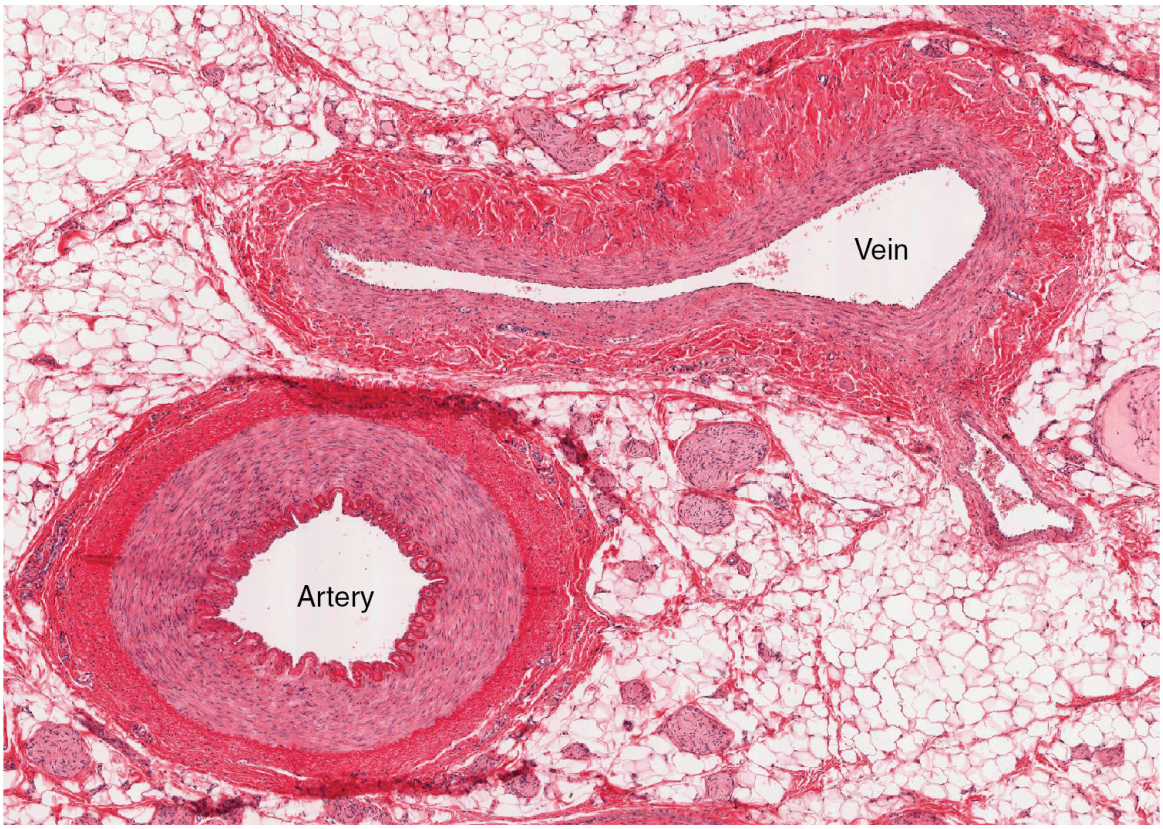


Figure 10.2 Structure of Blood Vessels. (a) Arteries and (b) veins share the same general features, but the walls of arteries are much thicker because of the higher pressure of the blood that flows through them. (c) A micrograph shows the relative differences in thickness. LM × 160. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

The table below compares the features of arteries and veins.

Table 10.2. Comparison of Arteries and Veins. From Betts et al., 2013. 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
Relative oxygen concentration	Higher in systemic arteries	Higher in pulmonary veins
	Lower in pulmonary arteries	Lower in systemic 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.

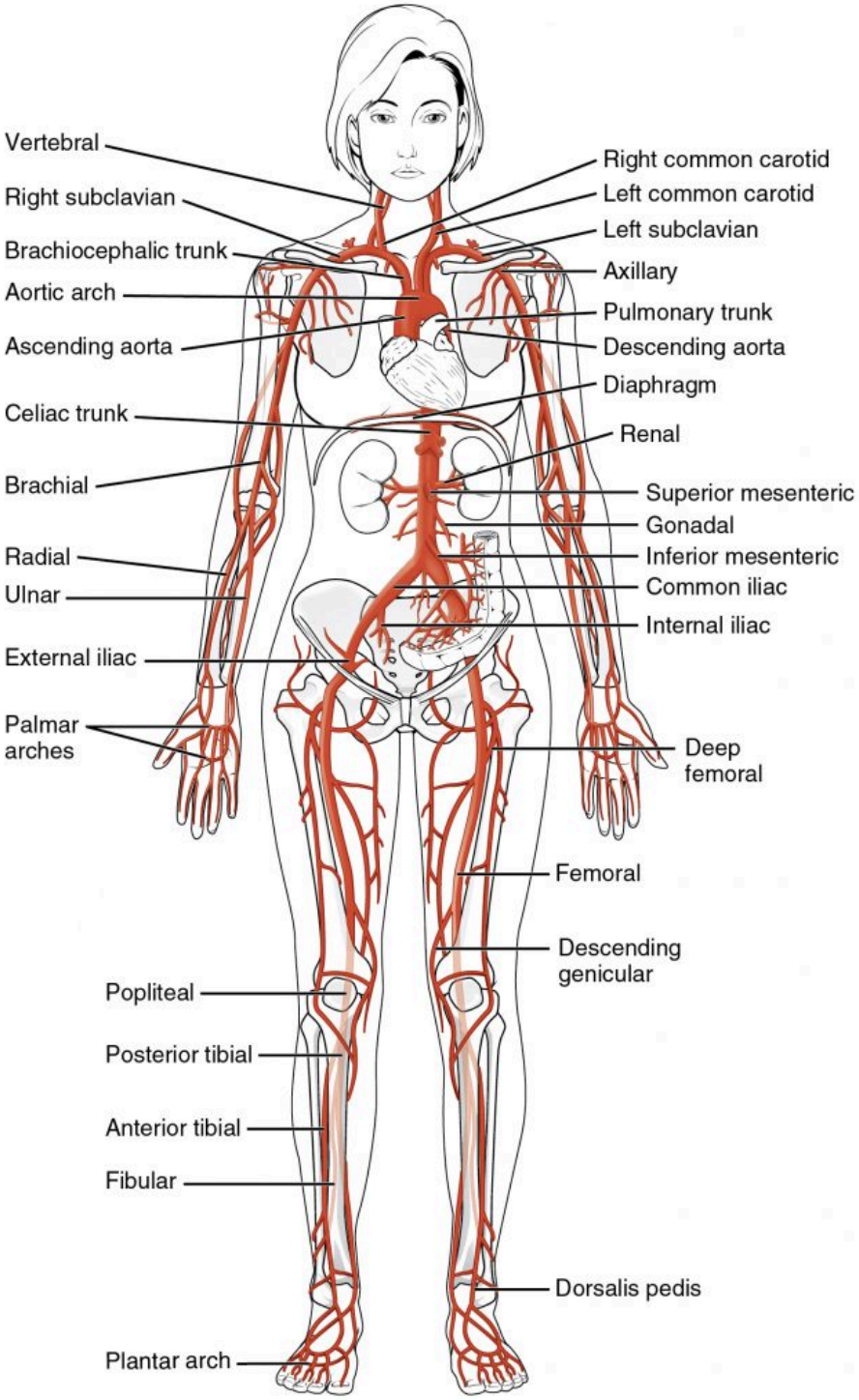


Figure 10.3 Systemic Arteries. The major systemic arteries shown here deliver oxygenated blood throughout the body. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

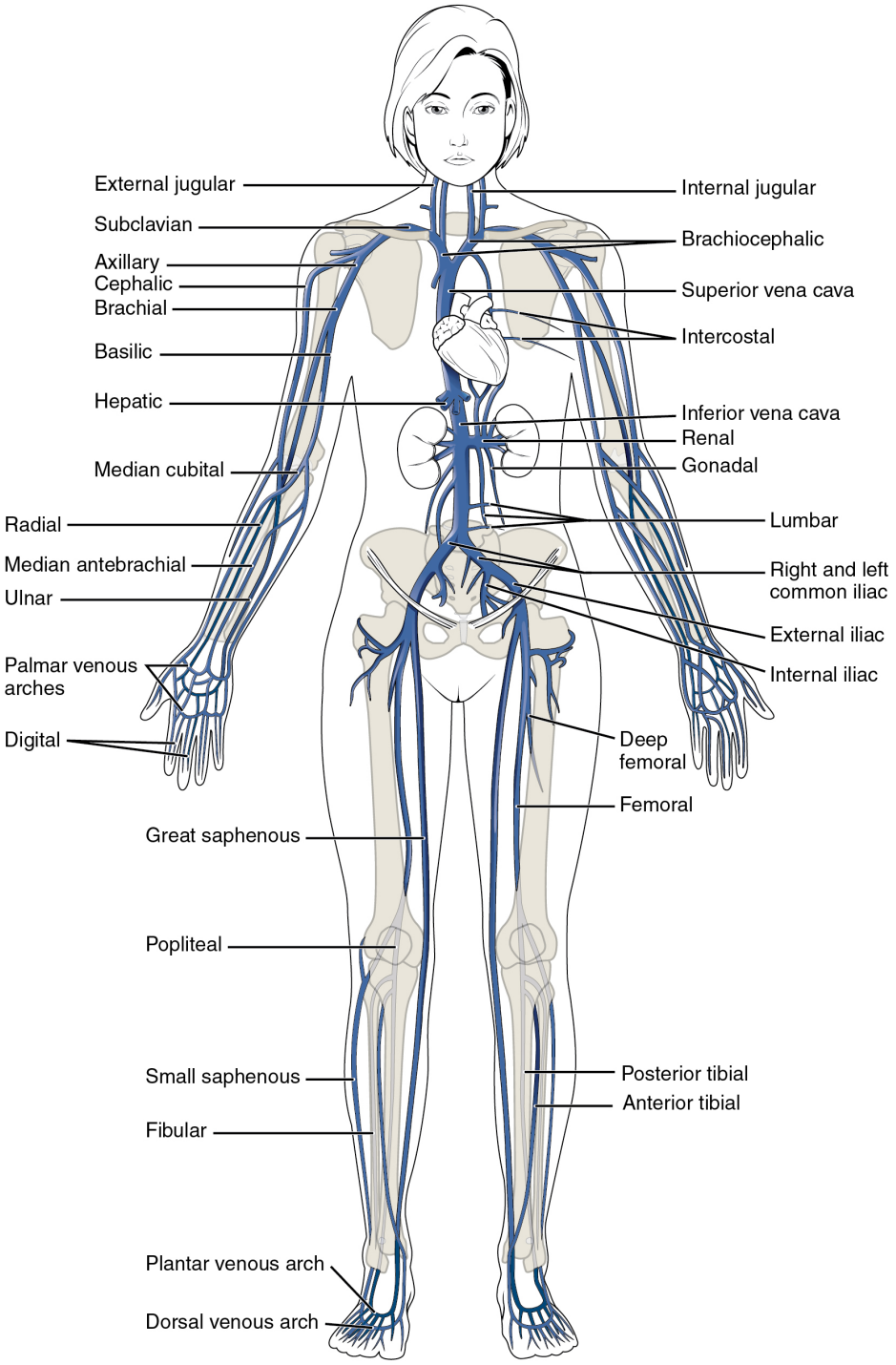


Figure 10.4 Major Systemic Veins of the Body. The major systemic veins of the body are shown here in an anterior view. From Betts et al., 2013. Licensed under CC BY 4.0. *[Image description.]*

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.

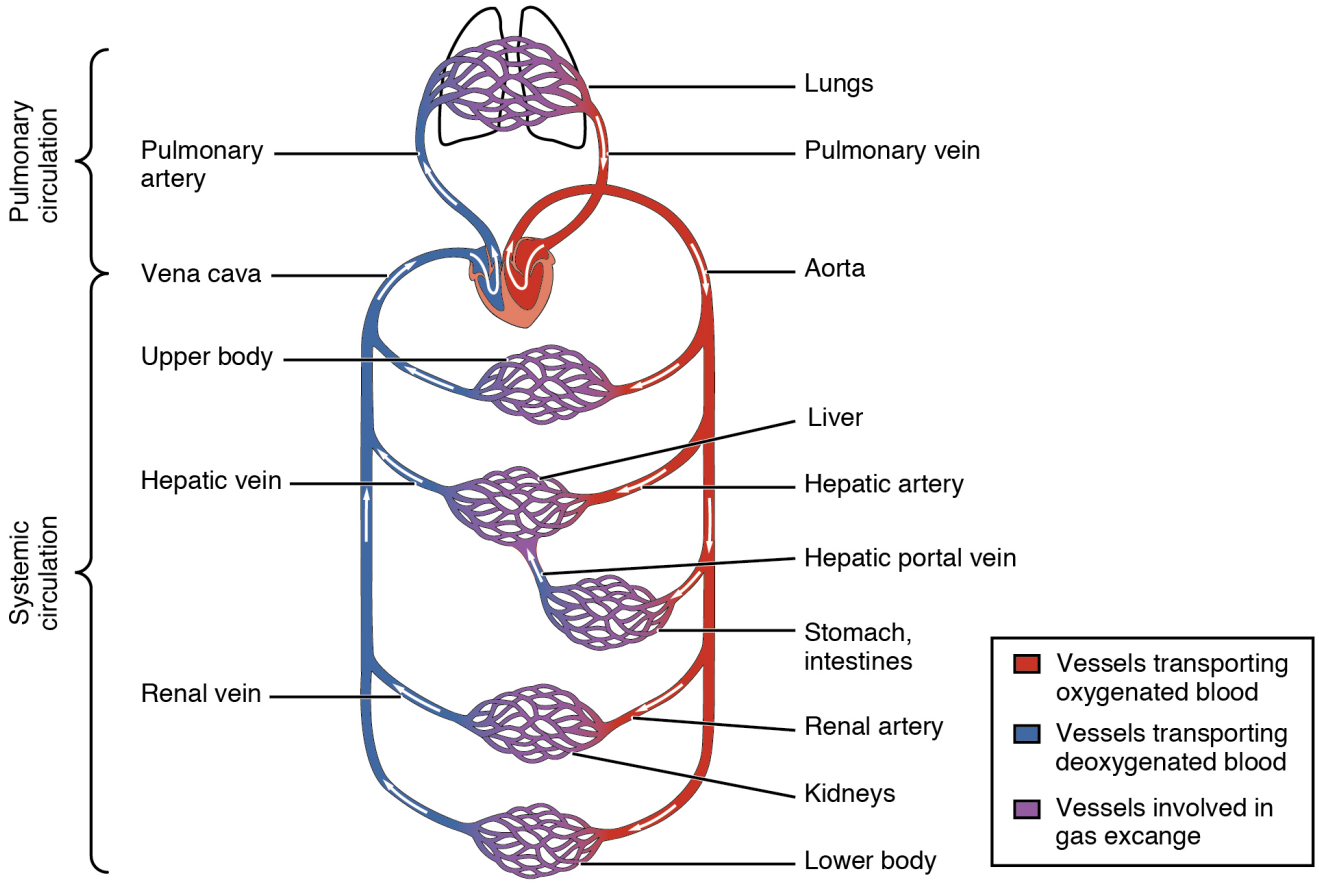


Figure 10.5 Cardiovascular Circulation. The pulmonary circuit moves blood from the right side of the heart to the lungs and back to the heart. The systemic circuit moves blood from the left side of the heart to the head and body and returns it to the right side of the heart to repeat the cycle. The arrows indicate the direction of blood flow, and the colors show the relative levels of oxygen concentration. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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**.

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

Did you know?

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

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.

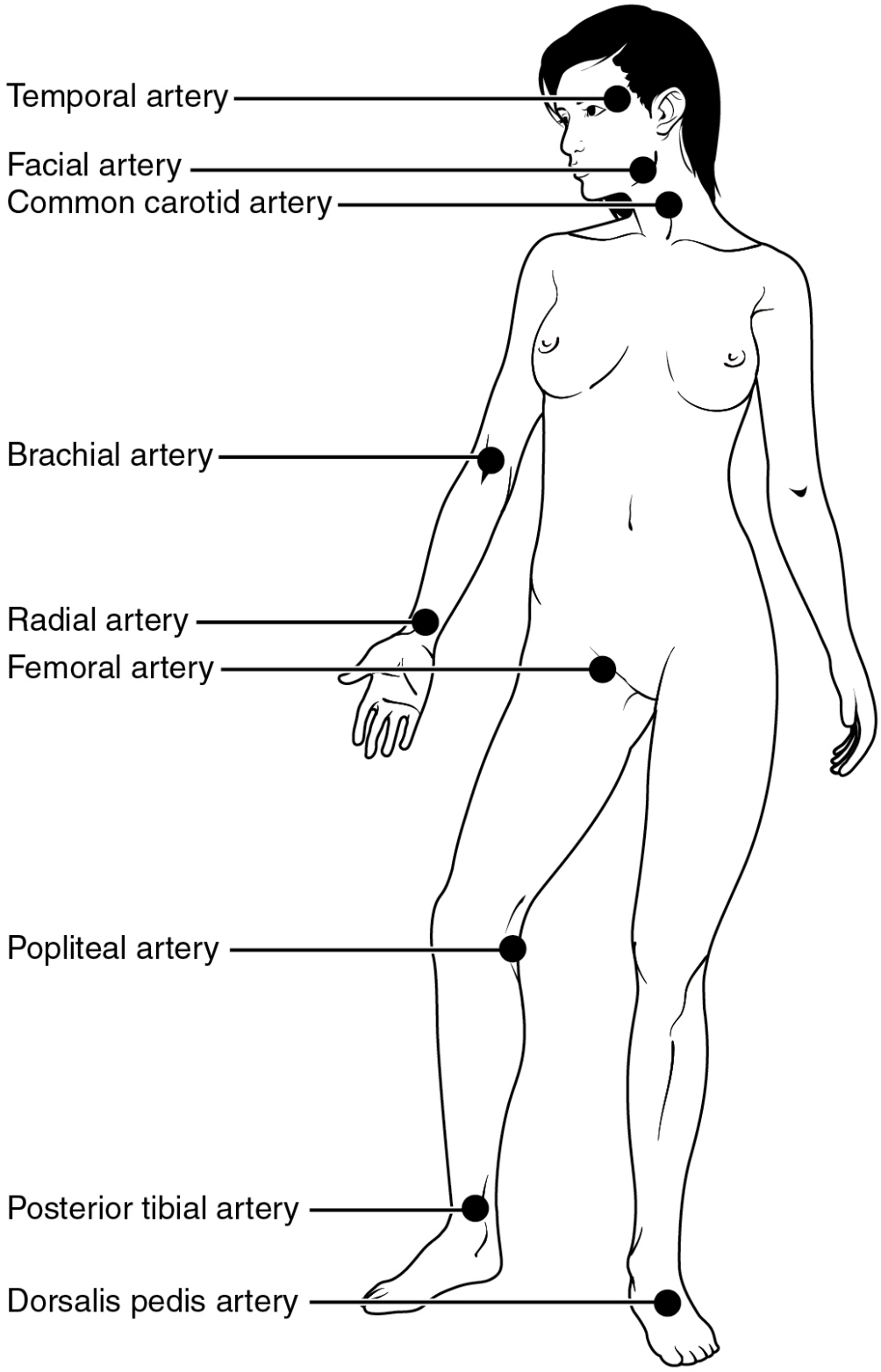


Figure 10.6 Pulse Sites. The pulse is most readily measured at the radial artery, but can be measured at any of the pulse points shown. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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. 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% of a sample is erythrocytes, which is referred to as the **hematocrit**. The hematocrit of any one sample can vary significantly, however, about 36 to 50%, 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%.

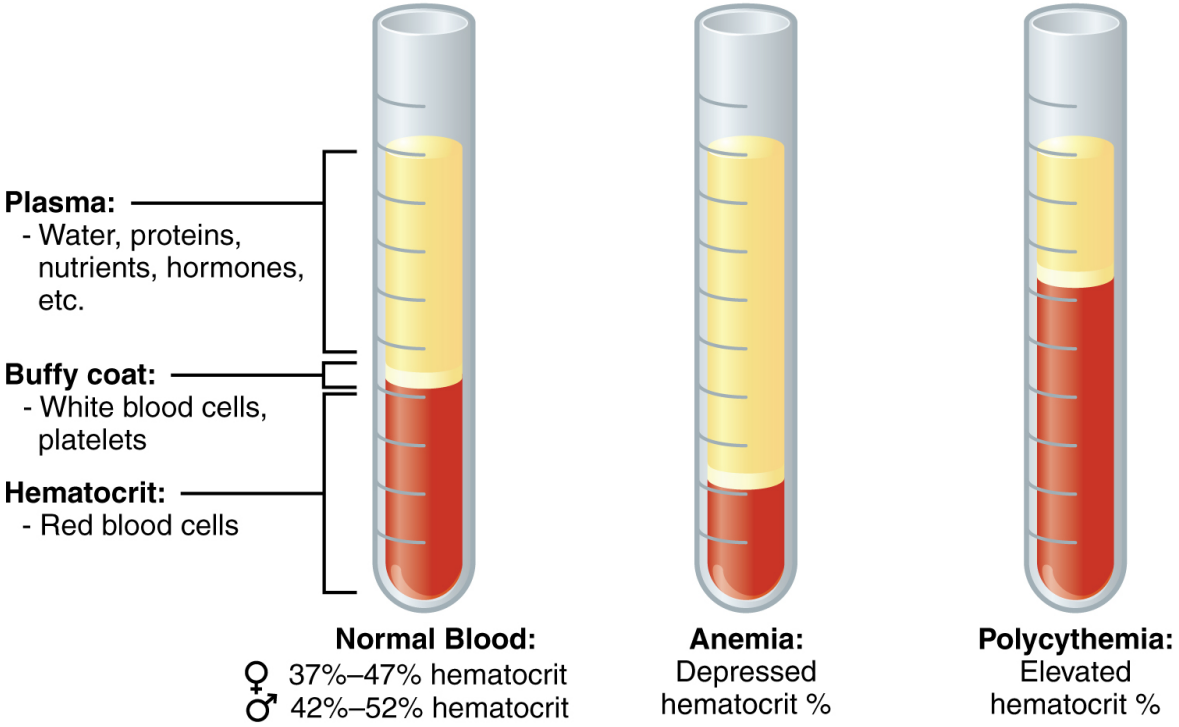


Figure 10.7 Composition of Blood. The cellular elements of blood include a vast number of erythrocytes and comparatively fewer leukocytes and platelets. Plasma is the fluid in which the formed elements are suspended. A sample of blood spun in a centrifuge reveals that plasma is the lightest component. It floats at the top of the tube separated from the heaviest elements, the erythrocytes, by a buffy coat of leukocytes and platelets. Hematocrit is the percentage of the total sample that is composed of erythrocytes. Depressed and elevated hematocrit levels are shown for comparison. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

The table below provides a useful summary of the components of blood and their functions.

Table 10.3 Major Blood Components. This table displays the components of blood and their associated functions. Adapted from Betts et al., 2013. Licensed under CC BY 4.0.

COMPONENT AND % OF BLOOD	SUBCOMPONENT AND % OF COMPONENT	TYPE AND % (WHERE APPROPRIATE)	SITE OF PRODUCTION	MAJOR FUNCTION(S)
Plasma 46 – 63 percent	Water 92 percent	Fluid	Absorbed by intestinal tract or produced by metabolism	Transport medium
	Plasma proteins	Albumin 54 – 60 percent	Liver	Maintain osmotic concentration, transport lipid molecules
		Globulins 35 – 38 percent	Alpha globulins – liver	Transport, maintain osmotic concentration
			Beta globulins – liver	Transport, maintain osmotic concentration
			Gamma globulins (immunoglobulins) – plasma cells	Immune responses
		Fibrinogen 4 – 7 percent	Liver	Blood clotting in hemostasis
	Regulatory proteins < 1 percent	Hormones and enzymes	Various sources	Regulate various body functions
	Other solutes 1 percent	Nutrients, gases, and wastes	Absorbed by intestinal tract, exchanged in respiratory system, or produced by cells	Numerous and varied
Formed elements 37 – 54 percent	Erythrocytes 99 percent	Erythrocytes	Red bone marrow	Transport gases, primarily oxygen and some carbon dioxide
	Leukocytes < 1 percent Platelets < 1 percent	Granular Leukocytes: neutrophils eosinophils basophils	Red bone marrow	Nonspecific immunity
		Agranular leukocytes: lymphocytes monocytes	Lymphocytes: bone marrow and lymphatic tissue	Lymphocytes: specific immunity
			Monocytes: redbone marrow	Monocytes: nonspecific immunity
	Platelets < 1 percent	n/a	Megakaryocytes: Red Bone Marrow	Hemostasis

Did you know?

Blood constitutes approximately 8% of adult body weight.

Concept Check

Use the table above to answer these questions:

- What substance makes up *most* of the plasma?
- What are some general functions of plasma and its components?
- What is the function of **erythrocytes**?
- What is the overall function of **leukocytes**? (Hint: which word appears in all 3 chart cells that list leukocyte functions?)
- What is the function of **platelets**?

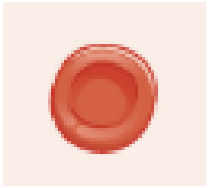
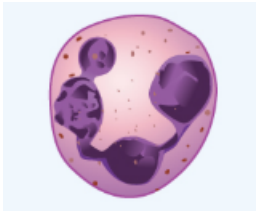
Blood Plasma

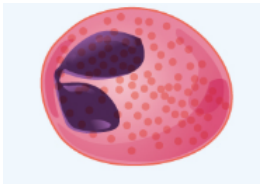
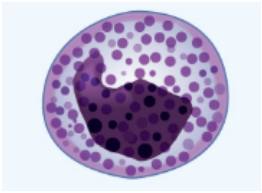
Like other fluids in the body, plasma is composed primarily of water. In fact, it is about 92% water. Dissolved or suspended within this water is a mixture of substances, most of which are proteins. The major components of plasma and their functions are summarized in the table above.

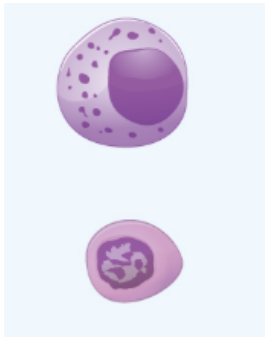
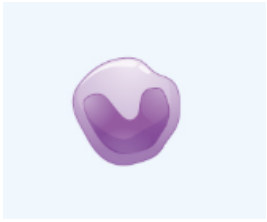
Formed Elements (Erythrocytes, Leukocytes, Thrombocytes)

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

Table 10.4 Summary of Formed Elements in Blood. Adapted from Betts et al., 2013. 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 color	Transport oxygen and some carbon dioxide between tissues and lungs	Lifespan of approximately 120 days
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

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (µL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
	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
	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

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (µL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
	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

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (µL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
Platelets  *Platelet 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

The lifespan of the formed elements is very brief. Although one type of leukocyte (memory cells) can survive for years, most **erythrocytes**, **leukocytes**, and **platelets** normally live only a few hours to a few weeks. Thus, the body must form new blood cells and platelets quickly and continuously, a process known as **hemopoiesis**.

In children, **hemopoiesis** can occur in the medullary cavity of long bones; in adults, the process is largely restricted to the cranial and pelvic bones, the vertebrae, the sternum, and the proximal **epiphyses** of the femur and humerus. Throughout adulthood, the liver and spleen maintain their ability to generate the formed elements. This process is referred to as **extramedullary hematopoiesis**. When a disease such as bone cancer destroys the bone marrow, causing hemopoiesis to fail, extramedullary hematopoiesis may be initiated .

All formed elements arise from stem cells of the red bone marrow, called hematopoietic stem cells, or hemocytoblast. Hemopoiesis begins when the hematopoietic stem cell is exposed to appropriate chemical stimuli collectively called **hemopoietic growth factors**, which prompt it to divide and differentiate. One daughter cell remains a hematopoietic stem cell, allowing hemopoiesis to continue. The other daughter cell becomes either of two types of more specialized stem cells. Follow the chart below from top to bottom to learn how stem cells become mature formed elements of blood.

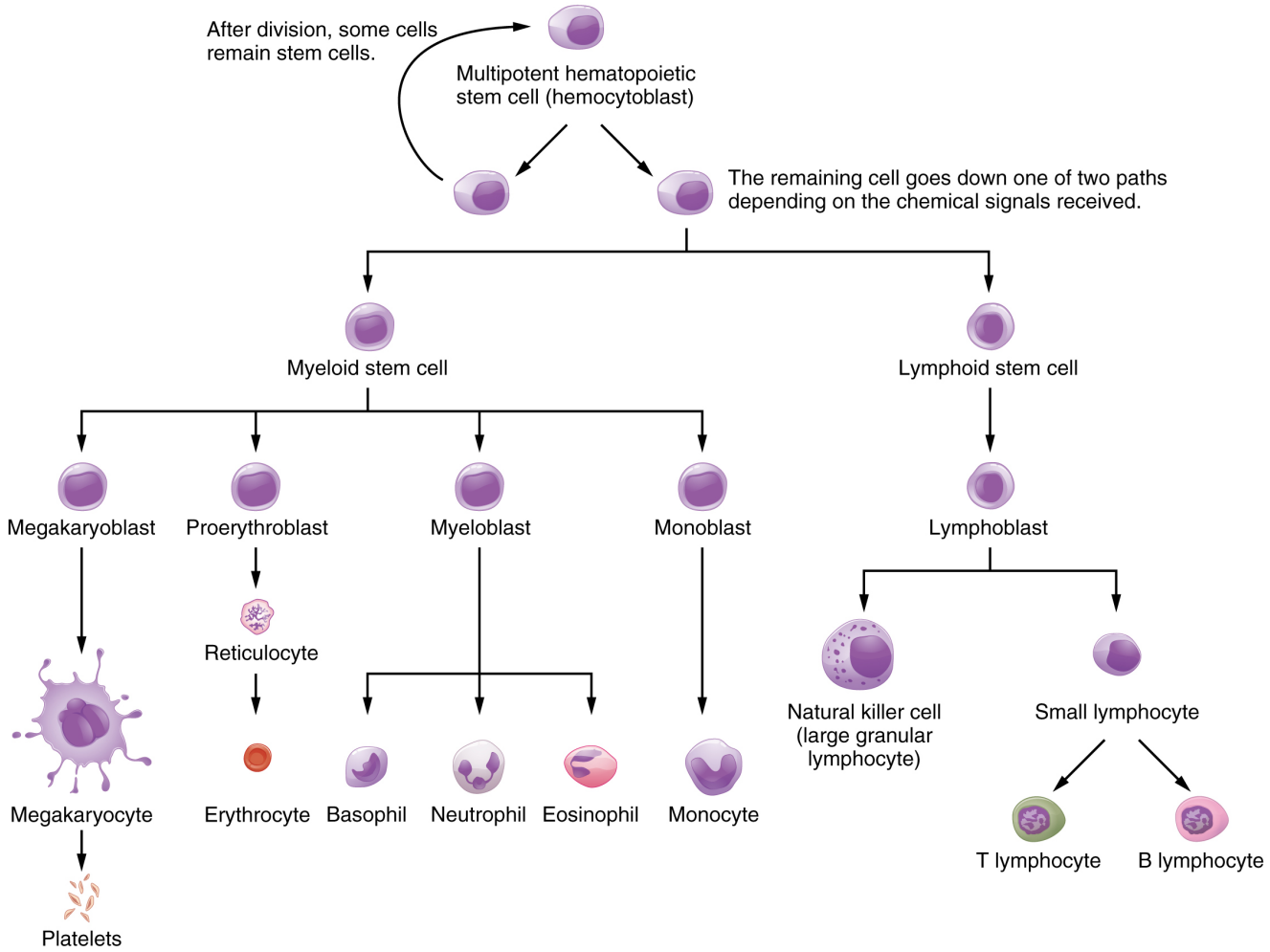


Figure 10.8 Hematopoietic System of Bone Marrow. Hemopoiesis is the proliferation and differentiation of the formed elements of blood. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

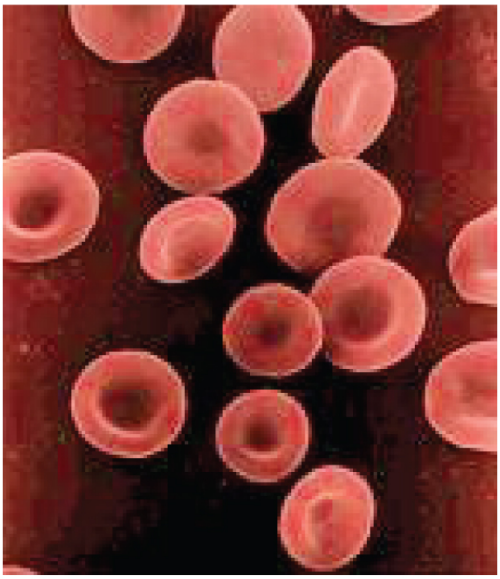


Figure 10.9 Shape of Red Blood Cells. Erythrocytes are biconcave discs with very shallow centers. This shape optimizes the ratio of surface area to volume, facilitating gas exchange. It also enables them to fold up as they move through narrow blood vessels. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 10.10 shows the different types of leukocytes.

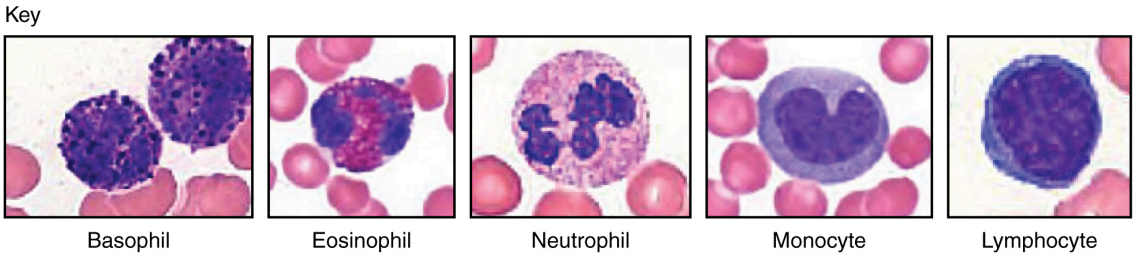


Figure 10.10 Leukocytes. (Micrographs provided by the Regents of University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Concept Check

- What is **hemoglobin**?
- Can you name the 5 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. As shown in Figure 10.11 below, they leave the capillaries—the smallest blood vessels—or other small vessels through a process known as **emigration** or **diapedesis** in which they squeeze through adjacent cells in a blood vessel wall.

Once they have exited the capillaries, some leukocytes will take up fixed positions in lymphatic tissue, bone marrow, the spleen, the thymus, or other organs. Others will move about through the tissue spaces, sometimes wandering freely, and sometimes moving toward the direction in which they are drawn by chemical signals, a mechanism known as **positive chemotaxis.**

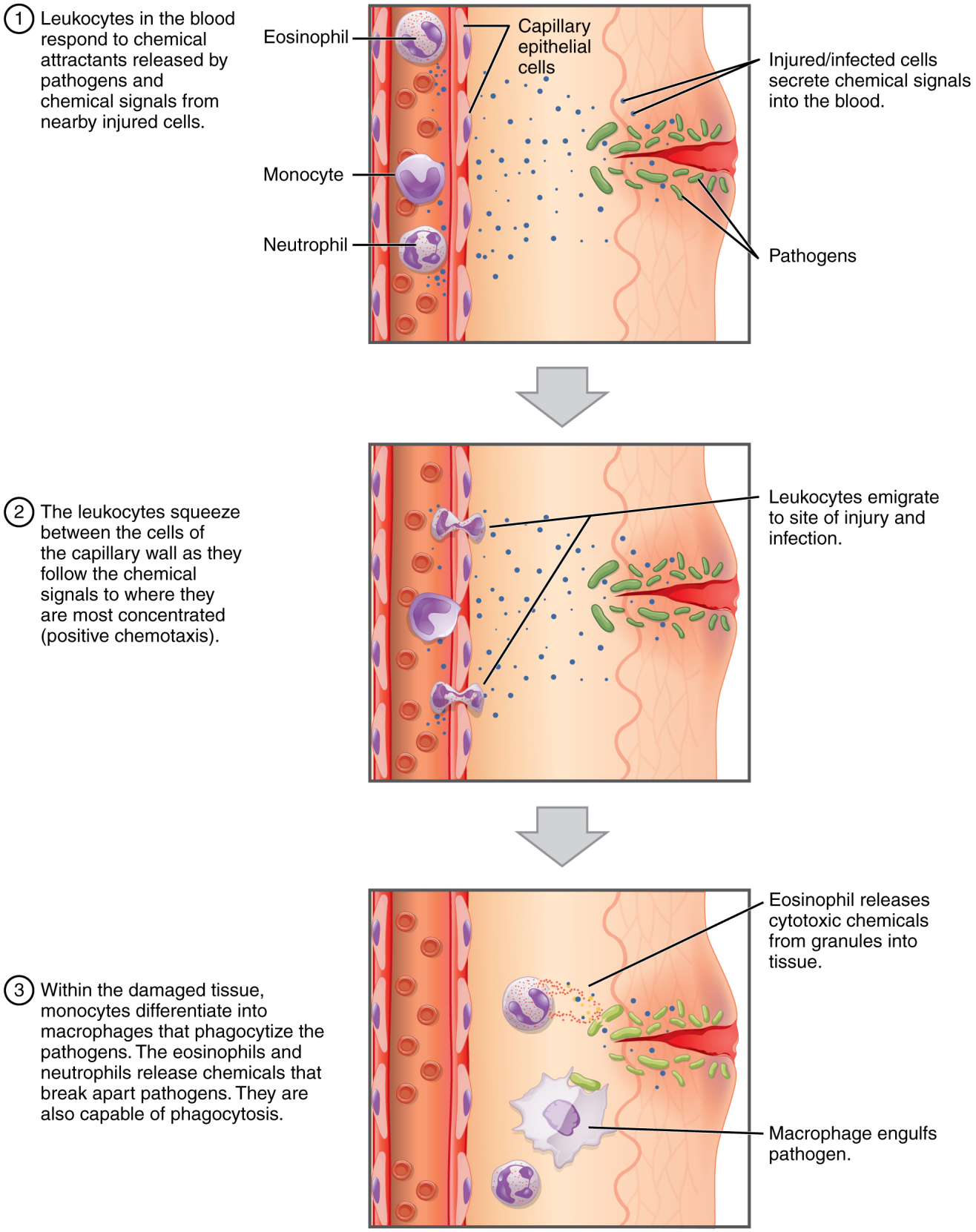


Figure 10.11 Emigration. Leukocytes exit the blood vessel and then move through the connective tissue of the dermis toward the site of a wound. Some leukocytes, such as the eosinophil and neutrophil, are characterized as granular leukocytes. They release chemicals from their granules that destroy pathogens; they are also capable of phagocytosis. The monocyte differentiates into a [pb_glossary id="411"]macrophage[/pb_glossary] that then [pb_glossary id="413"]phagocytizes[/pb_glossary] the pathogens. From Betts et al., 2013.

Lymphocytes

Lymphocytes are a type of leukocyte. 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, 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.

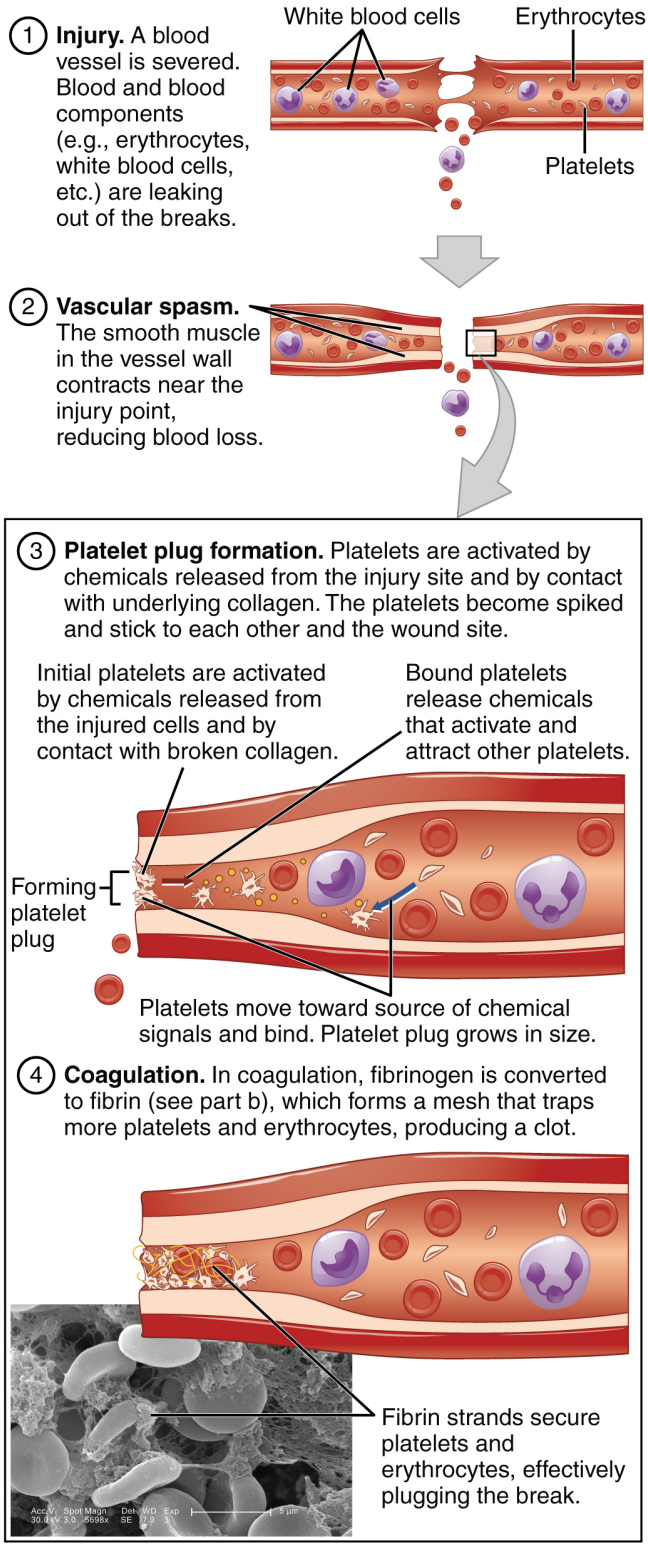


Figure 10.12 Hemostasis. (a) An injury to a blood vessel initiates the process of hemostasis. Blood clotting involves three steps. First, vascular spasm constricts the flow of blood. Next, a platelet plug forms to temporarily seal small openings in the vessel. Coagulation then enables the repair of the vessel wall once the leakage of blood has stopped. (b) The synthesis of fibrin in blood clots involves either an intrinsic pathway or an extrinsic pathway, both of which lead to a common pathway. (credit: Kevin MacKenzie). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 off 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 table below shows the ABO blood group as well as the universal donor and recipient in relation to blood transfusions.

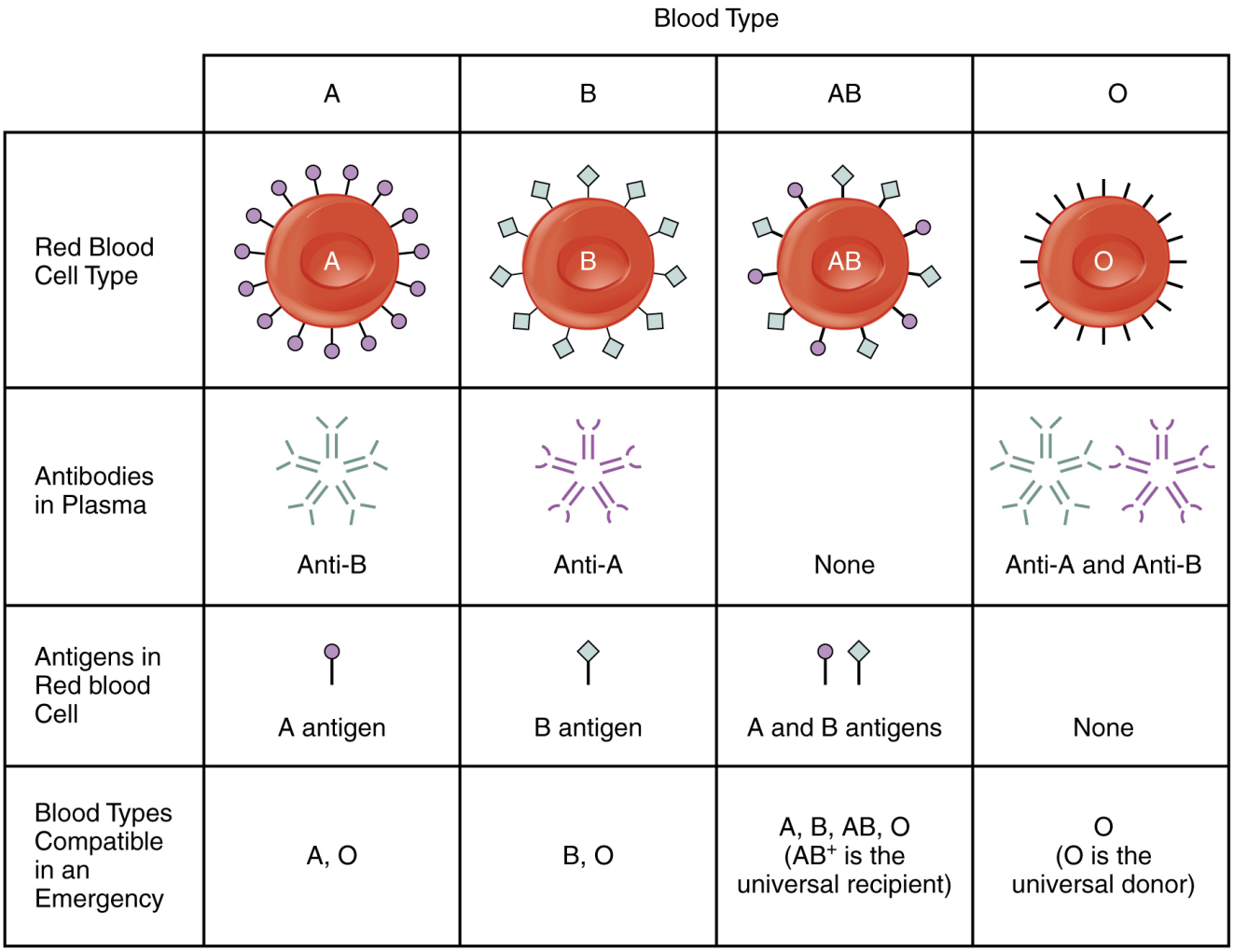


Figure 10.13 ABO Blood Groups. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

- 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 have preformed **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 preformed 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 10.14). Research has shown that this occurs in about 13 to 14% 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 to 28 of pregnancy and within 72 hours following birth.

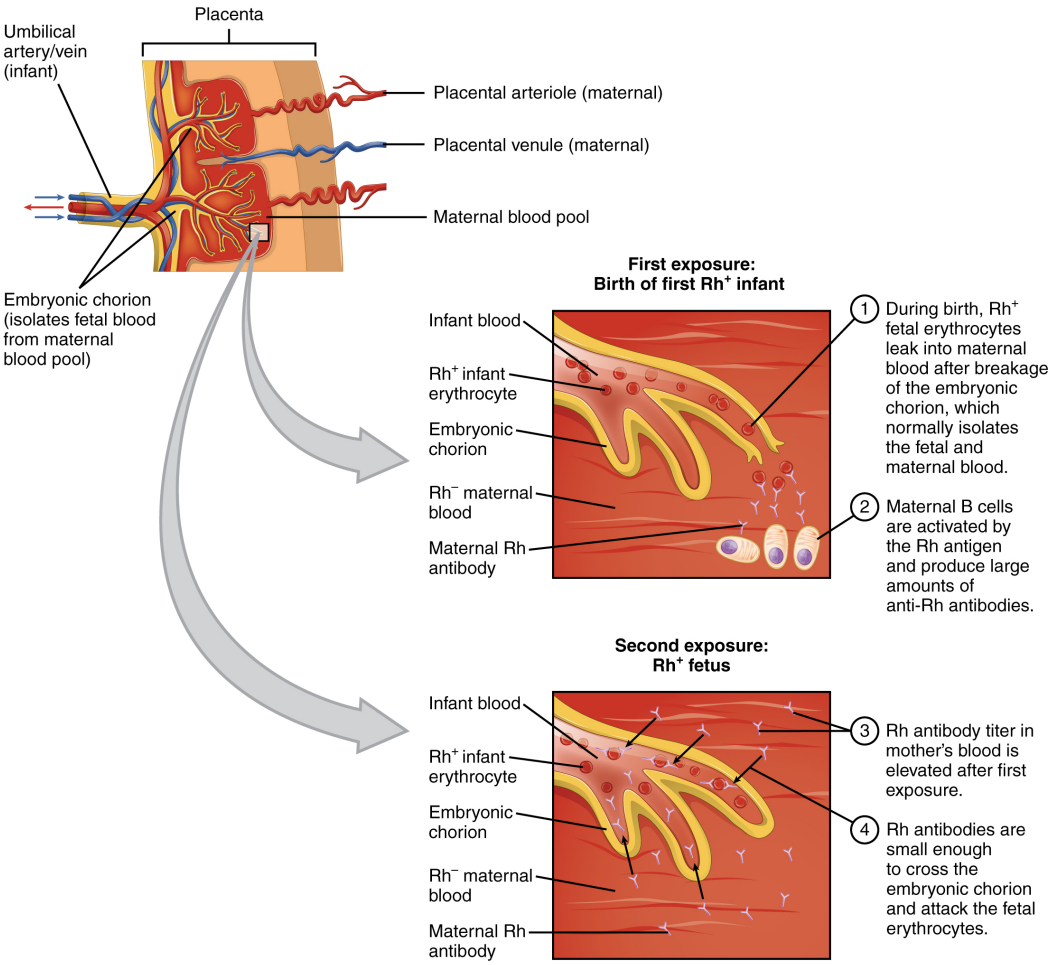


Figure 10.14 Erythroblastosis Fetalis. The first exposure of an Rh− mother to Rh+ erythrocytes during pregnancy induces sensitization. Anti-Rh antibodies begin to circulate in the mother's bloodstream. A second exposure occurs with a subsequent pregnancy with an Rh+ fetus in the uterus. Maternal anti-Rh antibodies may cross the placenta and enter the fetal bloodstream, causing agglutination and hemolysis of fetal erythrocytes. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Blood Transfusions

Figure 10.15 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.

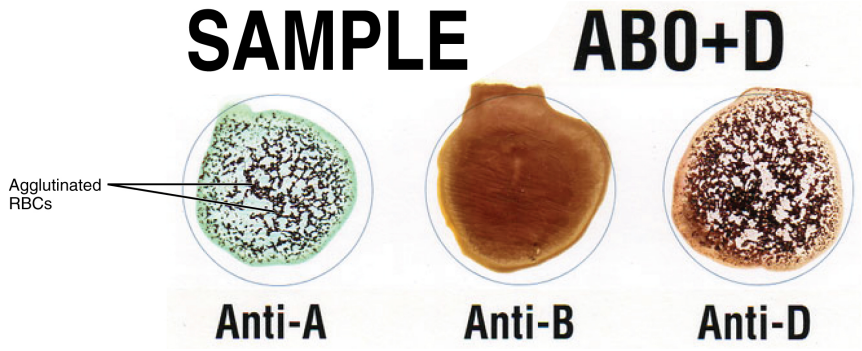


Figure 10.15. Cross Matching Blood Types. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

Practice Terms Related to the Blood Vessels and Blood

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.uwf.edu/medicalterminology/?p=111#h5p-64

Diseases and Disorders of Blood Vessels and Blood

Arteriosclerosis

Arteriosclerosis is normally defined as the more generalized loss of **compliance**, or "hardening of the arteries." **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 10.16).

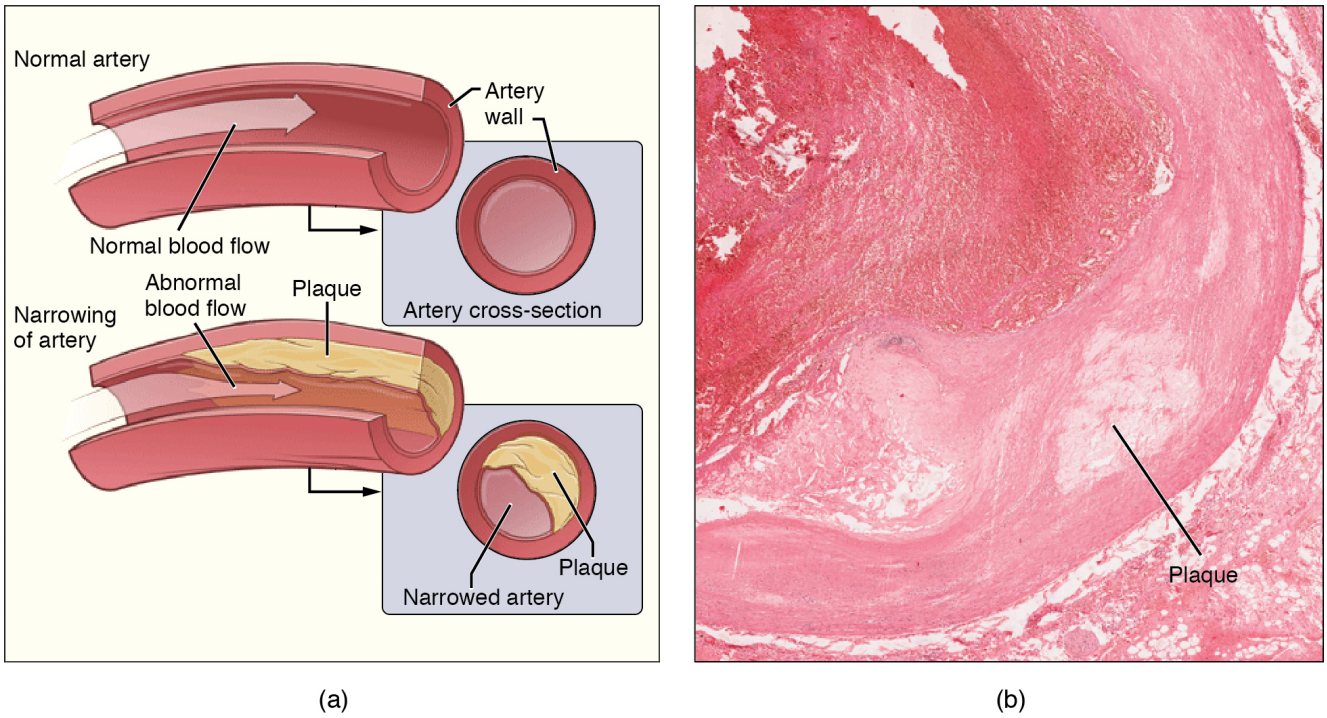


Figure 10.16 Atherosclerosis. (a) Atherosclerosis can result from plaques formed by the buildup of fatty, calcified deposits in an artery. (b) Plaques can also take other forms, as shown in this micrograph of a coronary artery that has a buildup of connective tissue within the artery wall. LM × 40. (Micrograph provided by the Regents of University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 a carotid endarterectomy, plaque is surgically removed from the walls of the **carotid artery**, which is the main source of oxygenated blood for the brain.

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 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.

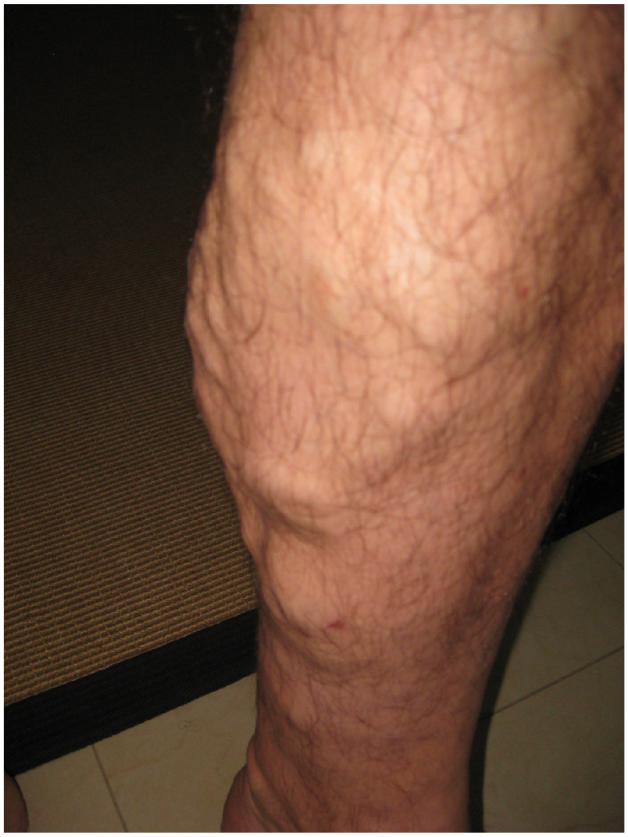


Figure 10.17 Varicose Veins. Varicose veins are commonly found in the lower limbs. (credit: Thomas Kriese). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Edema may be accompanied by varicose veins, especially in the superficial veins of the legs (see Figure 10.17). 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 a support hose, as well as elevating the feet and legs whenever possible, may be helpful in alleviating this condition.

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.

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% 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.

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.

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**.

Erythrocyte Disorders

Changes in the levels of RBCs can have significant effects on the body's ability to effectively deliver oxygen to the tissues.

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**.

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**
    - A genetic disorder involving the production of an abnormal type of hemoglobin that delivers less oxygen to tissues and causes erythrocytes to assume a sickle (or crescent) shape (Figure 10.18).
- **Iron deficiency anemia**
    - The most common type of anemia and results when the amount of available iron is insufficient to allow the 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 may 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.

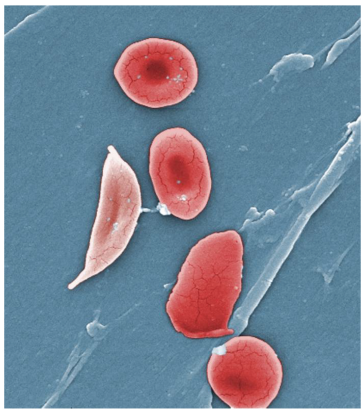


Figure 10.18 Sickle Cells. (credit: Janice Haney Carr). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

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 when 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 patients over 60 years of age.

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.

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.

Thrombocytopenia

Thrombocytopenia is a condition in which there is an insufficient number of platelets, possibly leading to ineffective blood clotting and excessive bleeding.

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 hemophilia patients. At some point, genetic therapy will become a viable option.

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.

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.

Leukemia

Leukemia is 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.

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.

Other Conditions Related to Abnormal Leukocyte Counts

Table 10.5. Conditions Related to Abnormal White Blood Cell Counts. From Betts et al., 2013. 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

Common Blood Vessels and Blood Abbreviations

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

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Medical Terms in Context

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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. For more information, please visit the Society for Vascular Surgery web page.

Hematologists

Hematologists are specialist physicians that diagnose and treat blood disorders (National Cancer Institute, n.d.). To learn more about hematologists, visit the American Society of Hematology.

Diagnostic Vascular Technologists

Diagnostic vascular technologists are specialists that image the vascular system. Most diagnostic vascular technologists have professional certification (Bureau of Labor Statistics, 2021a.). To learn more, visit the Society for Vascular Ultrasound's web page.

Phlebotomist

Phlebotomists are professionals trained to draw blood. 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.

Medical Laboratory Technologists/Technicians

Medical or clinical laboratories employ a variety of individuals in technical positions. Two specialized positions are medical laboratory technologists and technicians. Technologists and technicians operate laboratory equipment, analyze body fluids, and discuss their findings with physicians. Technologists generally perform more complex procedures than technicians. Some states require certification (Bureau of Labor Statistics, 2021b).

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.

Blood Vessels and Blood Vocabulary

Acquired immunodeficiency syndrome (AIDS)

A disease caused by the human immunodeficiency virus (HIV). People with acquired immunodeficiency syndrome are at an increased risk for developing certain cancers and for infections that usually occur only in individuals with a weak immune system (National Cancer Institute, n.d.)

Anaphylaxis

An acute hypersensitivity reaction due to exposure to a previously encountered antigen.

Anemia

A condition in which the number of red blood cells or hemoglobin is deficient.

Aneurysm

Weakening of the wall of a blood vessel, causing it to thin and balloon out, and possibly eventually burst, resulting in internal bleeding.

Angiography

A procedure to x-ray blood vessels.

Angioplasty

A procedure in which an occlusion is mechanically widened with a balloon.

Angioscope

Instrument used for visual examination of blood vessels.

Angioscopy

Endoscopic examination of blood vessels.

Anti-B antibodies

Proteins that will mount an immune response against B antigens.

Antibodies

Proteins made by plasma cells (a type of white blood cell) in response to an antigen (a substance that causes the body to make a specific immune response). Each antibody can bind to only one specific antigen. The purpose of this binding is to help destroy the antigen.

Antigens

Substances that provokes an immune response. This happens because the immune system sees the antigen as foreign, or 'non-self" (does not belong in that body).

Aortic stenosis

A condition in which the aortic valve becomes rigid and may calcify over time.

Artery

A blood vessel that transports blood away from the heart.

Arteriole

A very small artery that leads to a capillary.

Arteriogram

An x-ray of arteries.

Arteriosclerosis

The generalized loss of compliance; "hardening of the arteries".

Atherectomy

Excision of fatty plaque.

Atherosclerosis

A hardening of the arteries that involves the accumulation of fatty plaque.

Brachial artery

The large artery in the upper arm near the biceps muscle.

Capillaries

The smallest type of blood vessel. A capillary connects an arteriole (small artery) to a venule (small vein) to form a network of blood vessels in almost all parts of the body.

Cardiac output

The measurement of blood flow from the heart through the ventricles and is usually measured in liters per minute. Any factor that causes cardiac output to increase, by elevating heart rate or stroke volume or both, will elevate blood pressure and promote blood flow.

Cardiac tamponade

A potentially fatal condition in which excess fluid builds within the pericardial space, preventing the heart from beating effectively.

Cardiogenic

Originating from the heart.

Carotid artery

Located in the neck, it is one of the three major branches of the aortic arch.

Centrifugation

Process of using a rotating machine to generate centrifugal force to separate substances of different densities, remove moisture, or simulate gravitational effects.

Chemoreceptors

Cells that sense changes in chemical levels.

Chemotaxis

Movement in response to chemicals; a phenomenon in which injured or infected cells and nearby leukocytes emit the equivalent of a chemical "911" call, attracting more leukocytes to the site.

Compliance

The ability of the blood vessels to dilate and constrict as needed.

Coronary artery bypass graft (CABG)

Surgery in which a healthy blood vessel taken from another part of the body is used to make a new path for blood around a blocked artery leading to the heart. This restores the flow of oxygen and nutrients to the heart.

Coronary heart disease

A disease in which there is a narrowing or blockage of the coronary arteries.

Crohn's disease

A condition in which the gastrointestinal tract is inflamed over a long period of time.

Diapedesis

The migration of blood cells through the intact walls of blood vessels into the surrounding tissue.

Diastolic pressure

The arterial pressure of blood during ventricular relaxation, or diastole.

Edema

Swelling due to excessive liquid in the tissues.

Embolus

An obstruction such as a blood clot or plaque that blocks the flow of blood in an artery or vein.

Endarterectomy

Excision of plaque from within the artery.

Endothelium

Epithelium that lines vessels in the lymphatic and cardiovascular systems.

Epiphyses

The wider section at the end of long bones.

Erythrocyte

A red blood cell.

Erythropoietin (EPO)

A hormone produced by the kidneys that triggers the production of red blood cells.

Extramedullary hematopoiesis

Hematopoiesis outside the medullary cavity of adult bones.

Heart rate

The number of times the heart beats within a certain time period, usually a minute.

Hematocrit

A lab test which measures the percentage red blood cells in a sample of whole blood.

Hematologist

A doctor who has special training in diagnosing and treating blood disorders.

Hematology

The study of blood and blood-forming issues.

Hematoma

A pool of mostly clotted blood that forms in an organ, tissue, or body space.

Hemolysis

The breakdown of red blood cells.

Hemopoiesis

The process by which the body produces blood.

Hemopoietic growth factors

Chemical messengers which promote the proliferation and differentiation of formed elements and include erythropoietin, thrombopoietin, colony-stimulating factors, and interleukins.

Hemorrhage

Excessive bleeding.

Hemostasis

The process by which the body seals a ruptured blood vessel to prevent further blood loss.

Homeostasis

The state of steady internal conditions maintained by living things.

Hypertension

Abnormally high blood pressure.

Hypothermia

Abnormally low body temperature.

Hypothyroidism

The disease state caused by insufficient production of thyroid hormone by the thyroid gland.

Hypovolemic

An abnormally low volume of blood circulating through the body.

Hypoxemia

Below-normal level of oxygen saturation of blood (typically <95 percent).

Hypoxia

Lack of oxygen supply to the tissues.

Immunodeficiency

The decreased ability of the body to fight infections and other diseases.

Intravenous

Into or within the vein.

Ischemia

Lack of blood flow to body tissues.

Leukocyte

White blood cell(s).

Leukocytopenia

An abnormal decrease in the number of leukocytes.

Lupus

A chronic, inflammatory, connective tissue disease that can affect the joints and many organs.

Lymphadenitis

Inflammation of lymph nodes.

Lymphadenopathy

Disease or swelling of the lymph nodes.

Lymphoma

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. These leukocytes do not function properly, and the patient is vulnerable to infection.

Macrophage

A large cell derived from a monocyte; they participate in innate immune responses.

Medulla oblongata

A part of the brain stem responsible for control of heart rate and breathing.

Myeloma

Cancer that arises in plasma cells.

Myelopoiesis

Formation of bone marrow.

Pancytopenia

A condition in which there is a lower-than-normal number of red and white blood cells and platelets in the blood.

Perfusion

Penetration of blood.

Peripheral arterial disease

Obstruction of vessels in peripheral regions of the body.

pH

A measure of how acidic or alkaline a substance is, as determined by the number of free hydrogen ions in the substance.

Phagocytized

The process by which certain cells are able to "eat" other cells or substances by engulfing them.

Phlebitis

Inflammation of a vein.

Phlebotomist

A medical professional trained to draw blood, typically by performing a venipuncture of a surface vein of the arm.

Phlebotomy

A procedure in which a needle is used to take blood from a vein, usually for laboratory testing.

Placenta

The organ that supplies oxygen and nutrients to the fetus, excretes waste products, and produces and secretes estrogens and progesterone.

Plaque

A fatty material including cholesterol, connective tissue, white blood cells, and some smooth muscle cells.

Plasma cells

A type of B lymphocyte that produces antibodies which bind to specific foreign or abnormal antigens, in order to destroy them.

Plasmapheresis

A procedure in which a machine is used to separate the plasma from the blood cells.

Pneumothorax

An abnormal collection of air in the space between the thin layer of tissue that covers the lungs and the chest cavity that can cause all or part of the lung to collapse.

Polycythemia vera

A type of bone marrow disease that causes an excessive production of immature erythrocytes.

Pulmonary embolism

A blood clot within the lung.

Rheumatoid arthritis

An autoimmune disorder in which the body mounts an immune response against its own joint tissues, causing inflammation and damage to the joints.

Sepsis

Organismal-level inflammatory response to a massive infection.

Sickle cell disease

An inherited disease in which the red blood cells have an abnormal crescent shape, block small blood vessels, and do not last as long as normal red blood cells; also called sickle cell anemia.

Splenectomy

Excision of the spleen.

Splenomegaly

Enlarged spleen.

Sphygmomanometer

A blood pressure cuff attached to a measuring device, or gauge.

Systolic pressure

The arterial pressure resulting from the ejection of blood during ventricular contraction, or systole.

Thalassemia

A genetic disorder characterized by abnormal synthesis of globin proteins and excessive destruction of erythrocytes.

Thrombocyte

Platelets.

Thrombocytopenia

A condition in which there is an insufficient number of platelets.

Thrombocytosis

A condition in which there are too many platelets.

Thrombophlebitis

Inflammation of a vein that occurs when a blood clot forms.

Thrombosis

The formation of unwanted blood clots.

Thrombus

Aggregation of fibrin, platelets, and erythrocytes in an intact artery or vein.

Thrombolysis

The process of breaking up a thrombus that is blocking blood flow.

Thymectomy

Excision of the thymus gland.

Thymoma

Tumor of the thymus gland.

Tissue rejection

The recipient's immune system recognizes the transplanted tissue as non-self and mounts an immune response against it, ultimately destroying it.

Vasoconstriction

The physiological narrowing of blood vessels by contraction of the vascular smooth muscle.

Vasodilation

The physiological widening of blood vessels by relaxing the vascular smooth muscle.

Veins

Blood vessels that carry blood back to the heart.

Venules

Small blood vessels that carry blood to a vein.

Viscosity

A measure of a fluid's thickness or resistance to flow.

Test Yourself

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https://pressbooks.uwf.edu/medicalterminology/?p=111#h5p-67

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Image Descriptions

Figure 10.1 image description: The left panel shows the structure of a skeletal muscle vein pump when the muscle is relaxed, and the right panel shows the structure of a skeletal muscle vein pump when the muscle is contracted.[Return to Figure 10.1].

Figure 10.2 image description: The top left panel of this figure shows the ultrastructure of an artery (labels read from top: tunica externa, tunica media, tunica intima, smooth muscle, internal elastic membrane, vasa vasorum, external elastic membrane, nervi vasorum, endothelium, elastic fiber), and the top right panel shows the ultrastructure of a vein (labels read from top: tunica externa, tunica media, tunica intima, vasa vasorum, smooth muscle, endothelium). The bottom panel shows a micrograph with the cross-sections of an artery and a vein. [Return to Figure 10.2].

Figure 10.3 image description: The major arteries in the human body. Labels read (from the top, clockwise) right common carotid, left common carotid, axillary, pulmonary trunk, descending aorta, diaphragm, renal, superior mesenteric, gonadal, inferior mesenteric, common iliac, internal iliac, deep femoral, femoral, descending genicular, dorsalis pedis, plantar arch, fibular, anterior tibial, posterior tibial, popliteal, palmar arches, external iliac, ulnar, radial, brachial, celiac trunk, ascending aorta, aortic arch, brachiocephalic trunk, right subclavian, vertebral. [Return to Figure 10.3].

Figure 10.4 image description: The major veins in the human body. Labels read (from the top, clockwise) internal jugular, brachiocephalic, superior vena cava, intercostal, inferior vena cava, gonadal, lumbar, right and left common iliac, external iliac, internal iliac, deep femoral, femoral, posterior tibial, anterior tibial, dorsal venous arch, plantar venous arch, fibular, small saphenous, popliteal, great saphenous, digital, palmar venous arches, ulnar, median antebrachial, medial cubital, hepatic, basilic, brachial, cephalic, axillary, subclavian, external jugular. [Return to Figure 10.4].

Figure 10.5 image description: This diagram shows how oxygenated and deoxygenated blood flows through the major organs in the body. Pulmonary circulation involves the lungs, pulmonary artery and vein, vena cava, and aorta. Systemic circulation involves the upper body, hepatic vein, renal vein, aorta, liver, hepatic artery, hepatic portal vein, stomach, intestines, renal artery, kidneys, and lower body. [Return to Figure 10.5].

Figure 10.6 image description: The pulse points as shown on a woman's body. Labels read (from top) temporal artery, facial artery, common carotid artery, brachial artery, radial artery, femoral artery, popliteal artery, posterior tibial artery, dorsalis pedis artery. [Return to Figure 10.6].

Figure 10.7 image description: This figure shows three test tubes with a red and yellow liquid in them. The left panel shows normal blood, the center panel shows anemic blood and the right panel shows polycythemia. Labels indicate plasma (water, proteins, nutrients, hormones et cetera), buffy coat (white blood cells, platelets), and hematocrit (red blood cells). [Return to Figure 10.7].

Figure 10.8 image description: This flowchart shows the pathways in which a multipotent hematopoietic stem cell differentiates into the different cell types found in blood. From the top (multipotent hematopoietic stem cells can divide and some cells remain stem cells, while the remaining cell goes down one of two paths depending on the chemical signals received: myeloid stem cell or lymphoid stem cell. A myeloid stem cell then can become either a megakaryoblast (which then turns into a megakaryocyte, then becomes platelets), or it can become a proerythroblast (which then becomes a reticulocyte, then becoming an erythrocyte), or it can become a myeloblast (which then becomes either a basophil, neutrophil, eosinophil), or it can become a monoblast (which then it becomes a monocyte). If the cell becomes a lymphoid stem cell, it then becomes a lymphoblast, which then becomes either a natural killer cell or a small lymphocyte (either T or B lymphocyte). [Return to Figure 10.8].

Figure 10.9 image description: This image shows a microscopic view of erythrocytes (red blood cells). Erythrocytes have the appearance of a disc with a shallow center, which aids their function. [Return to Figure 10.9].

Figure 10.10 image description: This image shows a micrographic view of different leukocytes. From left to right: basophil, eosinophil, neutrophil, monocyte, lymphocyte. [Return to Figure 10.10].

Figure 10.11 image description: This figure shows how leukocytes respond to chemical signals from injured cells. The top panel shows chemical signals sent out by the injured cells (text labels read: 1) Leukocytes in the blood respond to chemical attractants released by pathogens and chemical signals from nearby injured cells). The middle panel shows leukocytes migrating to the injured cells (text labels read: 2)the leukocytes squeeze between the capillary wall as they follow the chemical signals to where they are most concentrated (positive chemotaxis)). The bottom panel shows macrophages phagocytosing the pathogens (text label reads: 3) Within the damaged tissue, monocytes differentiate into macrophages that phagocytize the pathogens. The eosinophils and neutrophils release chemicals that break apart pathogens. They are also capable of phagocytosis.). [Return to Figure 10.11].

Figure 10.12 image description: This figure details the steps in the clotting of blood. Each step is shown along with a detailed text box describing the steps on the left. On the right, a signaling pathway shows the different chemical signals involved in the clotting process. The steps described: 1. Injury: a blood vessel is severed. Blood and blood components (e.g. erythrocytes, white blood cells, et cetera) are leaking out of the breaks. 2. Vascular spasm: the smooth muscle in the vessel wall contracts near the injury point reducing blood loss. 3. Platelet plug formation: platelets are activated by chemicals released from the injury site and by contact with underlying collagen. The platelets become spiked and stick to each other and the wound site. Initial platelets are activated by chemicals released from the injured cells and by contact with broken collagen. Bound platelets release chemicals that activate and attract other platelets. platelets move toward the source of chemical signals and bind. Platelet plug grows in size. 4. Coagulation. In coagulation, fibrinogen is converted to fibrin (see part b), which forms a mesh that traps more platelets and erythrocytes, producing a clot. Part B Fibryn synthesis cascade: Intrinsic pathway (damaged vessel wall), Extrinsic pathway (trauma to extravascular cells), final common pathway (cross-linked fibrin clot). [Return to Figure 10.12].

Figure 10.13 image description: This chart shows the ABO blood group types. From left to right, the columns are blood types A, B, AB, and O. In descending order, the rows are: red blood cell type; antibodies in plasma; antigens in red blood cell; and blood types compatible in an emergency. Blood type A has anti-B antibodies and A antigens and is compatible with blood types A and O. Blood type B has anti-A antibodies and B antigens and is compatible with blood types B and O. Blood type AB has no antibodies, has A and B antigens, and is compatible with all blood types (AB^+ is the universal recipient). Blood type O has anti-A and anti-B antibodies, has no antigens, and is compatible with blood type O (O is the universal donor). [Return to Figure 10.13].

Figure 10.15 image description: This figure shows three different red blood cells with different blood types. [Return to Figure 10.15].

Figure 10.14 image description: This figure shows an umbilical artery and vein passing through the placenta on the top left. The top right panel shows the first exposure to Rh+ antibodies in the mother. The bottom right panel shows the response when the second exposure in the form of another fetus takes place. Textboxes detail the steps in each process: First exposure birth of first Rh+ infant: 1. During birth, Rh+ fetal erythrocytes leak into maternal blood after breakage of the embryonic chorion, which normally isolates the fetal and maternal blood. 2) Maternal B cells are activated by the Rh antigen and produce large amounts of anti-Rh antibodies. Second exposure: Rh+ fetus: 3) Rh antibody titer in mother's blood is elevated after first exposure. 4) Rh antibodies are small enough to cross the embryonic chorion and attach to the fetal erythrocytes. [Return to Figure 10.14].

Figure 10.16 image description: The left panel (a) shows the cross-section of a normal and a narrowed artery. A normal artery has no plaque along the artery walls which means there is normal blood flow. In a narrow artery, plague forms on the arterial walls causing abnormal blood flow. The right panel (b) shows a micrograph of an artery with plaque in it. [Return to Figure 10.16].

Figure 10.17 image description: This photograph shows varicose veins in the lower leg. Varicose veins are distended, twisted veins that may present in patients with edema. [Return to Figure 10.17].

Figure 10.18 image description: This photograph shows the red blood cells of a person suffering from sickle cell anemia. Instead of being discoid shaped like healthy blood cells, sickle red blood cells are shaped like a sickle. [Return to Figure 10.18].

11. Lymphatic and Immune Systems

Learning Objectives

- Examine the anatomy of the lymphatic and immune systems
- Determine the main functions of lymphatic and immune systems
- Differentiate lymphatic and immune systems medical terms and common abbreviations
- Recognize the medical specialties associated with lymphatic and immune systems
- Discover common diseases, disorders, and procedures related to lymphatic 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 to 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.

Watch this video:

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.uwf.edu/medicalterminology/?p=128#oembed-1

Media 11.1 Lymphatic System: Crash Course A&P #44 [Online video]. Copyright 2015 by CrashCourse.

Practice Medical Terms Related to the Lymphatic and Immune Systems

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Anatomy and Physiology of the Lymphatic and Immune Systems

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 to 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.

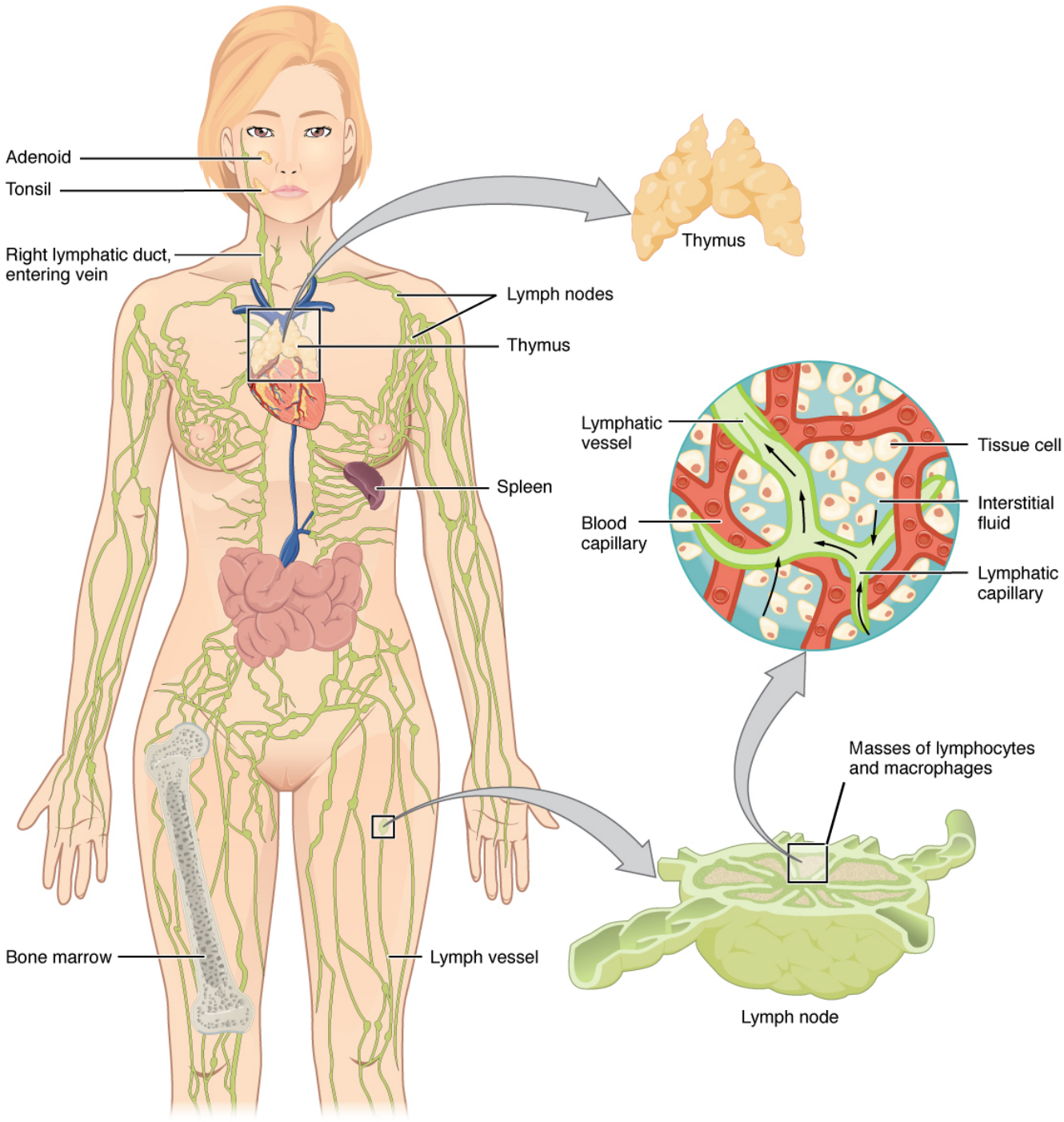


Figure 11.1 Anatomy of the Lymphatic System. Lymphatic vessels in the arms and legs convey lymph to the larger lymphatic vessels in the torso. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

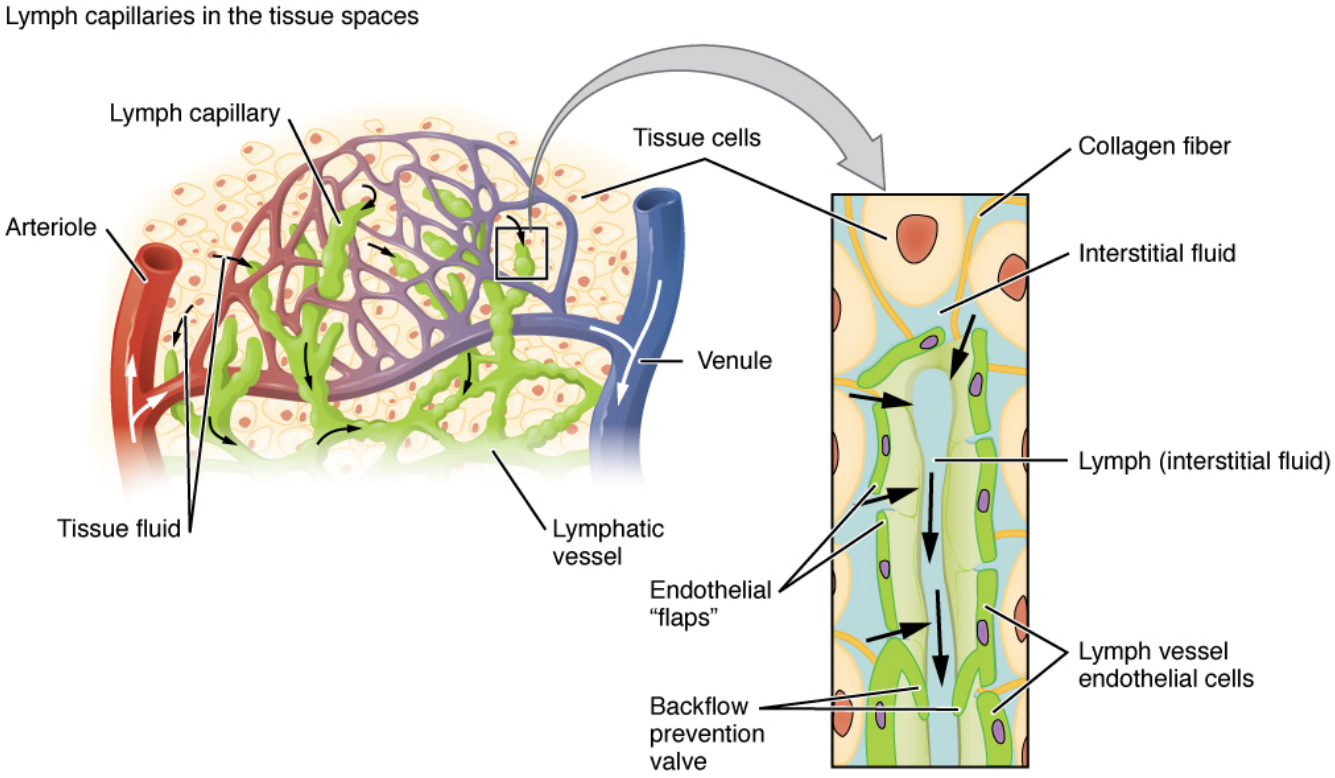


Figure 11.2 Lymphatic Capillaries. Lymphatic capillaries are interlaced with the arterioles and venules of the cardiovascular system. Collagen fibers anchor a lymphatic capillary in the tissue (inset). Interstitial fluid slips through spaces between the overlapping endothelial cells that compose the lymphatic capillary.From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

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 the **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**.

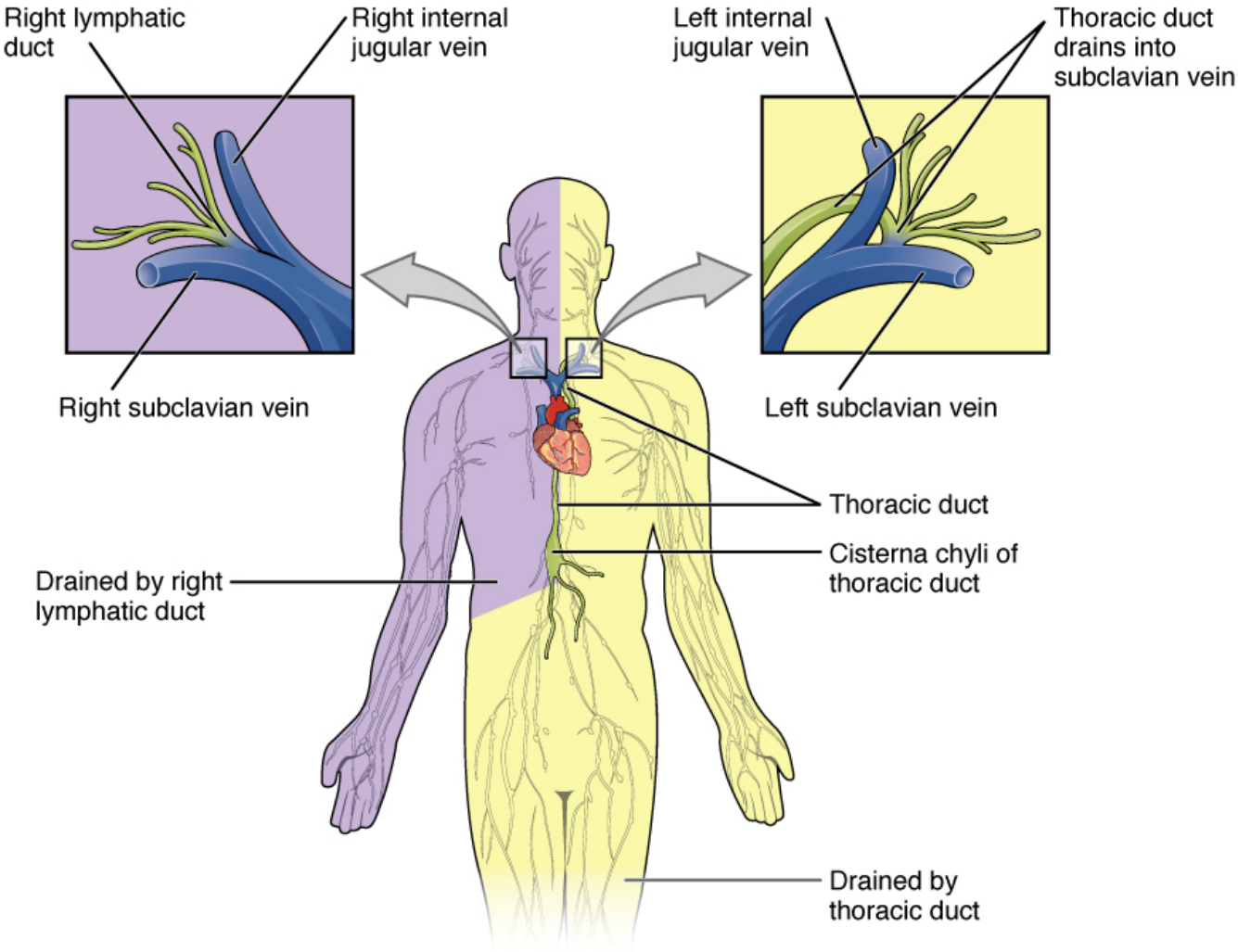


Figure 11.3 Major Trunks and Ducts of the Lymphatic System. The thoracic duct drains a much larger portion of the body than does the right lymphatic duct. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 3% tissue loss per year. This shrinking continues until 35 to 45 years of age when the rate declines to about 1% 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.

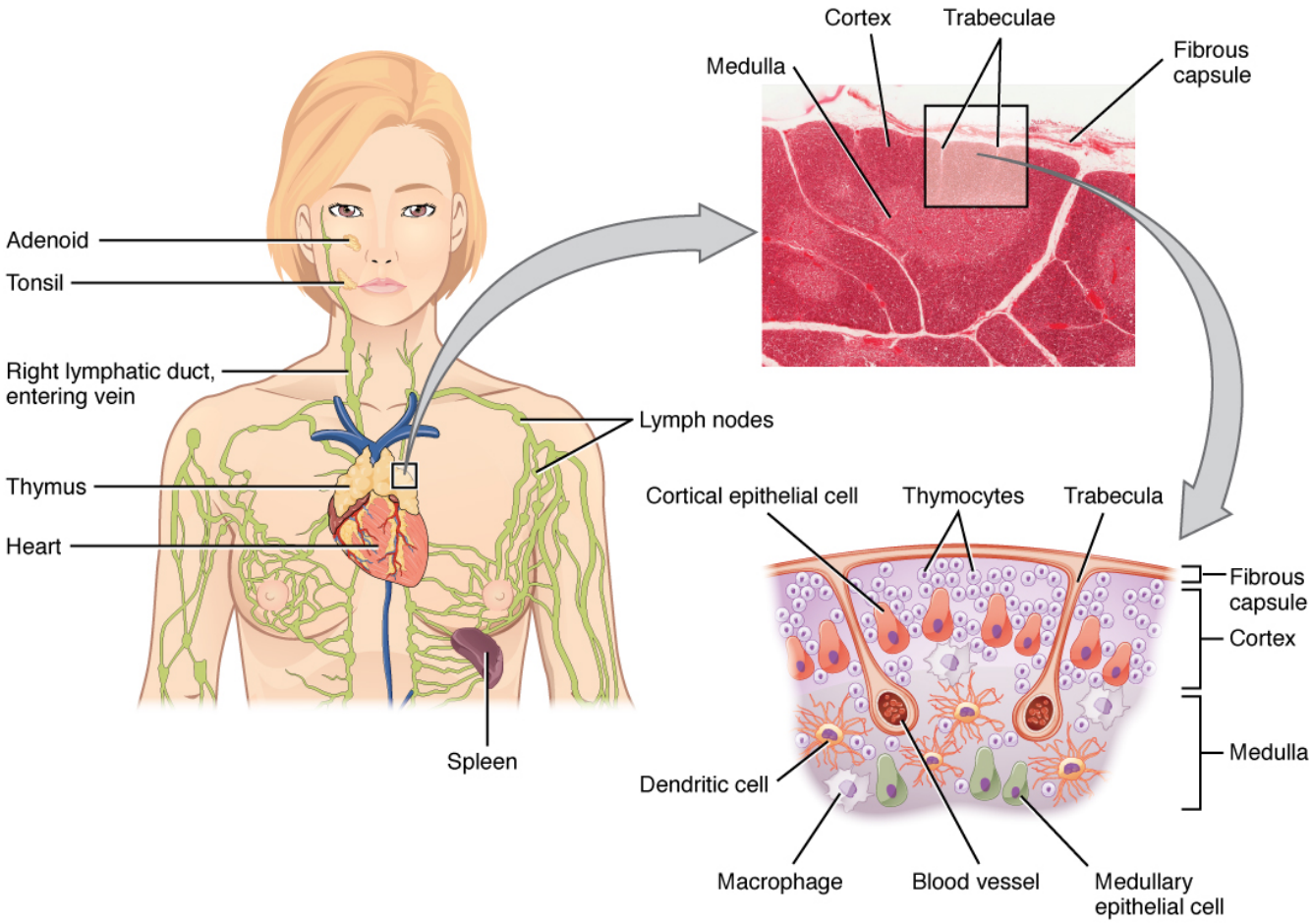


Figure 11.4 Location, Structure, and Histology of the Thymus. The thymus lies above the heart. The trabeculae and lobules, including the darkly staining cortex and the lighter staining medulla of each lobule, are clearly visible in the light micrograph of the thymus of a newborn. LM × 100. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Concept Check

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

Secondary Lymphoid Organs

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 (see Figure 11.5).

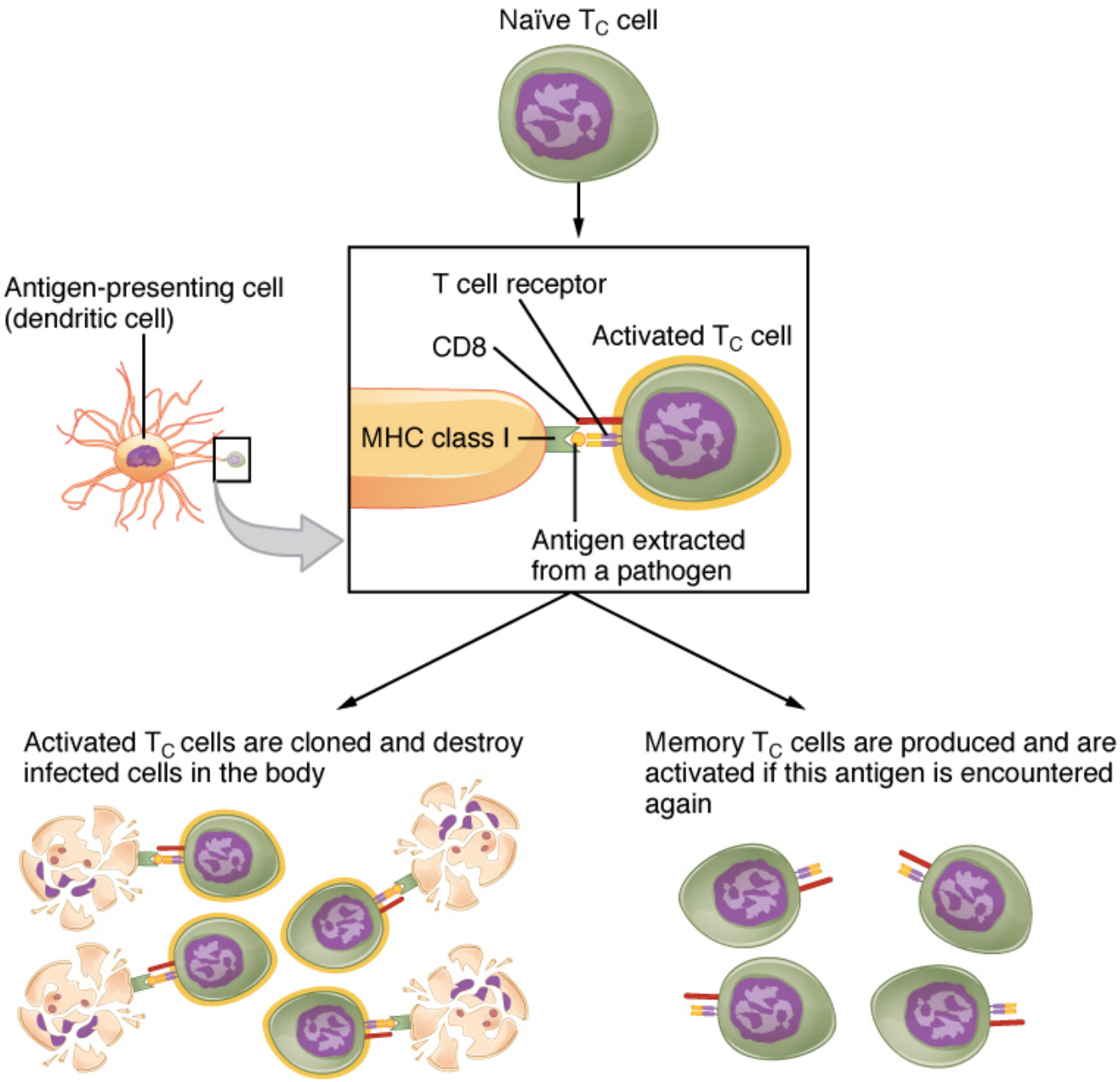


Figure 11.5 Clonal Selection and Expansion of T Lymphocytes. Stem cells differentiate into T cells with specific receptors, called clones. The clones with receptors specific for antigens on the pathogen are selected for and expanded. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Did you know?

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

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.

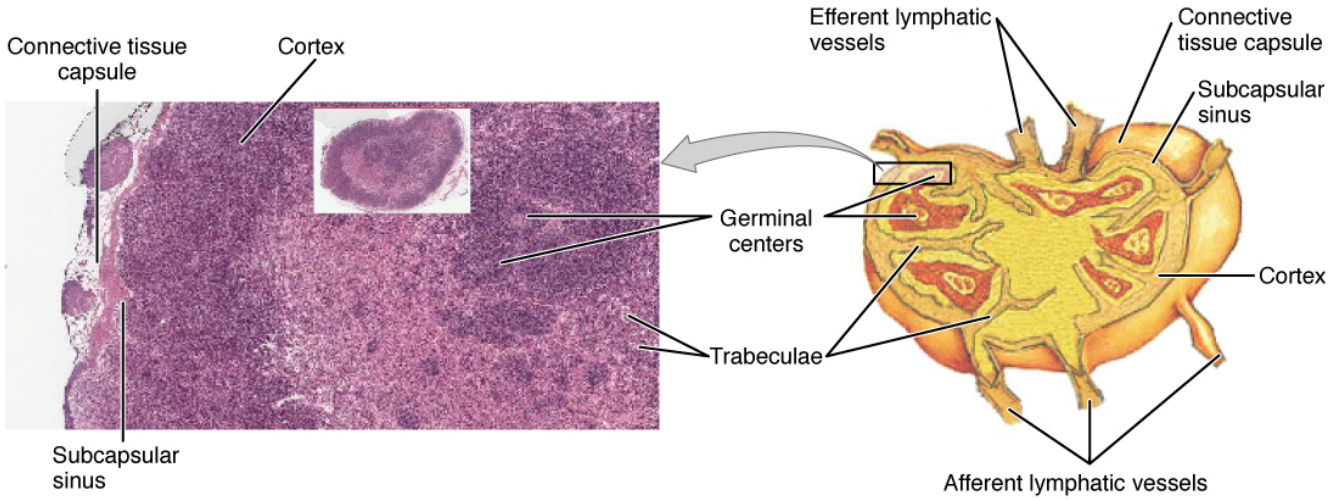


Figure 11.6 Structure and Histology of a Lymph Node. Lymph nodes are masses of lymphatic tissue located along the larger lymph vessels. The micrograph of the lymph nodes shows a germinal center, which consists of rapidly dividing B cells surrounded by a layer of T cells and other accessory cells. LM × 128. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

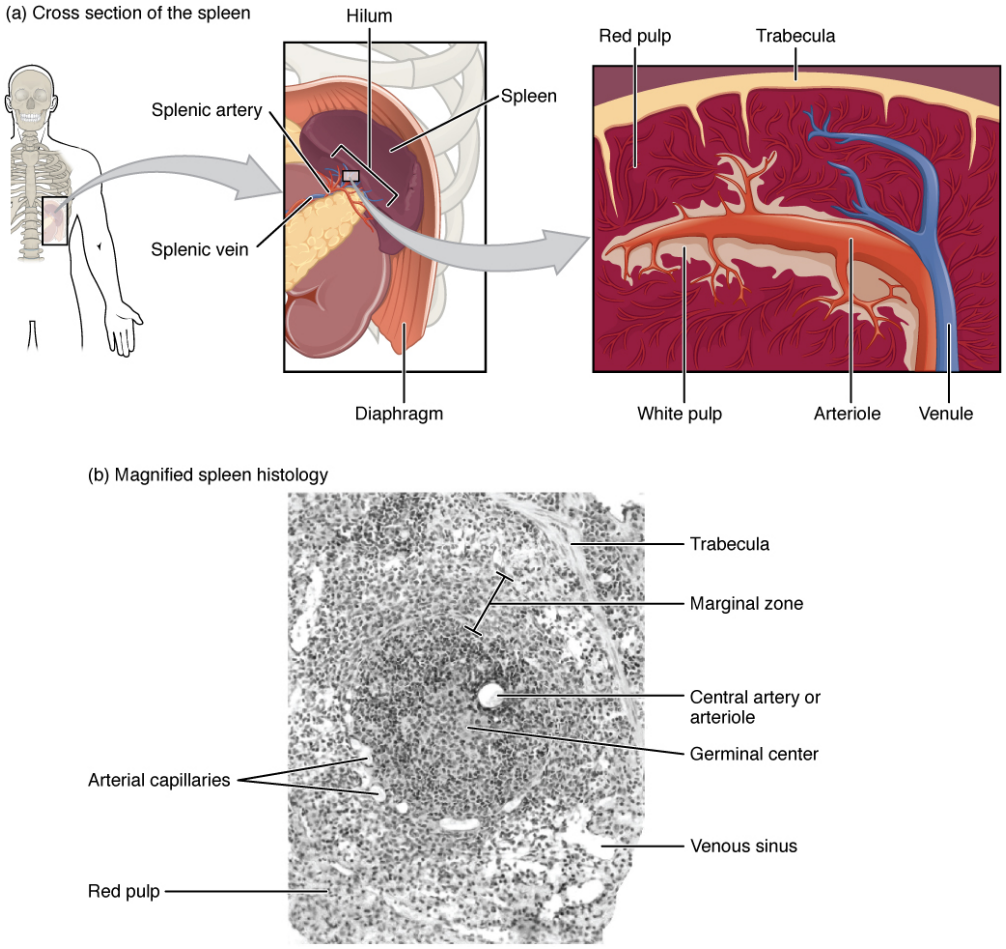


Figure 11.7 Spleen. (a) The spleen is attached to the stomach. (b) A micrograph of spleen tissue shows the germinal center. The marginal zone is the region between the red pulp and white pulp, which sequesters particulate antigens from the circulation and presents these antigens to lymphocytes in the white pulp. EM × 660. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

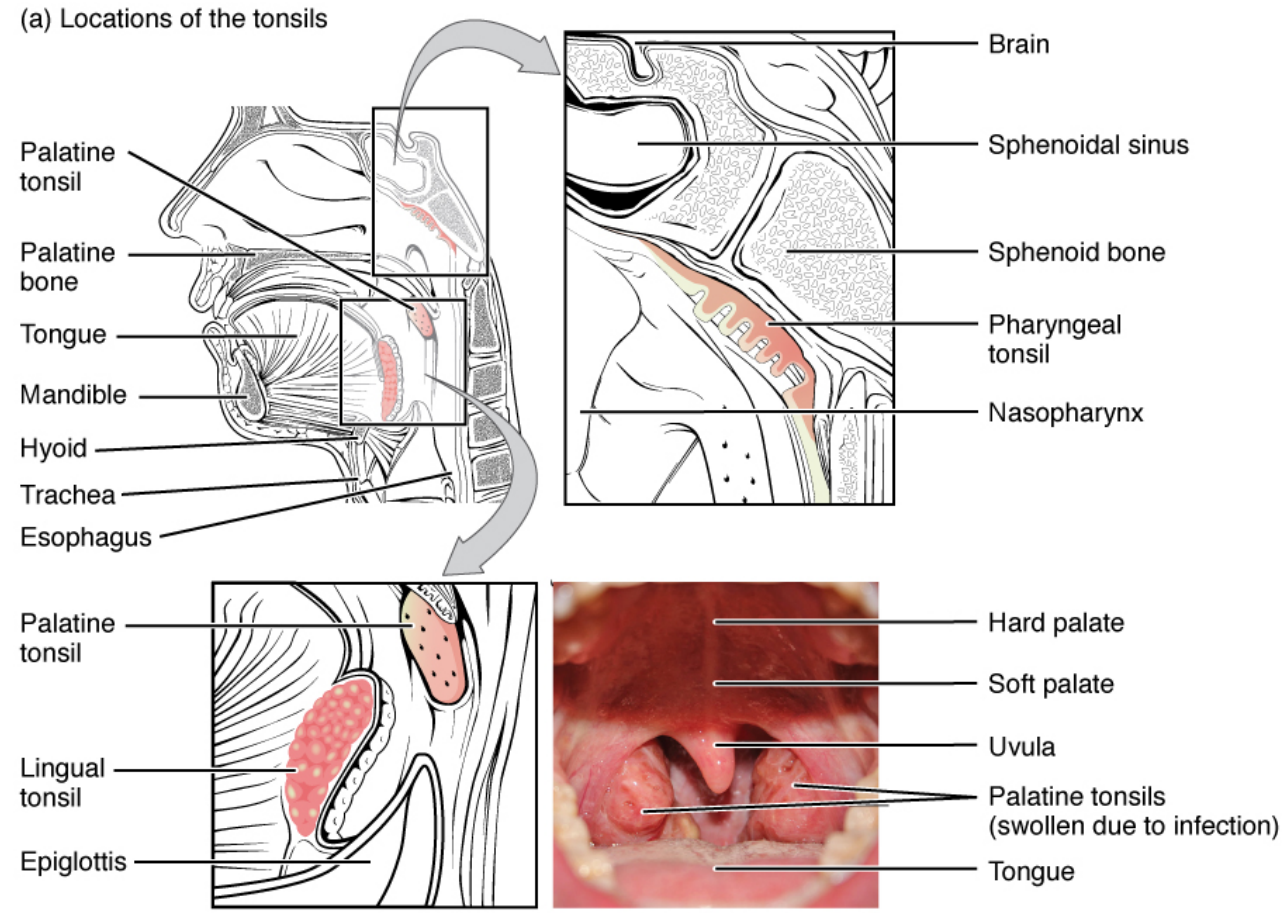
Did you know?

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

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 11.8). 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.



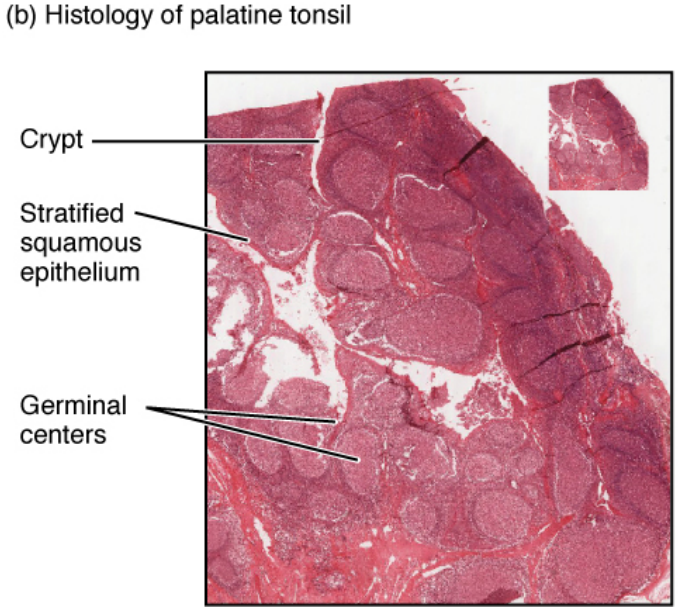


Figure 11.8. Locations and Histology of the Tonsils. (a) The pharyngeal tonsil is located on the roof of the posterior superior wall of the nasopharynx. The palatine tonsils lay on each side of the pharynx. (b) A micrograph shows the palatine tonsil tissue. LM × 40. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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**?

Bronchus-associated lymphoid tissue (BALT) consists of lymphoid follicular structures with an overlying epithelial layer found along the bifurcations of the bronchi, and between bronchi and arteries. These tissues, in addition to the tonsils, are effective against inhaled pathogens.

Mucosa-associated lymphoid tissue (MALT) consists of an aggregate of lymphoid follicles directly associated with mucous membrane. MALT makes up dome-shaped structures found underlying the mucosa of the gastrointestinal tract, breast tissue, lungs, and eyes. Peyer's patches, a type of MALT in the small intestine, are especially important for immune responses against ingested substances (see Figure 11.9). Peyer's patches contain specialized cells that sample material from the intestinal lumen and transport it to nearby follicles so that **adaptive immune responses** to potential pathogens can be mounted.

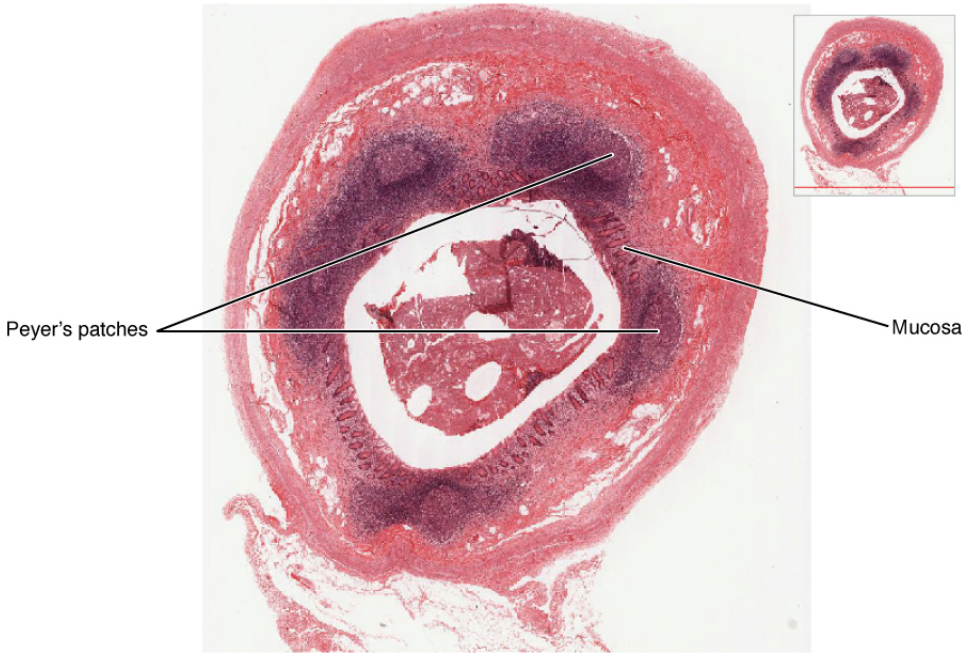


Figure 11.9 Mucosa-associated Lymphoid Tissue (MALT) Nodule. LM × 40. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

The Organization of the Immune System

The immune system is a collection of barriers, cells, and soluble proteins that interact and communicate with each other in extraordinarily complex ways. The modern model of immune function is organized into a three-phase immune response (based on the timing of their effects). Ideally, this response will rid the body of a pathogen entirely (see Figure 11.10).

Think of a primary infection as a race between the pathogen and the immune system:

1. The pathogen bypasses **barrier defenses** and starts to multiply in the host's body.
2. During the first 4 to 5 days, the **innate immune response** will partially control, but not stop the pathogen growth.
3. The slower but more specific and effective **adaptive immune response** gears up and becomes progressively stronger, it will begin to clear the pathogen from the body. This clearance is referred to as **seroconversion**. It should be noted that seroconversion does not necessarily mean a patient is getting well.

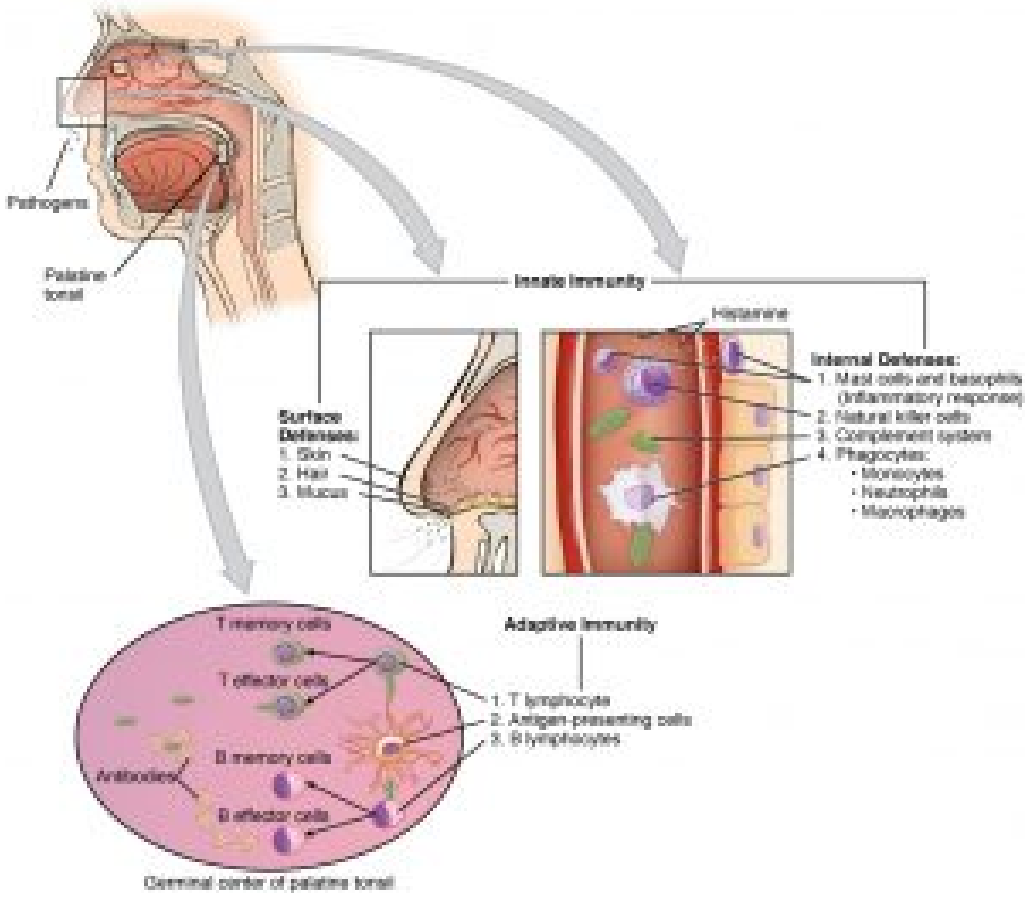


Figure 11.10 Cooperation between Innate and Adaptive Immune Responses. The innate immune system enhances adaptive immune responses so they can be more effective. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Phase 1: Barrier Defenses

Barrier defenses are part of the body's most basic innate defense mechanisms. They are not a *response* to infections, but

rather are continuously working to protect against pathogens by preventing them from entering the body, destroying them after they enter, or flushing them out before they can establish themselves.

Barrier defenses examples:

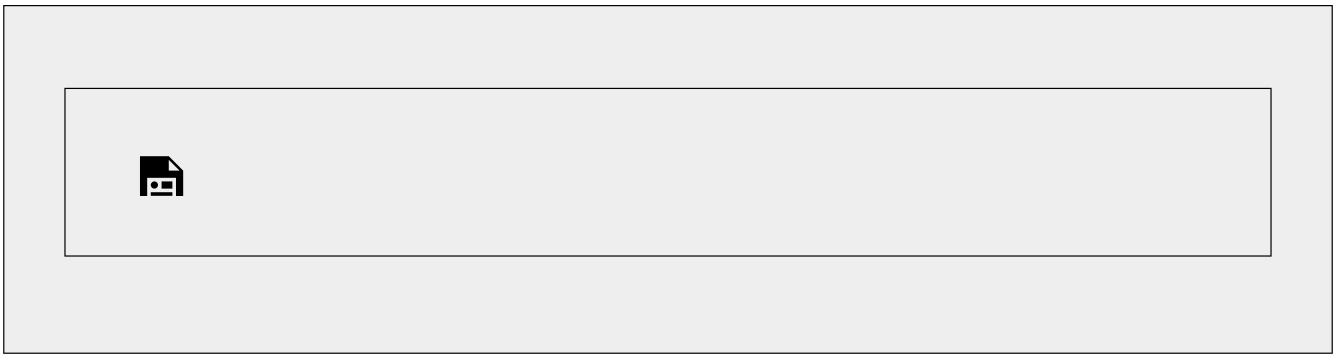
- **Skin**:
  - Keratinized cells of the surface are too dry for bacteria to grow and are continuously sloughed off, along with pathogens that are on their surfaces.
- **Skin (sweat glands, sebaceous glands)**:
  - Lower **pH** than pathogens prefer, may contain substances that are toxic to pathogens, washing action.
- **Oral Cavity (salivary glands):**
  - Lysozyme is an enzyme that destroys bacteria.
- **Stomach:**
  - Low pH which is fatal to many pathogens.
- **Mucosal:**
  - Traps both microbes and debris, and facilitates their removal.
- **Normal flora (nonpathogenic bacteria):**
  - Prevents pathogens from growing on **mucosal** surfaces.

Phase 2: Innate Immune Response

Innate immune responses are critical to the early control of infections. Whereas barrier defenses are the body's first line of physical defense against pathogens, innate immune responses are the first line of physiological defense. Innate responses occur rapidly, but with less specificity and effectiveness than the adaptive immune response. Within the first few days of an infection, a series of antibacterial proteins are induced, each with activities against certain bacteria. Additionally, **interferons** are induced that protect cells from viruses in their vicinity. Finally, the innate immune response does not stop when the adaptive immune response is developed. In fact, both can cooperate and one can influence the other in their responses against pathogens.

Innate immune responses (and early induced responses) are in many cases ineffective at completely controlling pathogen growth but they slow pathogen growth and allow time for the adaptive immune response to strengthen and either control or eliminate the pathogen. The innate immune system also sends signals to the cells of the adaptive immune system, guiding them in how to attack the pathogen.

Watch this video:



One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.uwf.edu/medicalterminology/?p=128#oembed-2

Media 11.2 Immune System, Part 1: Crash Course A&P #45 [Online video]. Copyright 2015 by CrashCourse.

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.

Macrophages not 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 (NK) Cells

Natural killer 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.

Soluble Mediators of the Innate Immune Response

The previous discussions have alluded to chemical signals that can induce cells to change various physiological characteristics, such as the expression of a particular receptor. These soluble factors are secreted during innate or early induced responses, and later during adaptive immune responses.

Concept Check

Do you know the difference between these terms?

- **Intercellular**
- **Intracellular**
- **Interstitial**

Cytokines and Chemokines

A **cytokine** is a 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.

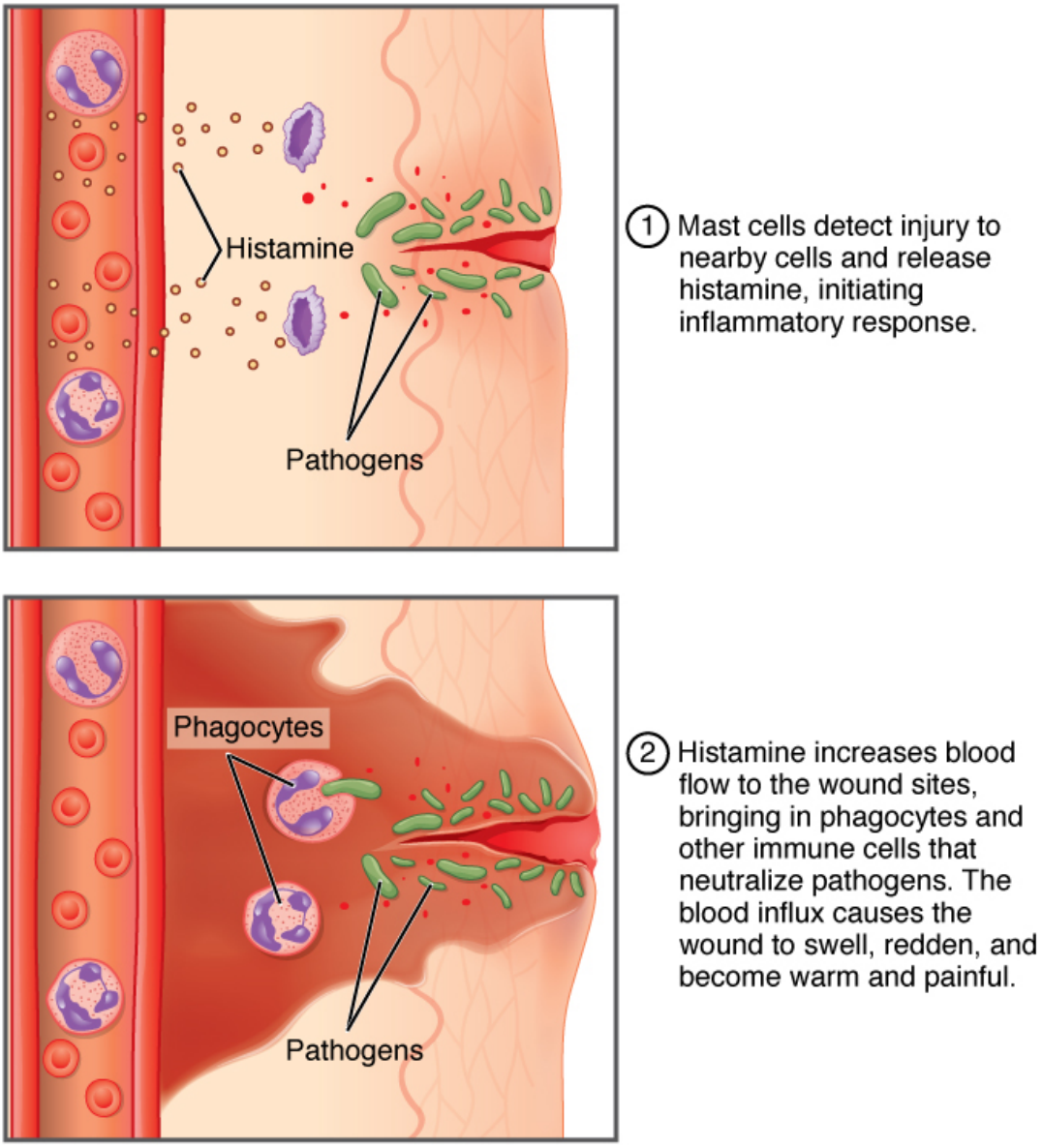


Figure 11.11 Inflammatory Response. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 than 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**.

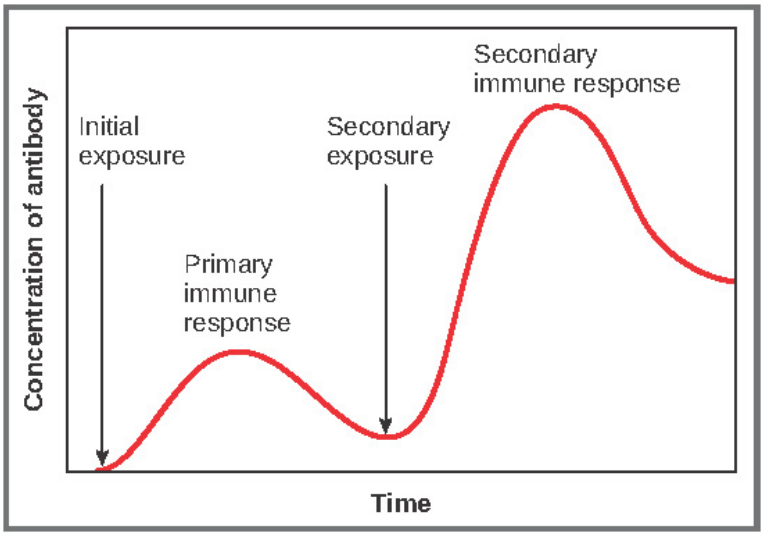

Figure 11.12 Primary and Secondary Antibody Responses. Antigen A is given once to generate a primary response and later to generate a secondary response. When a different antigen is given for the first time, a new primary response is made. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

- **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., 2013. 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 response
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 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.

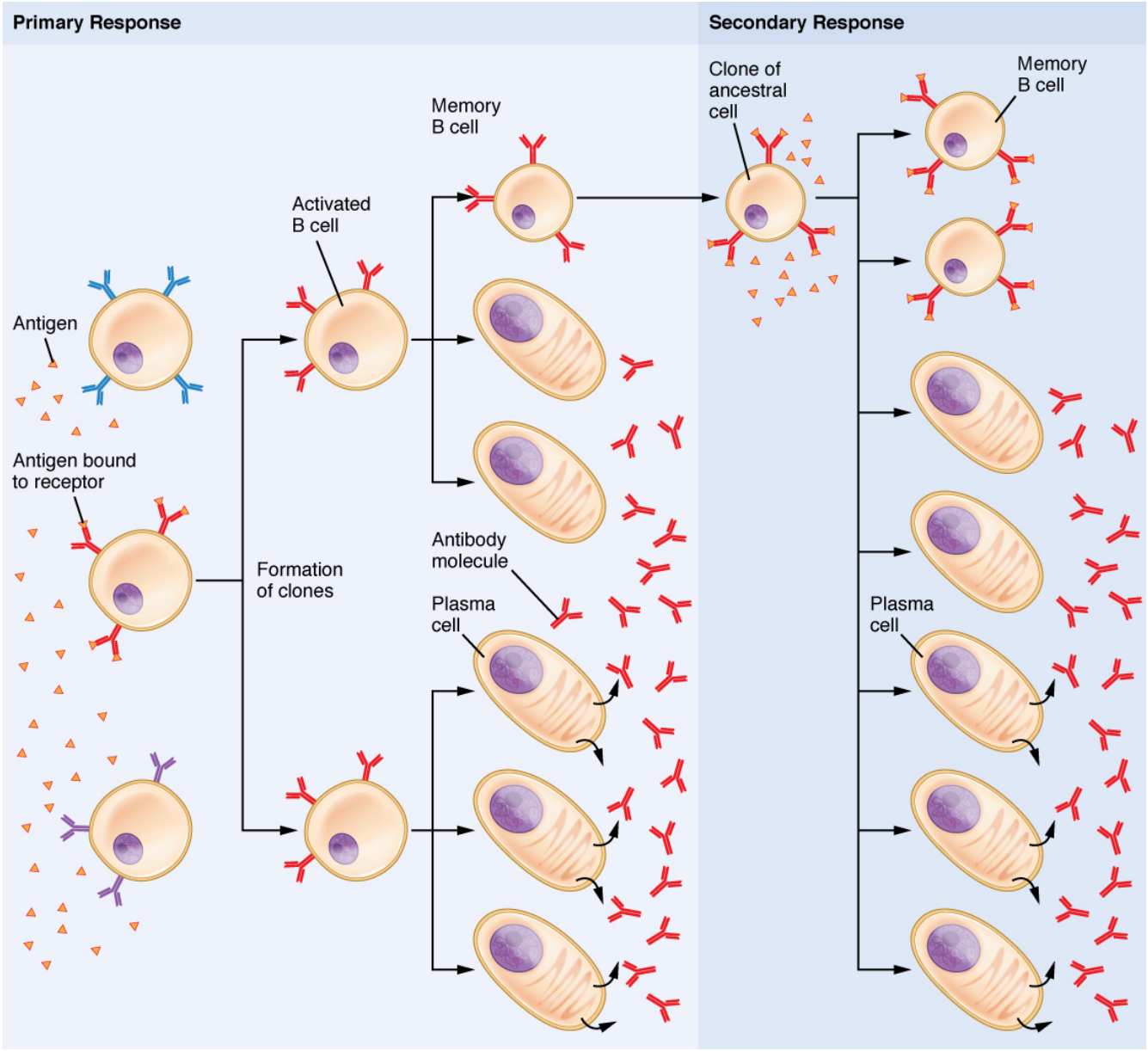

Figure 11.13 Clonal Selection of B Cells. During a primary B cell immune response, both antibody-secreting plasma cells and memory B cells are produced. These memory cells lead to the differentiation of more plasma cells and memory B cells during secondary responses. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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., 2013. 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 *Mycobacterium 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 **major histocompatibility complex (MHC)** molecules than unrelated individuals do.

One disease of transplantation occurs with bone marrow transplants, which are used to treat various diseases, including **severe combined immunodeficiency disease (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**. Signs and symptoms of this disease, which usually include a rash and damage to the liver and mucosa, are variable. 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 11.14), 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 papillomavirus. 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.

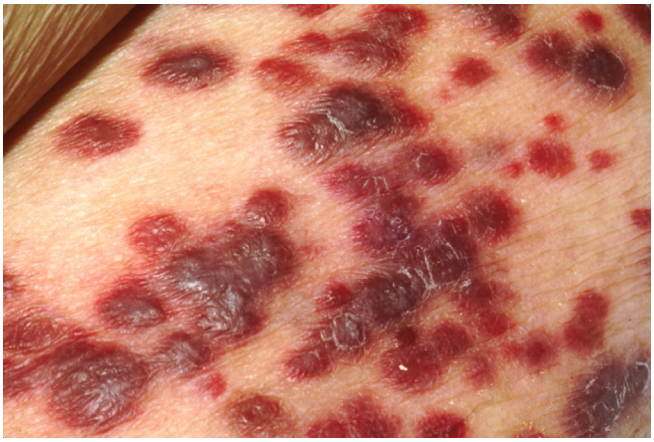

Figure 11.14 Kaposi's Sarcoma Lesions. (credit: National Cancer Institute). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 the human immunodeficiency virus (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., 2013. 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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Practice Terms Related to the Lymphatic and Immune Systems

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https://pressbooks.uwf.edu/medicalterminology/?p=128#h5p-71

Common Abbreviations for the Lymphatic and Immune Systems

Many terms and phrases related to the lymphatic and immune systems are abbreviated. Learn these common abbreviations by expanding the list below.

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https://pressbooks.uwf.edu/medicalterminology/?p=128#h5p-72

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.

Lymphedema

Lymphedema is a condition in which lymphatic fluid builds up in the body's soft tissues. Lymphedema often occurs in the arms and legs, although other body parts may be affected. There are two types of lymphedema: primary and secondary. Primary lymphedema may be congenital and is caused by abnormalities in the lymph system. Secondary lymphedema occurs when the lymph system is damaged or blocked due to injury, cancer, or cancer treatment. Signs and symptoms include swelling of the limbs and **digits**, difficulty moving the joints in the arms and legs, and the sensation that the skin is too tight. Lymphedema is rarely cured. Instead, treatment such as the use of pressure garments, light exercise, massage therapy, and surgery can reduce symptoms and lower the risk of complications. Patients with severe cases of lymphedema are at an increased risk of developing lymphangiosarcoma, an aggressive cancer of the lymph vessels (National Cancer Institute, 2021; Sleigh & Manna, 2021). For more information, visit the Mayo Clinic's web page on lymphedema.

Underactive Immune System: Immunodeficiencies

Suppressed immunity can result from inherited genetic defects or by acquiring viruses.

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.

New treatments for SCID using gene therapy, inserting non-defective 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.

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.

Overactive Immune System: Hypersensitivities and Autoimmune Diseases

Hypersensitivities

Over-reactive immune responses include the **hypersensitivities**: allergies and inflammatory responses to nonpathogenic environmental substances. The table below compares different hypersensitivities.

Table 11.4 Table Summarizing Types of Hypersensitivities. From Betts et al., 2013. 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 to 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 overreacting 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 11.15 below provides two examples of autoimmune diseases: rheumatoid arthritis (RA) and systemic lupus erythematosus (SLE).

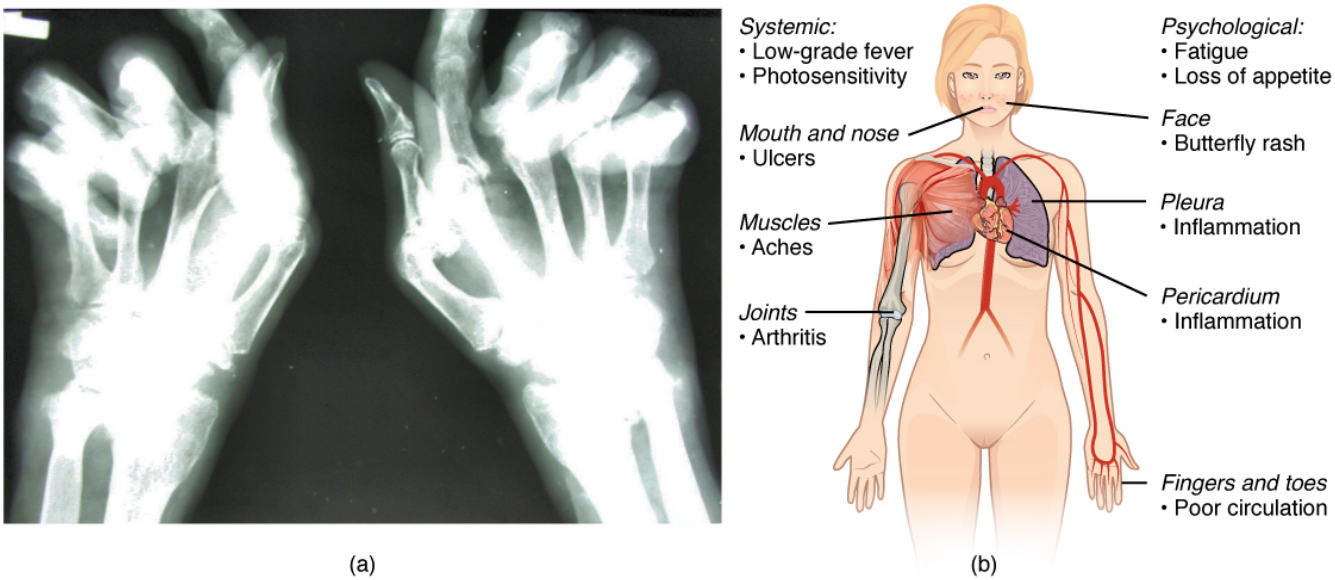

Figure 11.15 Autoimmune Disorders: Rheumatoid Arthritis and Lupus. (a) Extensive damage to the right hand of a rheumatoid arthritis sufferer is shown in the x-ray. (b) The diagram shows a variety of possible symptoms of systemic lupus erythematosus. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Overall, there are more than 80 different autoimmune diseases, which are a significant health problem in the elderly. Table 11.5 below lists several of the most common autoimmune diseases, the antigens that are targeted (autoantigen or "self" antigen), and the resulting tissue damage.

Table 11.5 Autoimmune Diseases. From Betts et al., 2013. 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 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.

Medical Terms in Context

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Medical Specialties and Procedures Related to the Lymphatic and Immune Systems

Clinical immunologists and allergists diagnose and treat diseases of the immune system (National Center for O*Net Development, 2021). For more information, please visit the American Academy of Allergy, Asthma, and Immunology's web page on careers in immunology.

Skin Testing

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.

Lymphatic and Immune Systems Vocabulary

Active immunity

Immunity developed from an individual's own immune system.

Acute inflammation

Inflammation occurring for a limited time period; rapidly developing.

Adaptive immune response

A relatively slow but very specific and effective immune response controlled by lymphocytes.

Afferent lymphatic vessels

Vessels that lead into a lymph node.

Allergens

Antigens that evoke type 1 hypersensitivity (allergy) responses.

Allergist

Specialist who specializes in treating individuals with a hypersensitivity to allergens.

Allergy

Inflammatory response due to a hypersensitivity to a substance that normally is harmless or would not cause an immune response in most people.

Anaphylactic shock

A severe and sometimes life-threatening immune system reaction to an antigen that a person has been previously exposed to. The reaction may include itchy skin, edema, collapsed blood vessels, fainting, difficulty in breathing, and death.

Antibody

A protein made by plasma cells (a type of white blood cell) in response to an antigen (a substance that causes the body to make a specific immune response). Each antibody can bind to only one specific antigen. The purpose of this binding is to help destroy the antigen.

Antigens

Substances that provokes an immune response. This happens because the immune system sees the antigen as foreign, or 'non-self" (does not belong in that body).

Apoptosis

Programmed cell death.

Autoimmune diseases/disorders

Disorders in which the immune system overreacts and begins to attack itself.

B cells

Lymphocytes that act by differentiating into an antibody-secreting plasma cell.

Barrier defenses

Antipathogen defenses deriving from a barrier that physically prevents pathogens from entering the body to establish an infection.

Bone marrow

Tissue found inside bones; the site of all blood cell differentiation and maturation of B lymphocytes.

Bronchus-associated lymphoid tissue (BALT)

Lymphoid nodule associated with the respiratory tract.

CD4 T Cells

CD4 is the receptor that HIV uses to get inside T cells and reproduce. CD4+ helper T cells play an important role in T cell immune responses and antibody responses.

Chemokine

Soluble, long-range, cell-to-cell communication molecule.

Chemotaxis

Movement in response to chemicals; a phenomenon in which injured or infected cells and nearby leukocytes emit the equivalent of a chemical "911" call, attracting more leukocytes to the site.

Chronic inflammation

Ongoing inflammation that can be caused by foreign bodies, persistent pathogens, and autoimmune diseases such as rheumatoid arthritis.

Chyle

Lipid-rich lymph inside the lymphatic capillaries of the small intestine.

Cisterna chyli

A sac-like chamber that receives lymph from the lower abdomen, pelvis, and lower limbs by way of the left and right lumbar trunks and the intestinal trunk.

Complement

Enzymatic cascade of constitutive blood proteins that have antipathogen effects, including the direct killing of bacteria.

Cytokine

A signaling molecule that allows cells to communicate with each other over short distances.

Deep lymphatic vessels

Lymphatic vessels of the organs.

Efferent lymphatic vessels

Vessels that lead out of a lymph node.

Erythroblastosis fetalis

An immune reaction between maternal and fetal blood due to the Rh antigen; also known as hemolytic disease of the newborn (HDN).

Genetic recombination

The combining of gene segments from two different pathogens.

Graft-versus-host disease (GVHD)

A condition that can occur in bone marrow transplant recipients; occurs when the transplanted cells mount an immune response against the recipient's tissue.

Histamine

A vasodilator involved in the inflammatory response.

Human immunodeficiency virus (HIV)

An infectious disease transmitted through semen, vaginal fluids, and blood that suppresses the immune system. HIV infection may be managed with antiviral drugs or may progress to acquired immune deficiency syndrome (AIDS).

Hypersensitivities

Reacting to something that would not normally evoke a reaction.

Immune system

Series of barriers, cells, and soluble mediators that combine to response to infections of the body with pathogenic organisms.

Immunity

Resistant to the effects of pathogens.

Immunodeficiency

The decreased ability of the body to fight infections and other diseases.

Immunological memory

Ability of the adaptive immune response to mount a stronger and faster immune response upon re-exposure to a pathogen.

Immunology

The study of the body's immune system.

Induration

A firm, raised reddened patch of skin.

Inflammation

Basic innate immune response characterized by heat, redness, pain, and swelling.

Innate immune response

Fast-acting non-specific immune mechanisms that are present from birth.

Intercellular

Between cells.

Interferons

Early induced proteins made in virally infected cells that cause nearby cells to make antiviral proteins.

Interstitial fluid

Extracellular fluid not contained within blood vessels.

Interstitial space

Spaces between individual cells in the tissues.

Intracellular

Inside the cell membrane or within the cell.

Leukemia

A cancer involving an abundance of leukocytes.

Lymph

The term used to describe interstitial fluid once it has entered the lymphatic system.

Lymph node

One of the bean-shaped organs found associated with the lymphatic vessels.

Lymphatic capillaries

Smallest of the lymphatic vessels and the origin of lymph flow.

Lymphatic system

Network of lymphatic vessels, lymph nodes, and ducts that carries lymph from the tissues and back to the bloodstream.

Lymphatic trunks

Large lymphatics that collect lymph from smaller lymphatic vessels and empties into the blood via lymphatic ducts.

Lymphocytes

The second most common type of leukocyte and are essential for the immune response.

Lymphoid nodules

Unencapsulated patches of lymphoid tissue found throughout the body.

Lymphoma

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. These leukocytes do not function properly, and the patient is vulnerable to infection.

Macrophage

A large cell derived from a monocyte; they participate in innate immune responses.

Major histocompatibility complex (MHC)

Protein structures found on the outside of cells that help the immune system recognize non-self antigens.

Mast cell

Cell found in the skin and the lining of body cells that contains cytoplasmic granules with vasoactive mediators such as histamine.

Memory T cells

Long-lived immune cells reserved for future exposure to a pathogen.

Monocyte

A type of immune cell that is made in the bone marrow.

Mucosa-associated lymphoid tissue (MALT)

Lymphoid nodule associated with the mucosa.

Mucous membranes

Epithelial membranes that line the body cavities and hollow passageways that open to the external environment.

Naïve lymphocyte

Mature B or T cell that has not yet encountered antigen for the first time.

Natural killer cell (NK)

Cytotoxic lymphocyte of innate immune response.

Neutrophil

Phagocytic white blood cell recruited from the bloodstream to the site of infection via the bloodstream.

Opsonization

A process by which an antibody or an antimicrobial protein binds to a pathogen, thereby marking it as a target for phagocytes.

Passive immunity

Transfer of immunity to a pathogen to an individual that lacks immunity to this pathogen usually by the injection of antibodies.

Pathogen

An organism that causes a disease.

Phagocytosis

Movement of material from the outside to the inside of the cells via vesicles made from invaginations of the plasma membrane; process where some white blood cells engulf invading microorganisms.

Plasma cells

A type of B lymphocyte that produces antibodies, which bind to specific foreign or abnormal antigens in order to destroy them.

Primary adaptive response

Immune system's response to the first exposure to a pathogen.

Primary lymphoid organs

Site where lymphocytes mature and proliferate; for example, red bone marrow and the thymus gland.

Right lymphatic duct

Drains lymph fluid from the upper right side of the body into the right subclavian vein.

Staphylococcus aureus

A bacteria that is commonly found in minor skin infections, as well as in the nose of some healthy people.

Secondary adaptive response

Immune response observed upon re-exposure to a pathogen, which is stronger and faster than a primary response.

Secondary lymphoid organs

Sites where lymphocytes mount adaptive immune responses, examples include lymph nodes and spleen.

Seroconversion

The reciprocal relationship between virus levels in the blood and antibody levels.

Severe combined immunodeficiency disease (SCID)

A rare, inherited disease that is marked by a lack of B and T lymphocytes.

Spleen

Secondary lymphoid organ that filters pathogens from the blood (white pulp) and removes degenerating or damaged blood cells (red pulp).

Superficial lymphatics

Lymphatic vessels of the subcutaneous tissues of the skin.

Systemic lupus erythematosus (SLE)

A chronic, inflammatory, connective tissue disease that can affect the joints and many organs; also called lupus.

T cell

Lymphocyte that acts by secreting molecules that regulate the immune system or by causing the destruction of foreign cells, viruses, and cancer cells.

Thoracic duct

Large duct that drains lymph from the lower limbs, left thorax, left upper limb, and the left side of the head.

Thymocytes

A type of white blood cell that is part of the immune system and develops from stem cells in the bone marrow; also called T cells and T lymphocytes.

Thymus

Primary lymphoid organ, where t lymphocytes proliferate and mature.

Tissue typing

The determination of major histocompatibility complex (MHC) molecules in the tissue to be transplanted to better match the donor to the recipient.

Tonsils

Lymphoid nodules associated with the nasopharynx.

Vaccine

A killed or weakened pathogen or its components that, when administered to a healthy individual, leads to the development of immunological memory (a weakened primary immune response) without causing much in the way of symptoms.

Vasodilation

The physiological widening of blood vessels by relaxing the vascular smooth muscle.

Wheal and flare response

A soft, pale swelling at the site surrounded by a red zone.

Test Yourself

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Image Descriptions

Figure 11.1 image description: The left panel shows a female human body, and the entire lymphatic system is shown Labels read (clockwise from top): thymus, lymph nodes, thymus, spleen, lymph vessel, bone marrow, right lymphatic duct, entering vein, tonsil, adenoid. The right panel shows magnified images of the thymus and the lymph node. Labels read (clockwise from top): tissue cell, interstitial fluid, lymphatic capillary, blood capillary, lymphatic vessel. Label of lymph node reads masses of lymphocytes and macrophages. [Return to Figure 11.1].

Figure 11.2 image description: This image shows the lymph capillaries in the tissue spaces. Labels read (clockwise, from top): lymph capillary, tissue cells, venule, lymphatic vessel, tissue fluid, arteriole). It also shows a magnified image showing the interstitial fluid and the lymph vessels. Labels read (clockwise, from top): collagen fiber, interstitial fluid, lymph, lymph vessel endothelial cells, backflow prevention valve, endothelial flaps. [Return to Figure 11.2].

Figure 11.3 image description: This figure shows the lymphatic trunks and the duct system in the human body. Labels read (clockwise from top) thoracic duct, cisterna chyli of thoracic duct, drained by thoracic duct, drained by right lymphatic duct. Callouts to the left and right show the magnified views of the left and right jugular vein respectively. Labels read (right lymphatic duct): right internal jugular vein, right subclavian vein, right lymphatic duct; (left jugular vein): left internal jugular vein, thoracic duct drains into subclavian vein, left subclavian vein.[Return to Figure 11.3].

Figure 11.4 image description: The left panel of this figure shows the head and chest of a woman and the location of the thymus is marked. Labels read (clockwise, from top) lymph nodes, spleen, heart, thymus, right lymphatic duct entering vein, tonsil, adenoid. The top right panel shows a micrograph of the thymus. Labels read (from left to right): medulla, cortex, trabeculae, fibrous capsule. The bottom right panel shows a magnified view of the structure of the thymus. Labels read (clockwise, from top): thymocytes, trabecula, fibrous capsule, cortex, medulla (layers), medullary epithelial cell, blood vessel, macrophage, dendritic cell, cortical epithelial cell.[Return to Figure 11.4].

Figure 11.5 image description: This flowchart shows the process in which a naïve T cell becomes activated T cells in the left part of the pathway and memory cells in the right part of the pathway. A naive T cell becomes an activated T cell when an antigen-presenting cell is introduced. The antigen is extracted from a pathogen and then either activated T cells are cloned and destroy the infected cells in

the body, and/or memory T cells are produced and are activated if this antigen is encountered again. [Return to Figure 11.5].

Figure 11.6 image description: The left panel of this figure shows a micrograph of the cross section of a lymph node. Labels indicate the connective tissue capsule, cortex, and subcapsular sinus. The right panel shows the structure of a lymph node. Labels indicate (from top, clockwise) the efferent lymphatic vessels, connective tissue capsule, subcapsular sinus, cortex, afferent lymphatic vessels, trabecula, and germinal centers. [Return to Figure 11.6].

Figure 11.7 image description: The top left panel shows the location of the spleen in the human body. The top center panel shows a close up view of the location of the spleen. Labels read (clockwise, from top): hilum, spleen, diaphragm, splenic vein, splenic artery. The top right panel shows the blood vessels and spleen tissue. Labels read (from left to right, top then bottom) red pulp, trabecula (bottom) white pulp, arteriole, venule. The bottom panel shows a histological micrograph Labels read (clockwise, from top): trabecula, marginal zone, central artery or arteriole, germinal center, venous sinus, red pulp, arterial capillaries. [Return to Figure 11.7].

Figure 11.8 image description: The top panel of this image shows the locations of the tonsils. Labels read (clockwise from top):palatine tonsil, palatine bone, tongue, mandible, hyoid, trachea, esophagus. Callout shows the location of the pharyngeal tonsil. Labels read (from top): brain, sphenoidal sinus, sphenoid bone, pharyngeal tonsil, nasopharynx. Another callout details the location of the palatine tonsil. Labels read (from top): palatine tonsil, lingual tonsil, epiglottis. Another callout shows a photograph of the back of the throat where the tonsils are located. Labels read (from top) hard palate, soft palate, uvula, palatine tonsils (swollen due to infection) and tongue. The bottom panel shows the histological micrograph of the tonsils. Labels read (from top): crypt, stratified squamous epithelium, germinal centers. [Return to Figure 11.8].

Figure 11.9 image description: This figure shows a micrograph of a mucosa associated lymphoid tissue (MAST) nodule. Labels indicate the mucosa and Peyer's patches (which appear to be dark purple). [Return to Figure 11.9].

Figure 11.10 image description: This figure shows a lateral view of a human face in the top left. A magnified callout shows the germinal center of the palatine tonsil. Another magnified view shows how the innate immune system works. This process is described in greater detail in the text below the figure. [Return to Figure 11.10].

Figure 11.11 image description: The top panel of this figure shows the mast cells detecting an injury and initiating an inflammatory response. The bottom panel shows the increase in blood flow in response to histamine. [Return to Figure 11.11].

Figure 11.12 image description: This graph shows the antibody concentration as a function of time in primary and secondary response. Initial exposure indicates a low concentration of antibody, which then elevates over time during the primary immune response. It decreases a little during secondary exposure, but then spikes during the secondary immune response. [Return to Figure 11.12].

Figure 11.13 image description: This flowchart shows how the clonal selection of B cells takes place. The left panel shows the primary response and the right panel shows the secondary response. 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. [Return to Figure 11.13].

Figure 11.14 image description: This image shows Kaposi's Sarcoma lesions on the surface of the skin. [Return to Figure 11.14].

Figure 11.15 image description: The left panel of this figure shows an x-ray image of a person's hand with rheumatoid arthritis, and the right panel of this figure shows a woman's body with labels showing the different responses in the body when the patient suffers from lupus. Labels (from top, clockwise) read: psychological: fatigue, loss of appetite, face butterfly rash, pleura inflammation, pericardium

inflammation, fingers and toes poor circulation, joints arthritis, muscles aches, mouth and nose ulcers, systemic: low-grade fever photosensitivity.[Return to Figure 11.15].

12. Respiratory System

Learning Objectives

- Examine the anatomy of the respiratory system
- Determine the main functions of the respiratory system
- Differentiate respiratory system medical terms and common abbreviations
- Recognize the medical specialties associated with the respiratory system
- Discover common diseases, disorders, and procedures related to 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

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.

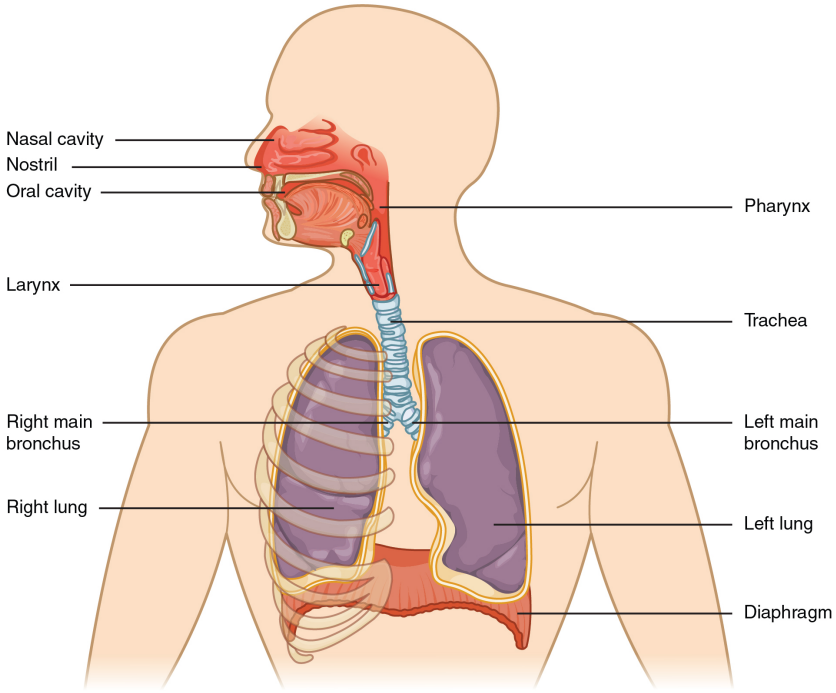

Figure 12.1 Major Respiratory Structures. The major respiratory structures span the nasal cavity to the diaphragm. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Did you know?

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

Watch this video:

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Media 12.1. Respiratory System, Part 1: Crash Course A&P #31 [Online video]. Copyright 2015 by CrashCourse.

Practice Medical Terms Related to the Respiratory System

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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 12.2). 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, disrupting the flow of air as it enters the nose and 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 the **hard palate** and the **soft palate**. Air exits the nasal cavities via the internal nares and moves into the pharynx.

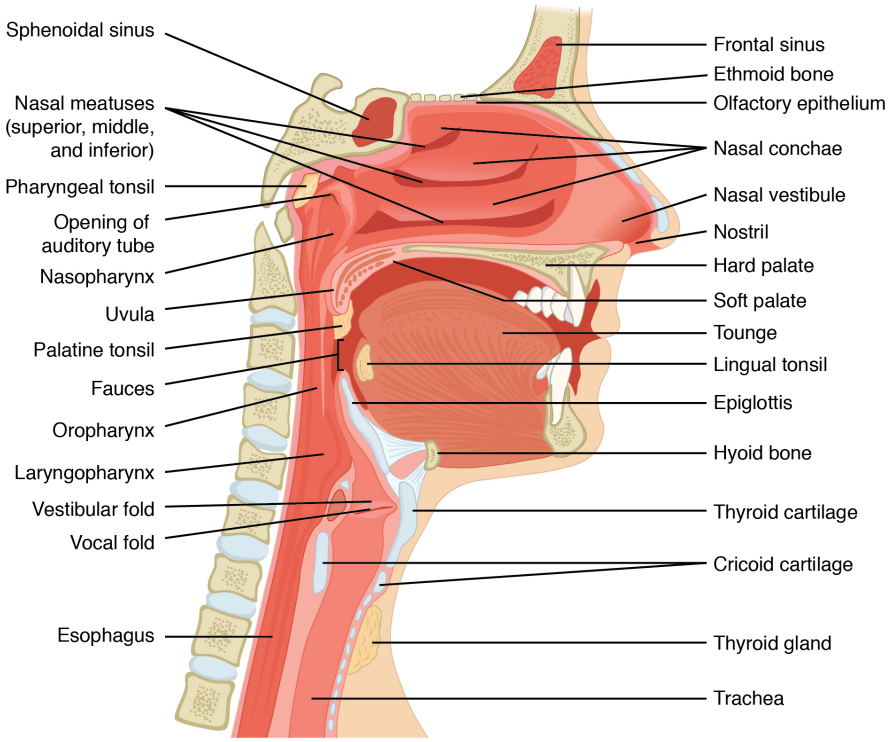

Figure 12.2 Upper Airway. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Paranasal sinuses serve to warm and humidify incoming air and 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.

The conchae, meatuses, and paranasal sinuses are lined by respiratory epithelium composed of pseudostratified ciliated columnar epithelium (Figure 12.3). The epithelium contains specialized epithelial cells that produce mucus to trap debris. 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. Capillaries located just beneath the nasal epithelium warm the air by convection. Serous and mucus-producing cells also secrete **defensins**, or immune cells that patrol the connective tissue providing additional protection.

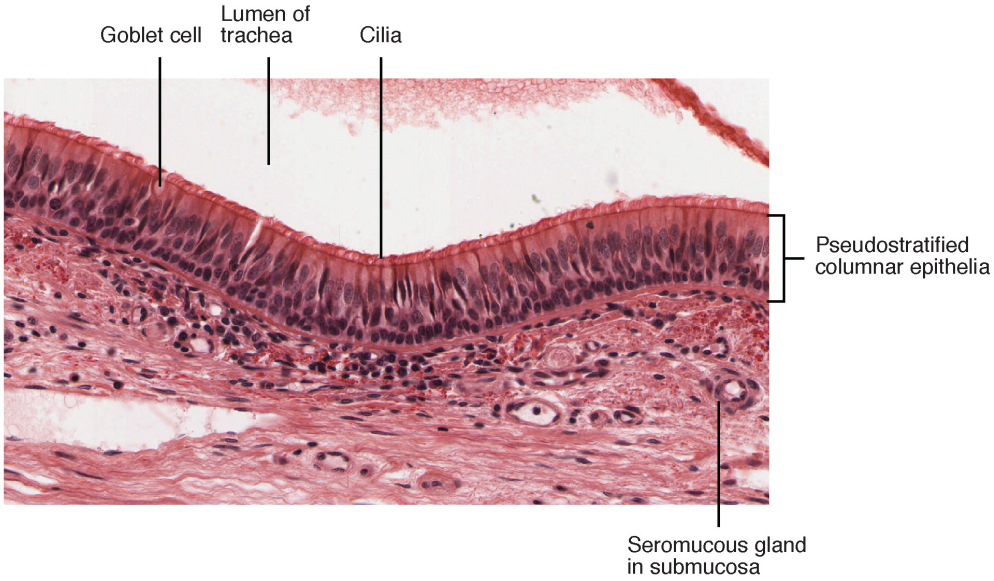

Figure 12.3 Pseudostratified Ciliated Columnar Epithelium. Respiratory epithelium is pseudostratified ciliated columnar epithelium. Seromucous glands provide lubricating mucus. LM × 680. (Micrograph provided by the Regents of University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Did you know?

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

Pharynx

The **pharynx** is divided into three major regions: the **nasopharynx**, the **oropharynx**, and the **laryngopharynx** (see Figure 12.4).

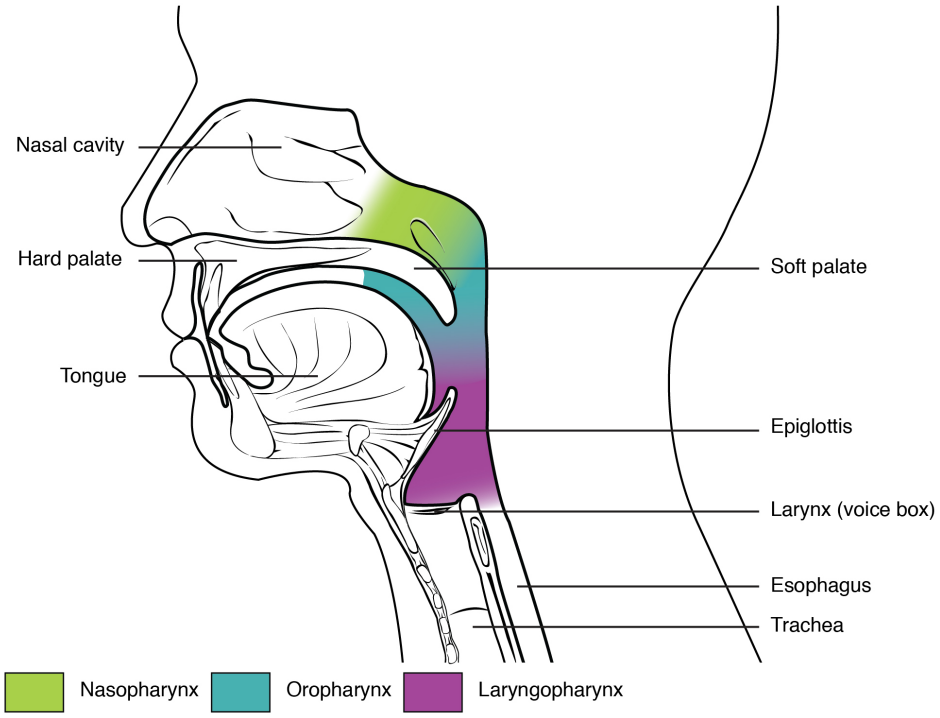

Figure 12.4 Divisions of the Pharynx. The pharynx is divided into three regions: the nasopharynx, the oropharynx, and the laryngopharynx. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 in the area of the **fauces**.
- 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. Three large cartilage pieces form the major structure of the larynx.

- Thyroid cartilage (anterior):
  - The thyroid cartilage is the largest piece of cartilage that makes up the larynx. The thyroid cartilage consists of the **laryngeal** prominence, or "Adam's apple," which tends to be more prominent in males.
- Epiglottis (superior):
  - Three smaller, paired cartilages—the arytenoids, corniculates, and cuneiforms—attach to the **epiglottis** and the vocal cords and muscle that help move the vocal cords to produce speech.
- Cricoid cartilage (inferior):
  - The thick cricoid cartilage forms a ring, with a wide posterior region and a thinner anterior region.

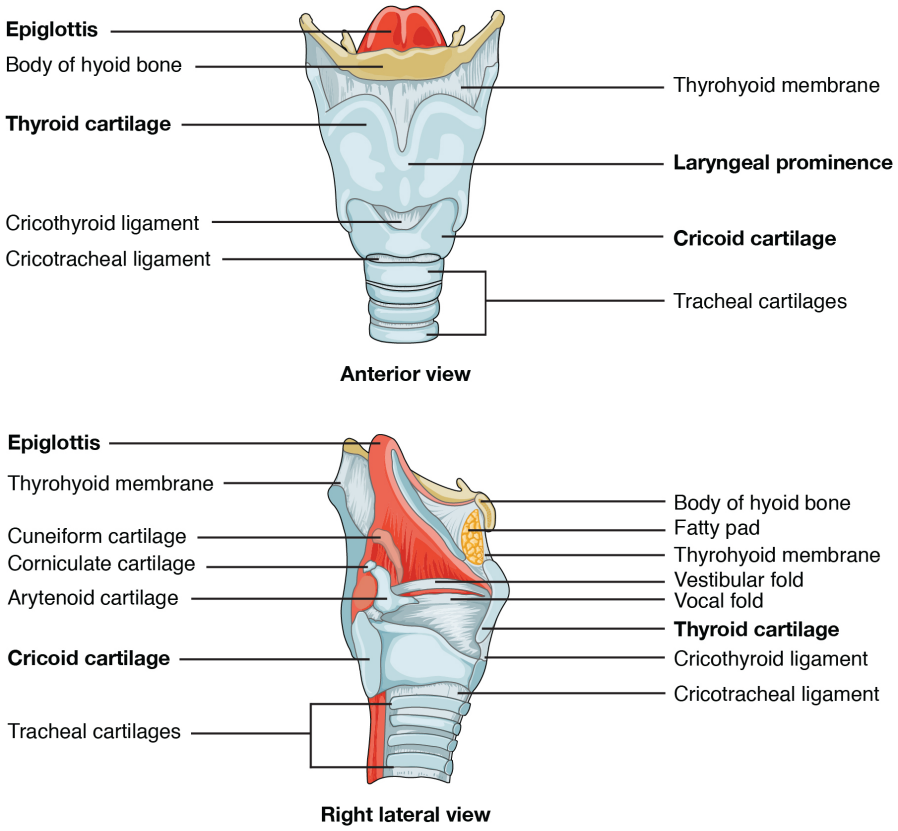

Figure 12.5 Larynx. The larynx extends from the laryngopharynx and the hyoid bone to the trachea. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

When the **epiglottis** is in the "closed" position, the unattached end of the epiglottis rests on the **glottis**. A vestibular fold, or false vocal cord, is one of a pair of folded sections of mucous membrane. A true vocal cord is one of the white, membranous folds attached by muscle to the thyroid and arytenoid cartilages of the larynx on their outer edges. The inner edges of the true vocal cords are free, allowing oscillation to produce sound.

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.

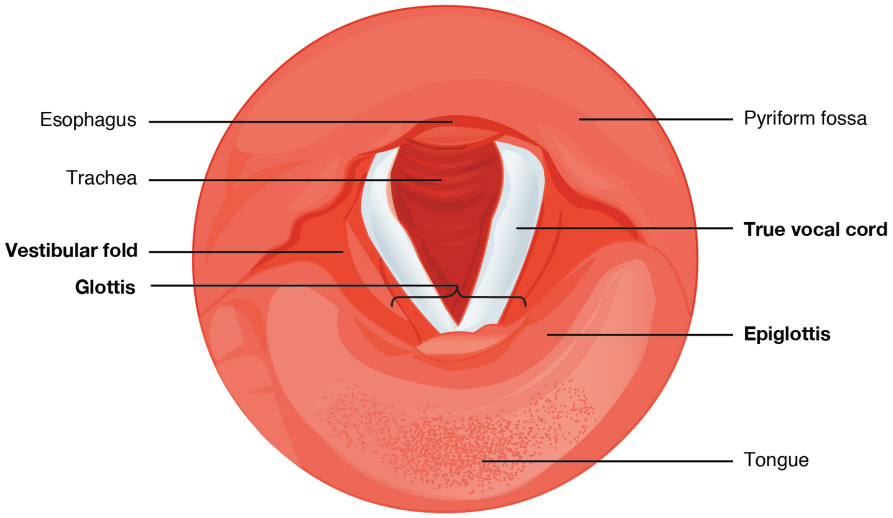

Figure 12.6 Vocal Cords. The true vocal cords and vestibular folds of the larynx are viewed inferiorly from the laryngopharynx. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

Did you know?

Folds of the true vocal cords differ between individuals resulting in voices with different pitches.

Trachea

The **trachea** is formed by 16 to 20 stacked, C-shaped pieces of hyaline cartilage that are connected by dense connective tissue. 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.

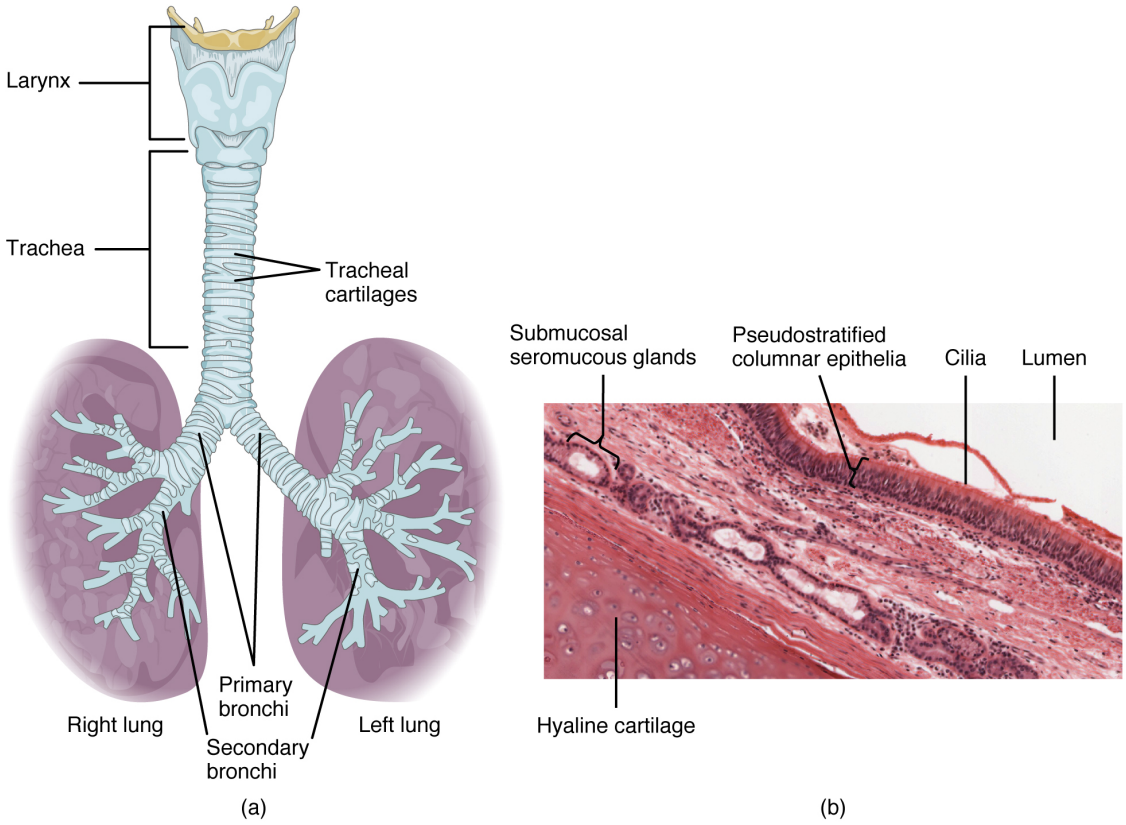

Figure 12.7 Trachea. (a) The tracheal tube is formed by stacked, C-shaped pieces of hyaline cartilage. (b) The layer visible in this cross-section of tracheal wall tissue between the hyaline cartilage and the lumen of the trachea is the mucosa, which is composed of pseudostratified ciliated columnar epithelium that contains goblet cells. LM × 1220. (Micrograph provided by the Regents of University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Bronchial Tree

The trachea branches into the right and left primary bronchi at the **carina**. These bronchi are also lined by pseudostratified ciliated columnar epithelium containing mucus-producing goblet cells (Figure 12.7b). 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 a bronchial 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.

A 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 1,000 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 12.8), which then leads to an alveolar duct, opening into a cluster of alveoli.

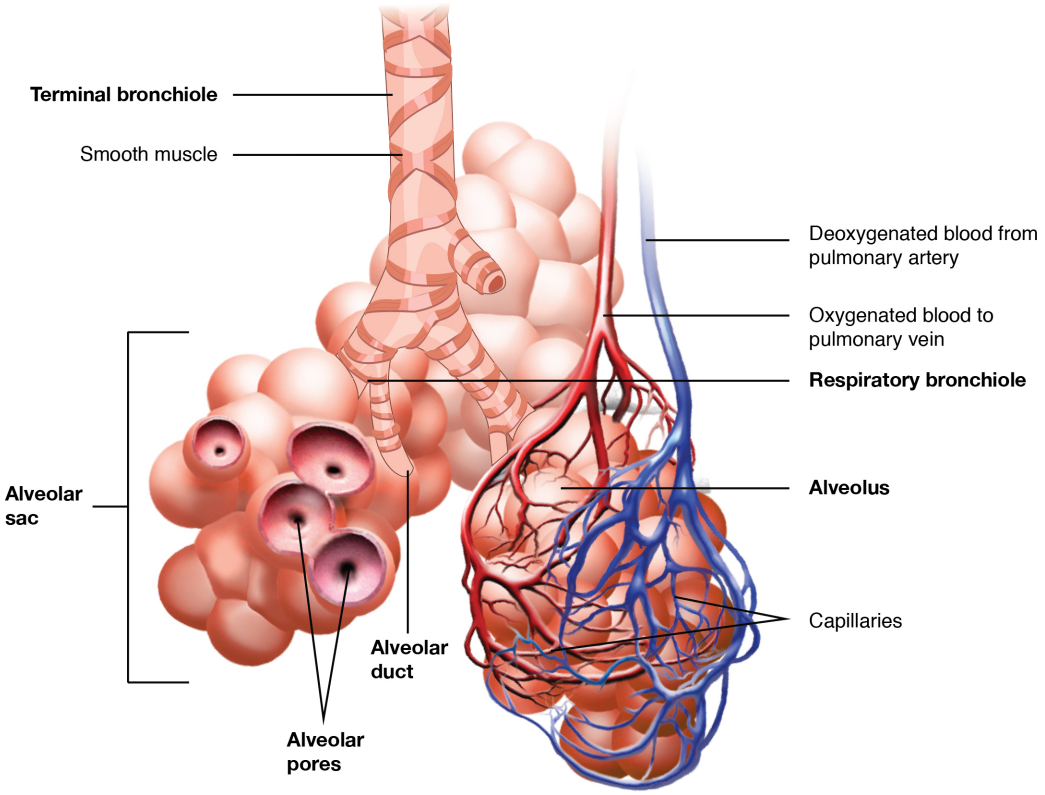

Figure 12.8 Respiratory Zone. Bronchioles lead to alveolar sacs in the respiratory zone, where gas exchange occurs. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 200 μm 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 Figure 12.9).

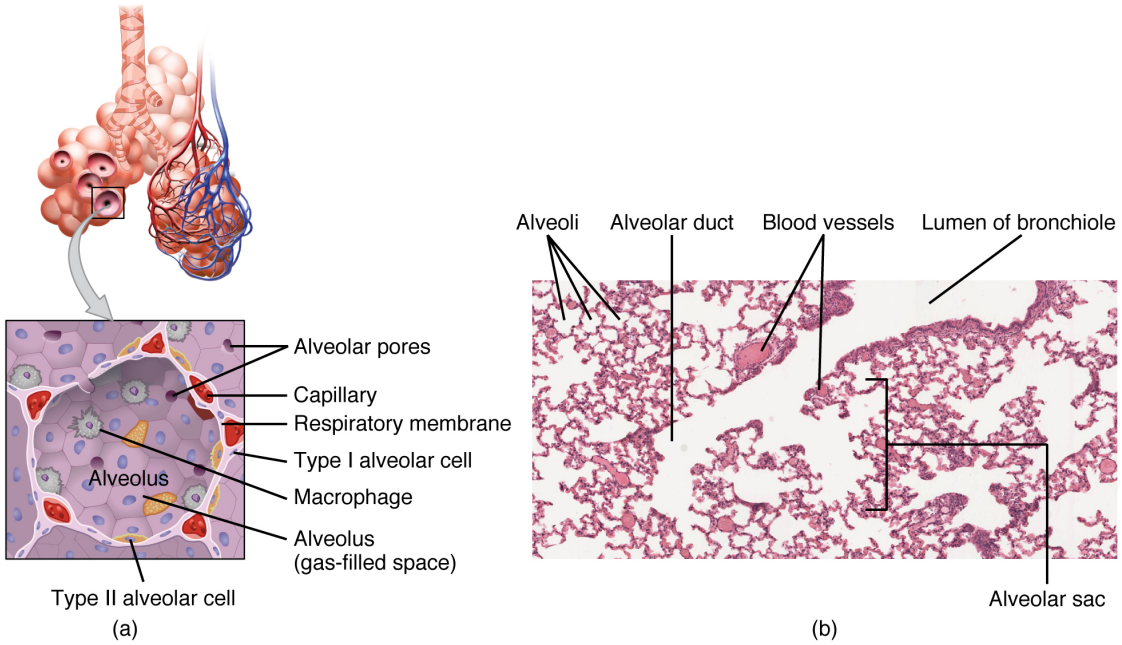

Figure 12.9 Structures of the Respiratory Zone. (a) The alveolus is responsible for gas exchange. (b) A micrograph shows the alveolar structures within lung tissue. LM × 178. (Micrograph provided by the Regents of University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 12.10). 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 midline.

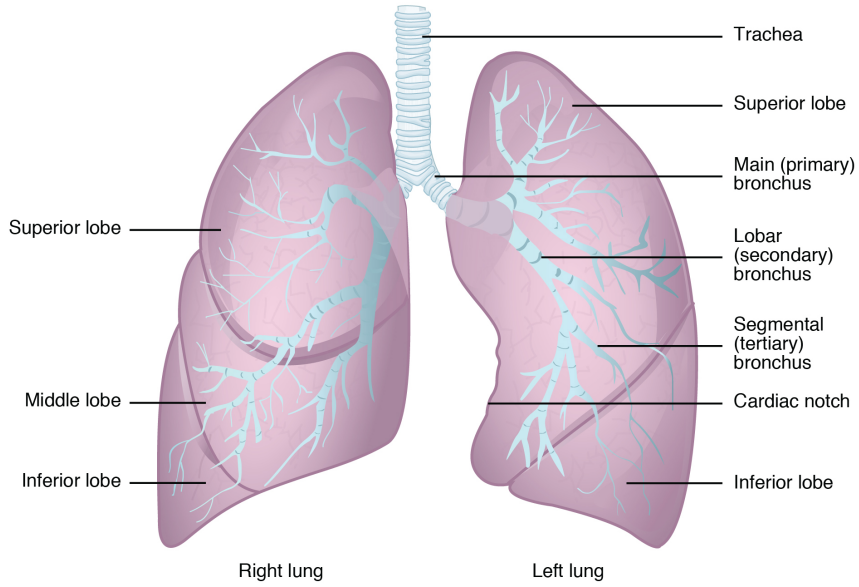

Figure 12.10 Gross Anatomy of the Lungs. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 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. Sensory nerve fibers arise from the vagus nerve, and from the second to fifth thoracic ganglia. The pulmonary plexus is a region on the lung root formed by the entrance of the nerves at the hilum. The nerves then follow the bronchi in the lungs and branch to innervate muscle fibers, glands, and blood vessels.

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 12.11).
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.

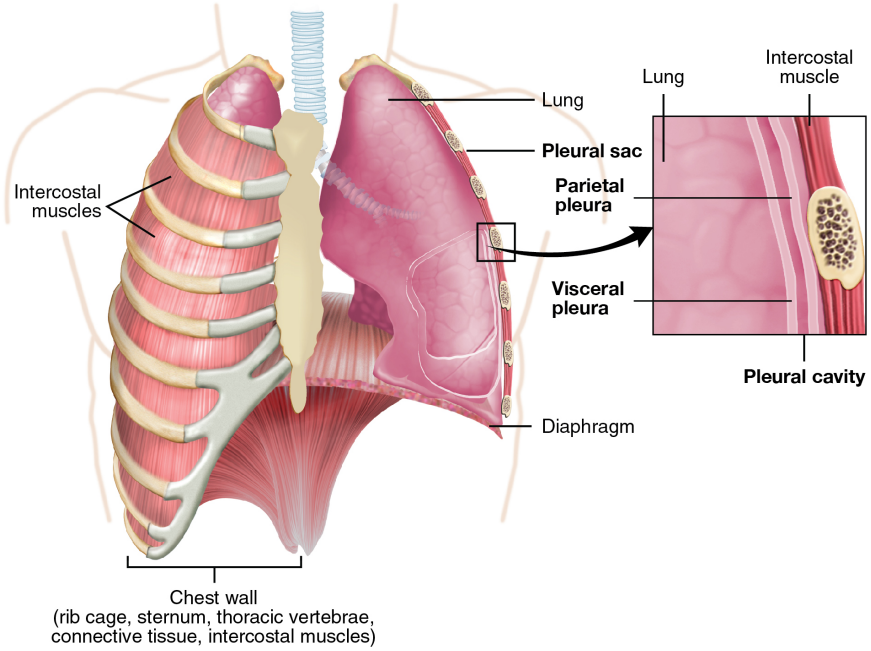

Figure 12.11 Parietal and Visceral Pleurae of the Lungs. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

The pleurae perform two major functions:

1. **Produce pleural fluid** 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. **Inspiration** is the process of having air enter the lungs and expiration is the process of expelling air from the lungs (Figure 12.12). 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 move 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.

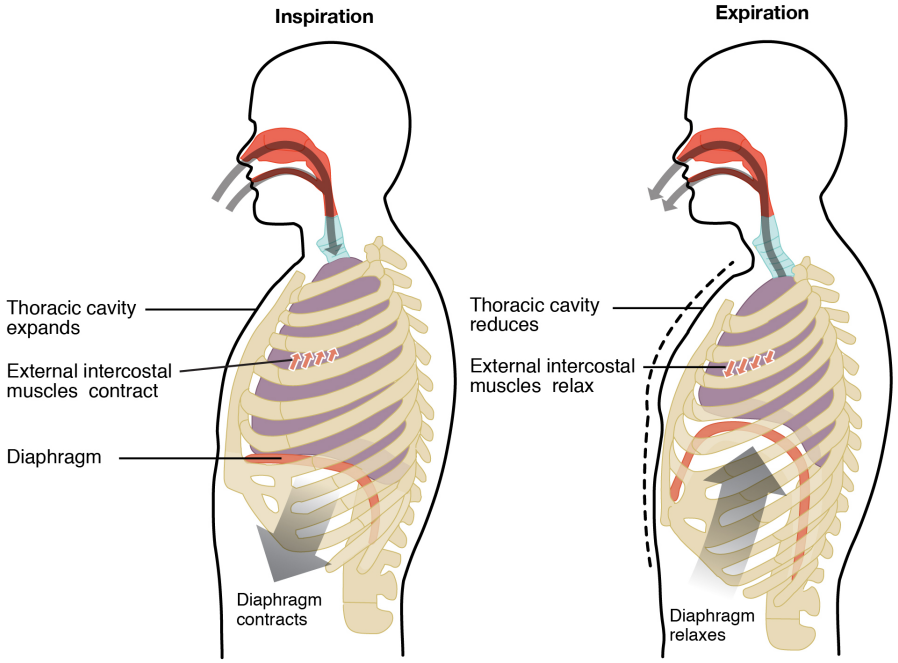

Figure 12.12 Inspiration and Expiration. Inspiration and expiration occur due to the expansion and contraction of the thoracic cavity, respectively. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 intrapulmonary pressure. The intrapulmonary 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.
- **Costal breathing**, 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 and 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

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.

Did you know?

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

Watch this video:

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Practice Terms Related to the Respiratory System

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Common Abbreviations for the Respiratory System

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

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Diseases and Disorders of the Respiratory System

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

The Effects of Second-Hand Tobacco Smoke

The burning of a tobacco cigarette creates multiple chemical compounds that are released through mainstream smoke, which is inhaled by the smoker, and through sidestream smoke, which is the smoke that is given off by the burning cigarette. **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% 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.

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 middle-aged or older adults. Signs and symptoms include shortness of breath, cough, and sputum production. 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 vaccinated against influenza and pneumococcal pneumonia, and reduce their exposure to pollution and cigarette smoke. While there are several risk factors, as many as 75% of cases are associated with cigarette smoking (National Heart, Lung, and Blood Institute, n.d.). To learn more about COPD, visit the National Heart, Lung, and Blood Institute's web page.

Asthma

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.

Signs and 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.

Lung Cancer

Lung cancer is a leading cause of cancer death among men and women. Smoking is the most significant risk factor for lung cancer, with 90% of cases in men and 80% of cases in women attributed to tobacco smoking. Signs and symptoms may include shortness of breath, wheezing, blood in the mucus, hoarseness, and trouble swallowing (MedlinePlus, n.d.).

There are two types of lung cancer, **small cell lung cancer (SCLC)** and non-small cell lung cancer (NSCLC). Both cancers occur when **malignant** cells form in the tissues of the lung. If **metastasis** occurs, lung cancer cells spread to other parts of the body. 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 (National Cancer Institute, 2021a, 2021b).

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. Signs and 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.

Medical Terms in Context

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Medical Specialties and Procedures Related to the Respiratory System

Respiratory Therapists (RTs)

Respiratory therapists (RTs) are healthcare professionals that monitor, assess, and treat people who are having problems breathing. RTs must have at least a two-year degree. RTs measure lung capacity, test oxygen and carbon dioxide levels, perform chest physiotherapy to remove mucus from patients' lungs, and operate ventilator equipment (Bureau of Labor Statistics, 2021). For more information, visit the American Association for Respiratory Care 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 (National Cancer Institute, n.d.). To learn about the career path, read this PDF from The Society of Thoracic Surgeons.

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.

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Media 12.3. Peak Flow and Spirometry – Lung Function Tests [Online video]. Copyright 2012 by Oxford Medical Education.

Respiratory System Vocabulary

Adenoidectomy
Excision of the adenoids.
Alveolar duct
Small tube that leads from the terminal bronchiole to the respiratory bronchiole and is the point of attachment for alveoli.
Alveolitis
Inflammation of the alveoli.
Aphonia
Condition of the absence of one's voice.
Apnea
A temporary absence of respiration.
Asphyxia

Condition caused by a lack of oxygen that leads to impending or actual death.

Aspirate

To withdraw fluid, tissue, or other substances from a body cavity, cyst, or tumor.

Atelectasis

Failure of the lung to expand (inflate) completely.

Autonomic

Involuntary or unconscious.

Benign

Non-cancerous.

Bronchiectasis

Dilation of the bronchi.

Bronchitis

Inflammation of the bronchus.

Bronchodilators

A type of drug that causes small airways in the lungs to open up.

Bronchogenic carcinoma

Cancer that begins in the tissue that lines or covers the airways of the lungs, including small cell and non-small cell lung cancer.

Bronchopneumonia

Inflammation of the lung, particularly the bronchioles and alveoli, that is associated with bronchitis.

Bronchoscope

A thin, tube-like instrument used to examine the inside of the trachea, bronchi, and lungs.

Bronchoscopy

A procedure involving a bronchoscope to examine the inside of the trachea, bronchi, and lungs.

Bronchospasm

Spasmodic contraction of the smooth muscle of the bronchi.

Carcinogen

Any substance that causes cancer.

Cardiac notch

An indentation on the surface of the left lung.

Carina

A ridge at the base of the trachea (windpipe) that separates the openings of the right and left main bronchi (the large air passages that lead from the trachea to the lungs).

Chronic

A condition that lasts a long time with periods of remission and exacerbation.

Computerized tomography (CT)

A noninvasive imaging technique that uses computers to analyze several cross-sectional X-rays in order to reveal minute details about structures in the body.

Conducting zone

The major functions of the conducting zone are to provide a route for incoming and outgoing air, remove debris and pathogens from the incoming air, and warm and humidify the incoming air.

Cyanotic

Pertaining to abnormal color of blue (bluish color, lips and nail beds) caused by deoxygenation.

Defensins

The lysozyme enzyme and proteins which have antibacterial properties.

Diaphragm

A sheet of skeletal muscle separating the thoracic and abdominal cavities that has to contract and relax for you to breathe.

Dysphonia

Condition of difficult speaking, including hoarseness and change in pitch or quality of the voice.

Dyspnea

Difficulty breathing.

Epiglottitis

Inflammation of the epiglottis.

Endoscope

A thin, tube-like instrument used to look at tissues inside the body.

Endoscopy

A procedure that uses an endoscope to examine the inside of the body.

Epiglottis

Leaf-shaped piece of elastic cartilage that is a portion of the larynx that swings to close the trachea during swallowing.

Epistaxis

Nosebleed.

Erythrocytes

Red blood cells.

Eupnea

A mode of breathing that occurs at rest and does not require the cognitive thought of the individual; also known as quiet breathing.

Expiration

Exhalation, or the process of causing air to leave the lungs.

External nose

The surface and skeletal structures that result in the outward appearance of the nose and contribute to its numerous functions.

Fauces

The opening of the oral cavity into the pharynx.

Fibroelastic membrane

A flexible membrane that closes the posterior surface of the trachea, connecting the C-shaped cartilages.

Glottis

Composed of the vestibular folds, the true vocal cords, and the space between these folds.

Hard palate

Located at the anterior region of the nasal cavity and is composed of bone.

Hemothorax

Hemorrhage within the pleural cavity.

Hematologist

A doctor who has special training in diagnosing and treating blood disorders.

Hematology

The study of blood and blood-forming issues.

Hilum of the lung

A concave region where blood vessels, lymphatic vessels, and nerves also enter the lungs.

Hypercapnia

Abnormally elevated blood levels of CO_2 (carbon dioxide).

Hyperpnea

Forced breathing or breathing that is excessive.

Hypocapnia

Abnormally low blood levels of CO_2 (carbon dioxide).

Hypoxemia

Below-normal level of oxygen saturation of blood (typically <95 percent).

Hypoxia
Lack of oxygen supply to the tissues.
Inferior
A position below or lower than another part of the body proper.
Influenza (flu)
An acute viral infection involving the respiratory tract.
Inspiration
Inhalation, or process of breathing air into the lungs.
Laryngeal
Pertaining to the larynx.
Laryngitis
Inflammation of the larynx.
Laryngopharynx
One of the three regions of the pharynx; inferior to the oropharynx and posterior to the larynx.
Laryngoplasty
Surgical repair of the larynx.
Laryngoscope
A thin, tube-like instrument used to examine the larynx.
Laryngoscopy
Examination of the larynx with a mirror or laryngoscope.
Larynx
A cartilaginous structure inferior to the laryngopharynx that connects the pharynx to the trachea and helps regulate the volume of air that enters and leaves the lungs; also known as the voice box.
Lobectomy
Excision of the lobe(s) of an organ.
Lymphocytes
The second most common type of leukocyte and are essential for the immune response.
Malignant
Cancerous.
Mucus
A thick, slippery fluid made by the membranes that line certain organs of the body.
Nasopharyngitis
Inflammation of the nose and pharynx.
Nasopharynx
The upper part of the throat behind the nose. An opening on each side of the nasopharynx leads into the ear.
Nebulizer
A device used to turn liquid into a fine spray.
Nosocomial infection
Infection acquired in hospital.
Oropharynx
A passageway for both air and food; borders the nasopharynx and the oral cavity.
Oximeter
Instrument used to measure the oxygenation of tissues.
Pharyngeal tonsil
The tonsil located at the back of the throat; also known as the adenoid when swollen.
Pharyngitis
Inflammation of the pharynx.
Pharynx

A tube formed by skeletal muscle and lined by mucous membrane that is continuous with that of the nasal cavities; also known as the throat.

Pleural effusion

An abnormal collection of fluid between the thin layers of tissue (pleura) lining the lung and the wall of the chest cavity.

Pleurisy

Inflammation of the pleura.

Pneumoconiosis

A condition caused by the inhalation of dust.

Pneumonectomy

Excision of the lung.

Pneumonia

A severe inflammation of the lungs in which the alveoli (tiny air sacs) are filled with fluid.

Pneumothorax

An abnormal collection of air in the space between the thin layer of tissue that covers the lungs and the chest cavity that can cause all or part of the lung to collapse.

Polysomnography (PSG)

Simultaneous and continuous monitoring of several parameters during sleep to study normal and abnormal sleep.

Posterior

Describes the back or direction toward the back of the body.

Pulmonary artery

Artery that arises from the pulmonary trunk.

Pulmonary edema

Fluid accumulation in alveoli and bronchioles (related to heart failure).

Pulmonary embolism

A blood clot within the lung.

Radiologist

A doctor who has special training in creating and interpreting pictures of areas inside the body.

Radiography

A procedure that uses x-rays to take pictures of areas inside the body.

Radiology

The use of radiation or other imaging technologies to diagnose or treat disease.

Respiratory zone

The respiratory zone includes structures that are directly involved in gas exchange.

Rhinitis

Inflammation of the mucous membranes of the nose.

Rhinoplasty

A plastic surgical operation on the nose, either reconstructive, restorative, or cosmetic.

Rhinorrhea

Excess nasal drainage; also called a “runny nose.”

Septal cartilage

The flexible hyaline cartilage connected to the nasal bone.

Sinusitis

Inflammation of the sinuses.

Soft palate

Located at the posterior portion of the nasal cavity and consists of muscle tissue.

Sonogram

A computer picture of areas inside the body created by high-energy sound waves.

Spirometry

The measurement of volume of air inhaled or exhaled by the lung.

Sputum

Mucus and other matter brought up from the lungs by coughing.

Stethoscope

An instrument is used to hear sounds produced by the heart, lungs, or other parts of the body.

Sympathetic nervous system (SNS)

The division of the nervous system involved in our fight-or-flight responses. It continuously monitors body temperature and initiates appropriate motor responses.

Tachypnea

Rapid breathing.

Thoracalgia

Pain in the chest.

Thoracentesis

Removal of fluid from the pleural cavity through a needle inserted between the ribs.

Thoracic

Pertaining to the chest.

Thoracoscope

A thin tube-like instrument used to examine the inside of the chest.

Thoracoscopy

Examination of the inside of the chest, using a thoracoscope.

Thoracotomy

An operation to open the chest.

Tonsillectomy

Excision of the tonsils.

Tonsillitis

Inflammation of the tonsils.

Tracheitis

Inflammation of the trachea.

Tracheostomy

Surgery to create an opening into the trachea.

Tracheotomy

Surgical incision of the trachea.

Trachea

The windpipe.

Upper respiratory infection

Infection of the nasal cavity, pharynx and larynx cause by a virus.

Uvula

A small bulbous, teardrop-shaped structure located at the apex of the soft palate.

Ventilator

A machine used to help a patient breathe.

Test Yourself

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Image Descriptions

Figure 12.1 image description: This figure shows the upper half of the human body. The major organs in the respiratory system are labeled. [Return to Figure 12.1].

Figure 12.2 image description: This figure shows a cross section view of the nose and throat. The major parts are labeled. [Return to Figure 12.2].

Figure 12.3 image description: This figure shows a micrograph of pseudostratified epithelium. [Return to Figure 12.3].

Figure 12.4 image description: This figure shows the side view of the face. The different parts of the pharynx are color-coded and labeled (from the top): nasal cavity, hard palate, soft palate, tongue, epiglottis, larynx, esophagus, trachea. [Return to Figure 12.4].

Figure 12.5 image description: The top panel of this figure shows the anterior view of the larynx, and the bottom panel shows the right lateral view of the larynx. [Return to Figure 12.5].

Figure 12.6 image description: This diagram shows the cross-section of the larynx. The different types of cartilages are labeled (clockwise from top): pyriform fossa, true vocal cord, epiglottis, tongue, glottis, vestibular fold, trachea, esophagus. [Return to Figure 12.6].

Figure 12.7 image description: The top panel of this figure shows the trachea and its organs. The major parts including the larynx, trachea, bronchi, and lungs are labeled. [Return to Figure 12.7].

Figure 12.8 image description: This image shows the bronchioles and alveolar sacs in the lungs and depicts the exchange of oxygenated and deoxygenated blood in the pulmonary blood vessels. [Return to Figure 12.8].

Figure 12.9 image description: This figure shows the detailed structure of the alveolus. The top panel shows the alveolar sacs and the bronchioles. The middle panel shows a magnified view of the alveolus, and the bottom panel shows a micrograph of the cross section of a bronchiole. [Return to Figure 12.9].

Figure 12.10 image description: Diagram of the lungs with the major parts labelled (from top, clockwise): trachea, superior lobe, main bronchus, lobar bronchus, segmental bronchus, inferior lobe, inferior lobe, middle lobe, superior lobe of the left lung. [Return to Figure 12.10].

Figure 12.11 image description: This figure shows the lungs and the chest wall, which protects the lungs, in the left panel. In the right panel, a magnified image shows the pleural cavity and a pleural sac. [Return to Figure 12.11].

Figure 12.12 image description: The left panel of this image shows a person inhaling air and the location of the chest muscles. The right panel shows the person exhaling air and the contraction of the thoracic cavity. [Return to Figure 12.12].

13. Digestive System

Learning Objectives

- Examine the anatomy of the digestive system
- Determine the main functions of the digestive system
- Differentiate the medical terms of the digestive system and common abbreviations
- Recognize the medical specialties associated with the digestive system
- Discover common diseases, disorders, and procedures related to 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.

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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).

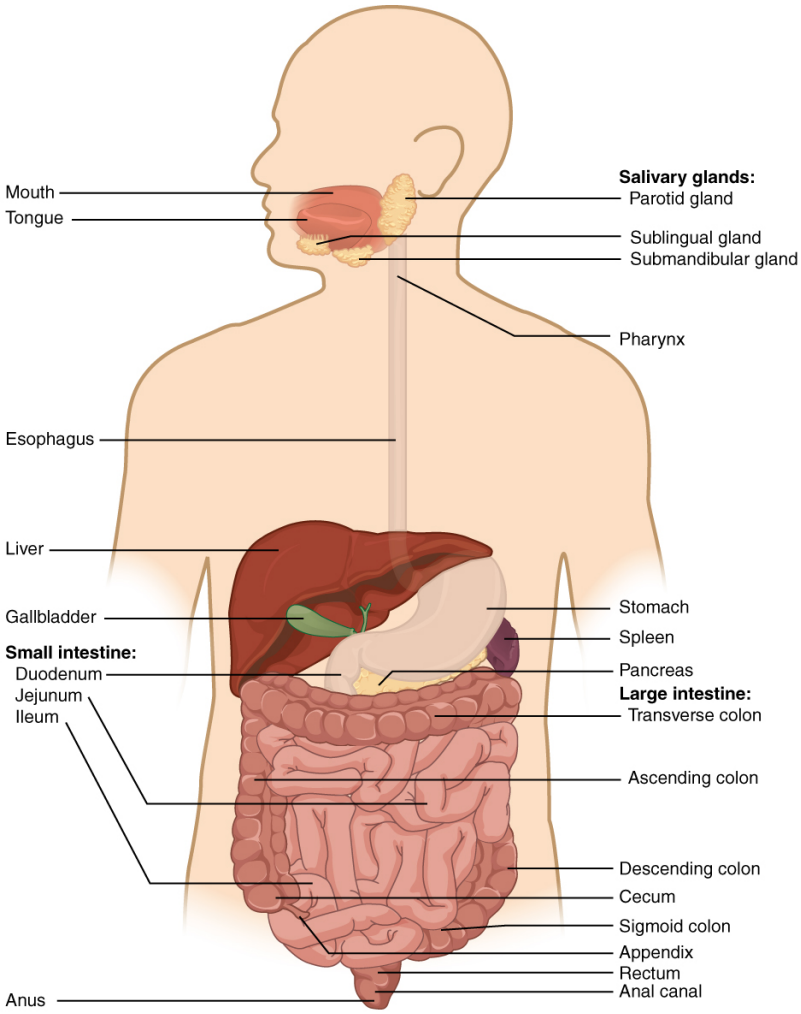

Figure 13.1 Components of the Digestive System. All digestive organs play integral roles in the life-sustaining process of digestion. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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Media 13.1 Digestive System, Part 1: Crash Course A&P #33. Copyright 2015 by CrashCourse.

Practice Medical Terms Related to the Digestive System

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Practice with This Activity:

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Anatomy (Structures) of the Digestive System

The Mouth

The cheeks, tongue, and palate frame the mouth, which is also called the **oral cavity** (or buccal cavity). The structures of the mouth are illustrated in Figure 13.2.

At the entrance to the mouth are the lips, or **labia** (singular = labium). Their outer covering is skin, which transitions to a mucous membrane in the mouth proper. Lips are very vascular with a thin layer of keratin; hence, the reason they are red.

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**. Moving farther into the mouth, the opening between the oral cavity and throat (oropharynx) is called the **fauces** (like the kitchen "faucet"). 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).

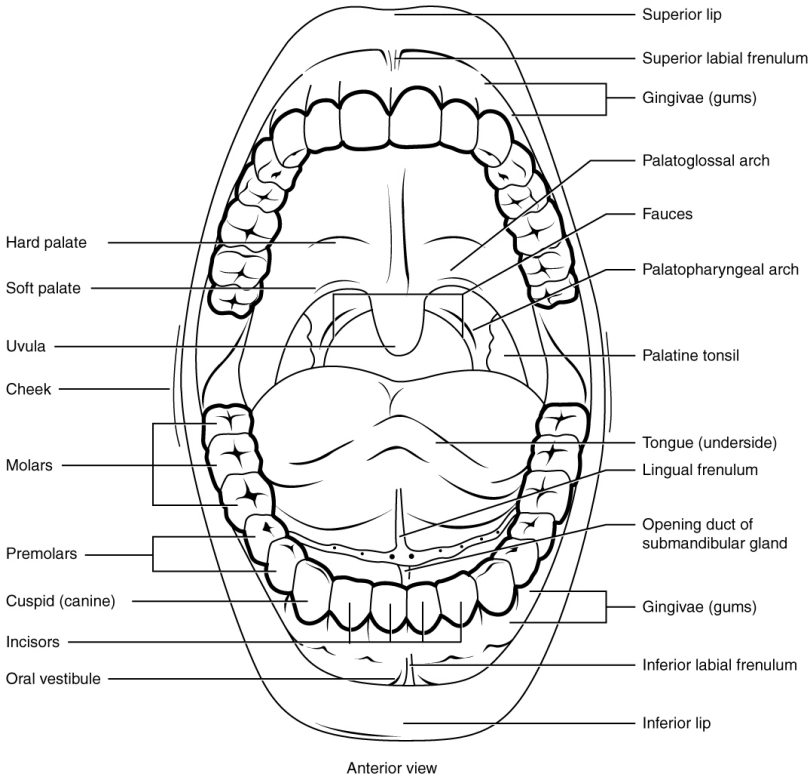

Figure 13.2 Mouth. The mouth includes the lips, tongue, palate, gums, and teeth. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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. Toward the front, the **palatoglossal arch** lies next to the base of the tongue; behind it, the **palatopharyngeal arch** forms the superior and lateral margins of the fauces. Between these two arches are the **palatine tonsils**, clusters of lymphoid tissue that protect the pharynx. The **lingual tonsils** are located at the base of the tongue.

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.

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 proportional 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 tongue is attached to the mandible, the styloid processes of the temporal bones, and the hyoid bone. The hyoid is unique in that it only distantly/indirectly articulates with other bones. The tongue is positioned over the floor of the oral cavity. A medial septum extends the entire length of the tongue, dividing it into symmetrical halves.

The top and sides of the tongue are studded with papillae, extensions of lamina propria of the mucosa, which are covered in **stratified squamous epithelium** (see Figure 13.3).

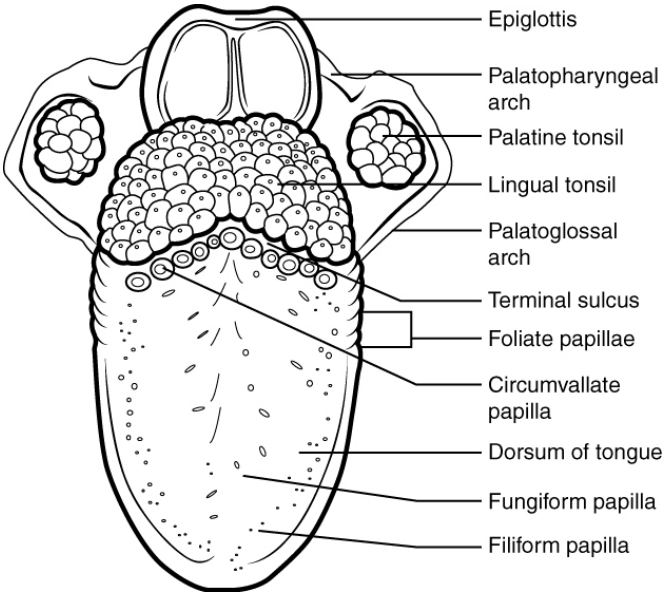

Figure 13.3 Tongue. This superior view of the tongue shows the locations and types of lingual papillae. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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.

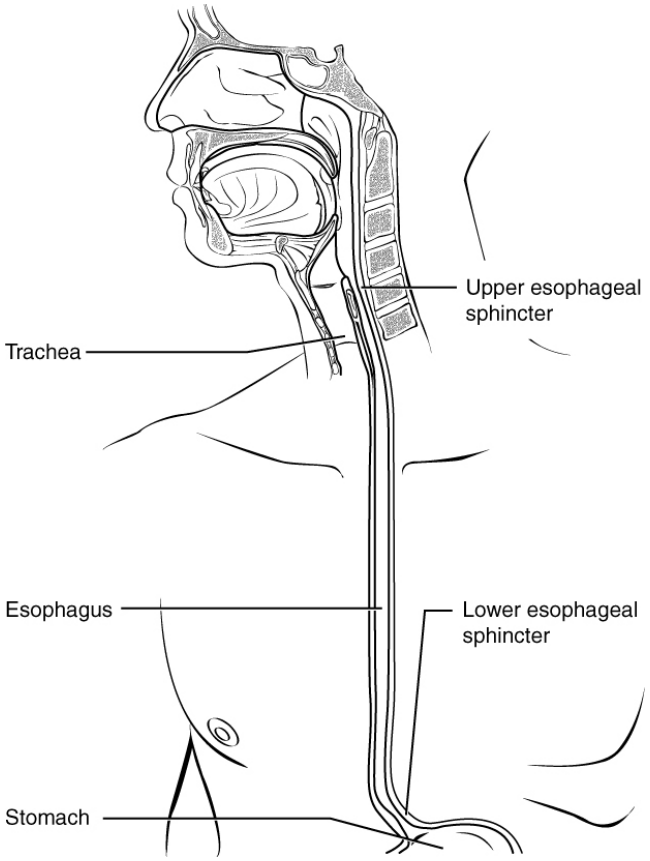

Figure 13.4 Esophagus. The upper esophageal sphincter controls the movement of food from the pharynx to the esophagus. The lower esophageal sphincter controls the movement of food from the esophagus to the stomach. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Passage of Food Through the Esophagus

The upper **esophageal sphincter**, which is continuous with the inferior pharyngeal **constrictor,** 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, with the latter fading out in the bottom third of the esophagus. Rhythmic waves of **peristalsis**, which begin in the upper esophagus, propel the bolus of food toward the stomach. Meanwhile, secretions from the esophageal mucosa lubricate the esophagus and food. Food passes from the esophagus into the stomach at the lower esophageal sphincter (also called the gastroesophageal or cardiac sphincter). 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.

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. The wider

end of the funnel, the **pyloric antrum**, connects to the body of the stomach. The narrower end is called the **pyloric canal**, which connects to the duodenum. The smooth muscle **pyloric sphincter** is located at this latter point of connection and controls stomach emptying. In the absence of food, the stomach deflates inward, and its mucosa and submucosa fall into a large fold called a **ruga.**

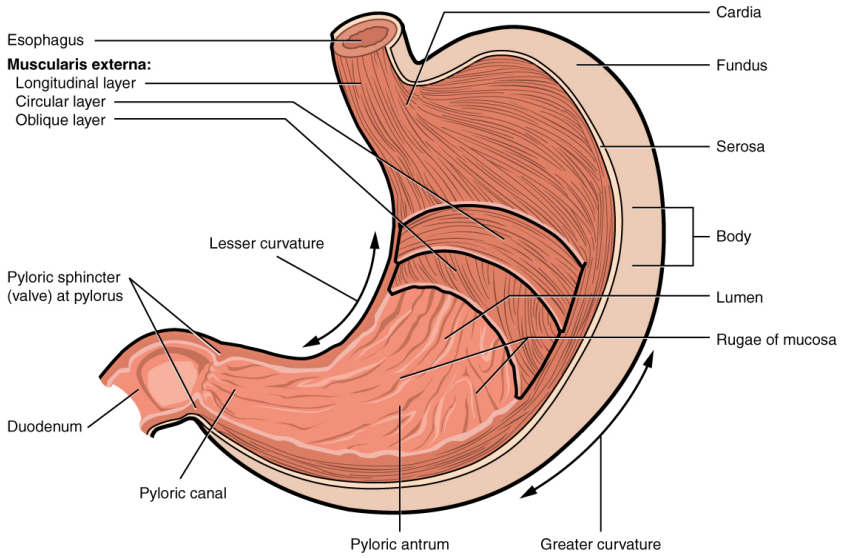

Figure 13.5 Stomach. The stomach has four major regions: the cardia, fundus, body, and pylorus. The addition of an inner oblique smooth muscle layer gives the muscularis the ability to vigorously churn and mix food. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

The convex lateral surface of the stomach is called the greater curvature; the **concave** medial border is the lesser curvature. The stomach is held in place by the lesser omentum, which extends from the liver to the lesser curvature, and the greater **omentum**, which runs from the greater curvature to the posterior abdominal wall.

Small Intestines

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, but 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 you will 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, which is approximately 200 m^2, 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** to **distal**, these are the duodenum, jejunum, and ileum (see Figure 13.6).

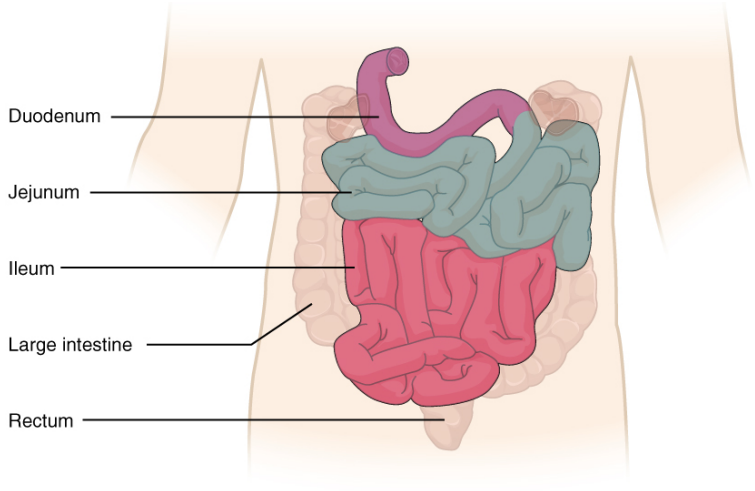

Figure 13.6 Small Intestine. The three regions of the small intestine are the duodenum, jejunum, and ileum. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Did you know?

Your body absorbs 90% of your nutrients through the **small intestine** into your blood.

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. The **mesoappendix**, the mesentery of the appendix, tethers it to the mesentery of the ileum.

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 form the **right colic flexure** (hepatic flexure) and becomes the **transverse colon**. The region defined as the hindgut begins with the last third of the transverse colon and continues. Food residue passing through the transverse colon travels across to the left side of the abdomen, where the colon angles sharply immediately inferior to the spleen, at the **left colic flexure** (splenic flexure). 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. The transverse and sigmoid colon are tethered to the posterior abdominal wall by the mesocolon.

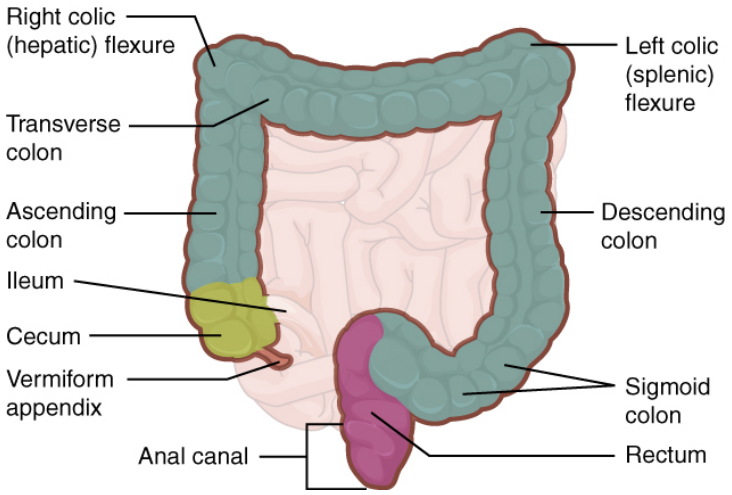

Figure 13.7 Large Intestine. The large intestine includes the cecum, colon, and rectum. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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 13.8). 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

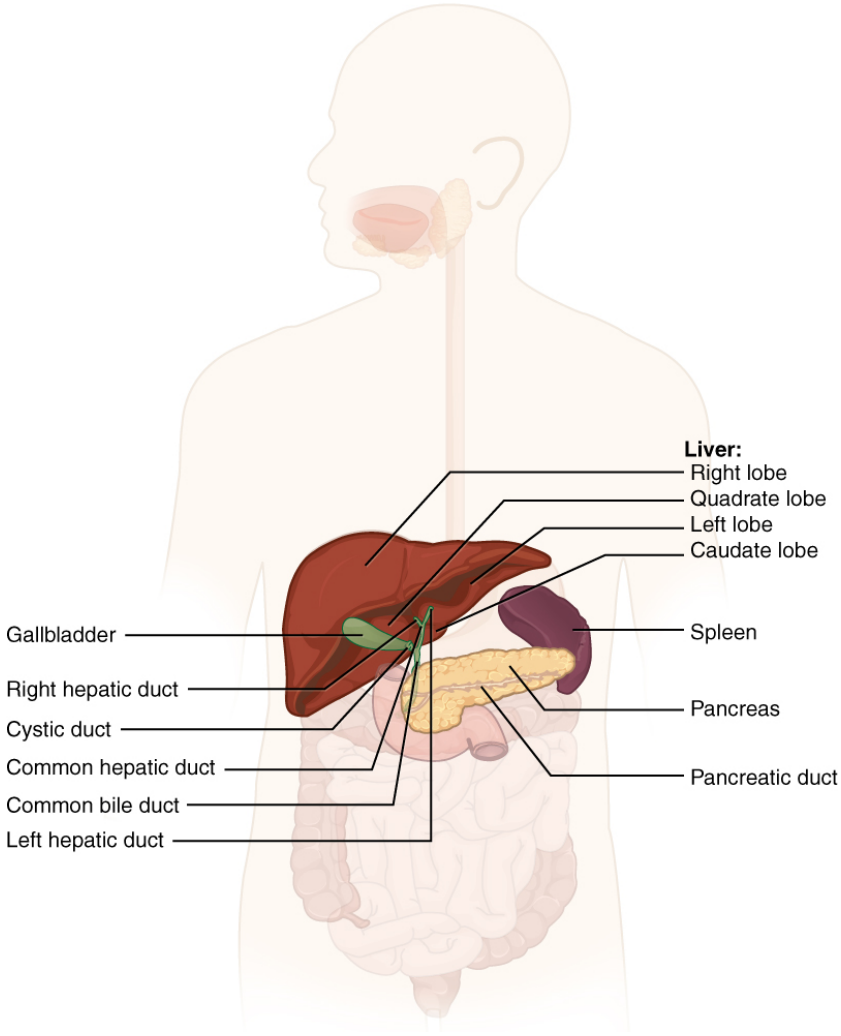

Figure 13.8 Accessory Organs. The liver, pancreas, and gallbladder are considered accessory digestive organs, but their roles in the digestive system are vital. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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. In the right lobe, some anatomists also identify an inferior quadrate lobe and a posterior caudate lobe, which are defined by internal features. The liver is connected to the abdominal wall and diaphragm by five peritoneal folds referred to as ligaments.

The **porta hepatis** ("gate to the liver") is where the **hepatic artery** and **hepatic portal vein** enter the liver. These two vessels, along with the common hepatic duct, run behind the lateral border of the lesser omentum on the way to their destinations. 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.

Bile produced 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).

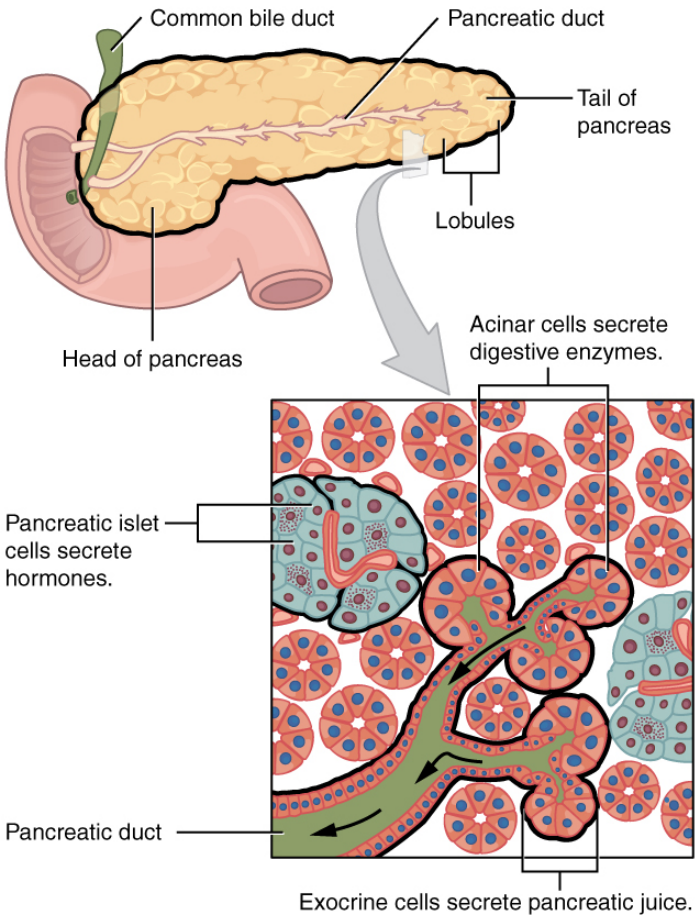

Figure 13.9 Exocrine and Endocrine Pancreas. The pancreas has a head, a body, and a tail. It delivers pancreatic juice to the duodenum through the pancreatic duct. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

The exocrine part of the pancreas arises as little grape-like cell clusters, each called an **acinus** (plural = acini), located at the terminal ends of pancreatic ducts. These acinar cells secrete enzyme-rich **pancreatic juice** into tiny merging ducts that form two dominant ducts. The larger duct fuses with the common bile duct (carrying bile from the liver and gallbladder) just before entering the duodenum via a common opening (the hepatopancreatic ampulla). The smooth muscle sphincter of the hepatopancreatic **ampulla** controls the release of pancreatic juice and bile into the small intestine. The second and smaller pancreatic duct, the **accessory duct** (duct of Santorini), runs from the pancreas directly into the duodenum, approximately 1 inch above the hepatopancreatic ampulla. When present, it is a persistent remnant of pancreatic development.

Scattered through the sea of exocrine acini are small islands of endocrine cells, the islets of Langerhans. These vital cells produce the hormones pancreatic polypeptide, insulin, glucagon, and somatostatin.

Gallbladder

The **gallbladder** is 8 to 10 cm (~3 to 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. The neck angles slightly superiorly as it approaches the hepatic duct. The cystic duct is 1 to 2 cm (less than 1 in) long and turns inferiorly as it bridges the neck and hepatic duct.

The simple columnar epithelium of the gallbladder mucosa is organized in rugae, similar to those of the stomach. There is no submucosa in the gallbladder wall. The wall's middle, muscular coat is made of smooth muscle fibers. When these fibers contract, the gallbladder's contents are ejected through the **cystic duct** and into the bile duct (Figure 13.10). The visceral peritoneum reflected from the liver capsule holds the gallbladder against the liver and forms the outer coat of the gallbladder. The gallbladder's mucosa absorbs water and ions from bile, concentrating it by up to 10-fold.

Concept Check

- Locate the **cystic duct** on the diagram shown below (Figure 13.10).
- Consider what **complications** could arise if this duct was blocked or obstructed.

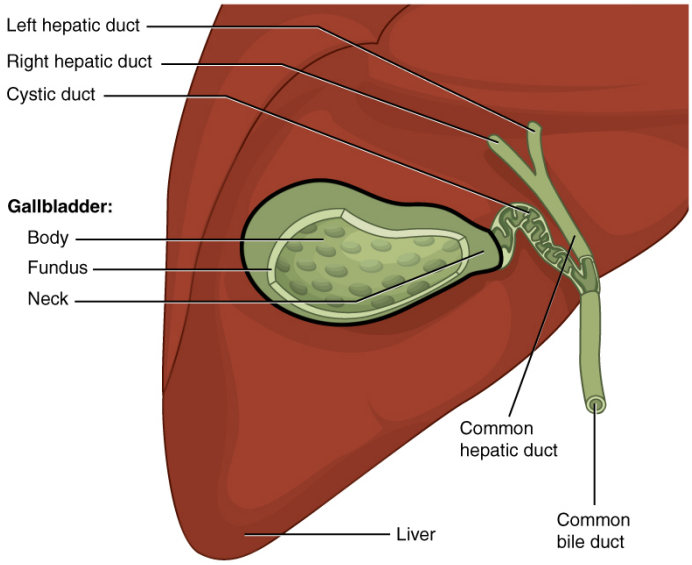

Figure 13.10 Gallbladder. The gallbladder stores and concentrates bile, and releases it into the two-way cystic duct when it is needed by the small intestine. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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Media 13.2 What does the liver do? – Emma Bryce. Copyright 2014 by TED-Ed.

Concept Check

At rest, about 1500 mL of blood per minute flows through the liver. What percentage of this blood flow comes from the hepatic portal system?

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 13.11). 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.

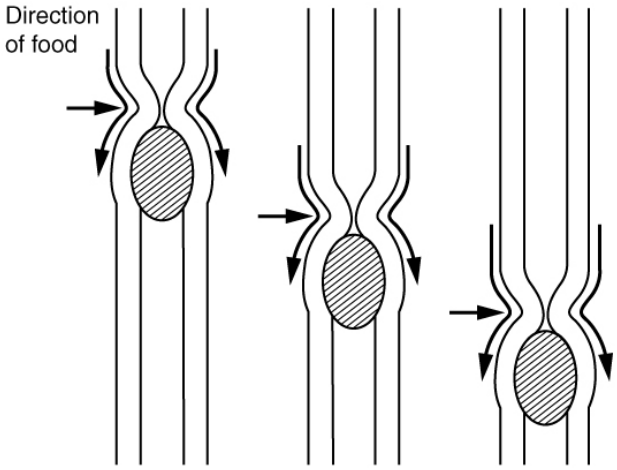

Figure 13.11. Peristalsis. Peristalsis moves food through the digestive tract with alternating waves of muscle contraction and relaxation. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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**.

Segmentation, which occurs mainly in the small intestine, consists of localized contractions of circular muscle of the muscularis layer of the alimentary canal. These contractions isolate small sections of the intestine, moving their contents back and forth while continuously subdividing, breaking up, and mixing the contents. By moving food back and forth in the intestinal lumen, segmentation mixes food with digestive juices and facilitates absorption.

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. There, most nutrients are absorbed from the lumen of the alimentary canal into the bloodstream through the epithelial cells that make up the mucosa. Lipids are absorbed into **lacteals** and are transported via the lymphatic vessels to the bloodstream.

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. Neurosensory feedback is also dampened, slowing the transmission of messages that stimulate the release of enzymes and hormones.

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 13.12). Some chemical digestion occurs in the mouth. Some absorption can occur in the mouth and stomach; for example, alcohol and aspirin.

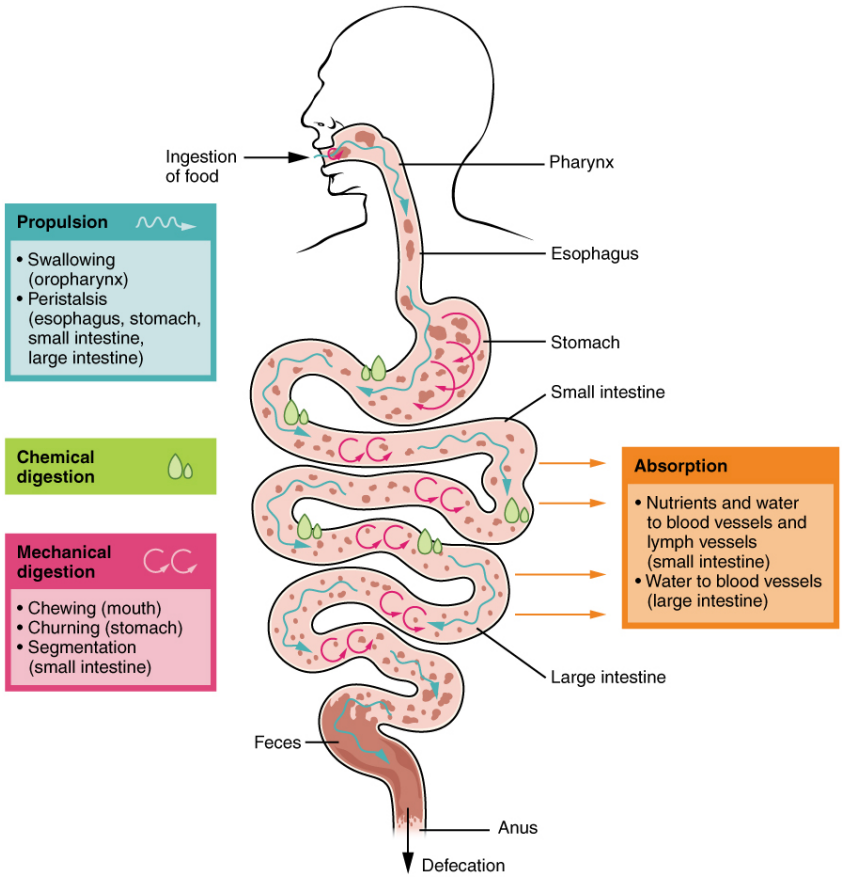

Figure 13.12. Digestive Processes. The digestive processes are ingestion, propulsion, mechanical digestion, chemical digestion, absorption, and defecation. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Regulatory Mechanisms

Neural and endocrine regulatory mechanisms work to maintain the optimal conditions in the lumen needed for digestion and absorption. These regulatory mechanisms, which stimulate digestive activity through mechanical and chemical activity, are controlled both extrinsically and intrinsically.

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Media 13.3 *Digestive System, Part 3: Crash Course A&P #35. Copyright* 2015 *by CrashCourse.*

Practice Terms Related to the Digestive System

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Common Abbreviations for the Digestive System

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

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Diseases and Disorders of the Digestive System

Gastroesophageal Reflux Disease

Gastroesophageal reflux disease (GERD) is caused by stomach acid flowing upwards into the esophagus. Those suffering from the condition will often feel a burning sensation in the chest or throat (MedlinePlus, 2021a). To learn more about GERD, visit the National Institute of Diabetes and Digestive and Kidney Diseases' web page.

Cholecystitis

Cholecystitis is known as inflammation of the gallbladder. Gall stone development can block the gallbladder's release of bile, leading to an inflammatory response. Cholecystitis can be characterized as acute (the sudden onset of irritation of the gallbladder) or chronic (prolonged irritation of the gallbladder usually caused by repeated bouts of acute cholecystitis). Treatment may require a cholecystectomy (Jones, Genova, et al., 2021; Jones, Gnanapandithan, et al., 2021). To learn more, visit the Mayo Clinic's web page on cholecystitis.

Cirrhosis

Cirrhosis is a condition whereby the liver scars. Potentially fatal complications can arise, including liver failure. It generally cannot be reversed, although many of the underlying causes of cirrhosis can be treated and may help lower the likelihood of cirrhosis-related complications. Cirrhosis is caused by different forms of liver disease and chronic alcoholism (National Institute of Diabetes and Digestive and Kidney Diseases, n.d.-a).

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**
- **Ascites** (National Institute of Diabetes and Digestive and Kidney Diseases, n.d.-a)

To learn more, visit the National Institute of Diabetes and Digestive and Kidney Diseases' web page on cirrhosis.

Esophageal Cancer

Esophageal cancer begins in the innermost layer of the esophagus and spreads to the other layers. Risk factors include tobacco use, heavy alcohol use, and older age (National Cancer Institute, 2021a). To learn more, visit the Mayo Clinic's web page on esophageal cancer.

Hepatitis

Inflammation of the liver is referred to as hepatitis. It can be caused by heavy alcohol use, toxins, drugs, or as a result of an autoimmune response, but it is most often caused by a virus. Viral hepatitis is caused by one of several viruses: hepatitis A, B, C, D, or E. In the United States, 90% of hepatitis cases are caused by the A, B, and C viruses. Many cases are asymptomatic (Mehta & Reddivari, 2021).

- **Hepatitis A** is transmitted via the **fecal-oral route**. Infection may last for a few weeks or several months, although

most individuals recover without long-term liver damage. Hepatitis A can be prevented with a vaccine.

- **Hepatitis B** is transmitted via bodily fluid, sexual transmission, contact with shared objects (such as utensils), the sharing of equipment (such as needles or medical equipment), **nosocomial** transmission, or childbirth. Infection may be mild or can develop into a chronic condition. Hepatitis B can be prevented with a vaccine.
- **Hepatitis C** is transmitted via bodily fluid, sexual transmission, nosocomial infection, childbirth, or blood transfusion. Although infection may be mild, most people develop a chronic condition. There is no vaccine for hepatitis C (Centers for Disease Control and Prevention, n.d.-a).
- **Hepatitis D** only occurs in people with hepatitis B. It is transmitted via bodily fluid, sexual transmission, childbirth, needle-sharing, needle stick injuries, and shared items such as toothbrushes or razors. Infection may last for a short time or may develop into a chronic condition. There is no vaccine for hepatitis D, although the hepatitis B vaccine can protect individuals from hepatitis D infection (Centers for Disease Control and Prevention, n.d.-b).
- **Hepatitis E** is transmitted most often via the **fecal-oral route**. In some countries, it may also be transmitted via contaminated water and undercooked or uncooked meat. In the United States, most cases are related to travel to countries where hepatitis E is prevalent. Most people with hepatitis E recover without treatment, although it can be fatal. There is no vaccine for hepatitis E approved for use in the United States (Centers for Disease Control and Prevention, n.d.-c).

For more information, visit the National Institute of Diabetes and Digestive and Kidney Diseases' web page on viral hepatitis.

Celiac Sprue (Celiac Disease)

Individuals who possess celiac disease have an immune sensitivity reaction occurring in the small intestines when they consume gluten. Typically people with this condition are genetically predisposed to the condition. Damage to the small intestine will occur if continued consumption of gluten occurs. Following a gluten-free diet generally resolves most symptoms and complications of celiac disease (National Institute of Diabetes and Digestive and Kidney Diseases, n.d.-b). For more information, visit the Mayo Clinic's web page on celiac disease.

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 the malabsorption of nutrients from food. Ulcerative colitis is localized inflammation and ulcers in the colon (National Institute of Diabetes and Digestive and Kidney Diseases, n.d.-c, n.d.-d). To learn more, visit the Mayo Clinic's web pages on Crohn's disease and ulcerative colitis.

Colon Cancer

Colon cancer is cancer formation in the colon portion of the digestive tract. Familial or personal history of rectal or colon cancer, heavy use of tobacco or alcohol, and older age are risk factors for colon cancer. It is often diagnosed through a

colonoscopy (National Cancer Institute, 2021b). To learn more, visit the National Cancer Institute's web page on colon cancer.

Hernia

A hernia occurs when part of an organ or tissue squeezes through a weak spot in a surrounding muscle. A hernia can happen in the groin (inguinal hernia), around the belly button (umbilical hernia), through a scar (incisional hernia), through the diaphragm (hiatal hernia), or as a result of a birth defect (congenital diaphragmatic hernia) (MedlinePlus, 2021b). For more information, visit the Cleveland Clinic's web page on hernias.

Irritable Bowel Syndrome

Irritable bowel syndrome (IBS) is a common disorder affecting the large intestines. It often involves abdominal pain, bloating, and changes in bowel movements, although individuals with IBS may experience **remission** and flare-ups. Diet and lifestyle modifications often help in the management of the condition. (National Institute of Diabetes and Digestive and Kidney Diseases, n.d.-e). To learn more, visit the National Institute of Diabetes and Digestive and Kidney Diseases' web page on IBS.

Polyps

A polyp is a small growth of tissue protruding from the intestinal wall. Most are harmless but can transition over time into a cancerous growth. Typically, they are found in men and adults. over the age of 45 (National Institute of Diabetes and Digestive and Kidney Diseases, n.d.-f). To learn more, review the National Institute of Diabetes and Digestive and Kidney Diseases' web page on polyps.

Medical Terms in Context

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Medical Specialties and Procedures Related to the Digestive System

Gastroenterology

Gastroenterology is a branch of internal medicine that focuses on the diagnosis and treatment of conditions afflicting the digestive system. A physician who specializes in this area is known as a gastroenterologist. (Bureau of Labor Statistics, 2021; National Cancer Institute, n.d.). To learn more about gastroenterology, visit the American College of Gastroenterology's web page.

Procedures

Upper and Lower Gastrointestinal Series

Upper and lower gastrointestinal series are procedures that involve 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 are taken of the upper and lower gastrointestinal system structures (National Institute of Diabetes and Digestive and Kidney Diseases, n.d.-g, n.d.-h). To learn more, visit the National Institute of Diabetes and Digestive and Kidney Diseases' web pages on upper GI series and lower GI series.

Fecal Occult Blood Test

The fecal occult blood test is a test for hidden blood in a fecal sample. It can be performed at home and involves the patient putting a small segment of fecal output on a test card that is then mailed to their healthcare provider or a laboratory. Blood detection can be an indicator of bleeding along the digestive tract or an abnormal growth, such as colorectal cancer (MedlinePlus, 2020a).

Stool Culture

A stool culture procedure involves the collection of a small sample of feces. The sample is analyzed for abnormal bacterial growth and parasites through a culture check (MedlinePlus, 2020b).

Esophagogastroduodenoscopy

An EGD (upper endoscopy) is a procedure whereby 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 (Ahlawat et al., 2021)

Digestive System Vocabulary

Abdominal
Pertaining to the abdomen.
Abdominoplasty
Surgical repair of the abdomen.
Ampulla
A sac-like enlargement of a canal or duct.
Anal
Pertaining to the anus.
Appendectomy
Excision of the appendix.
Appendicitis
Acute inflammation of the appendix.
Ascites
Abnormal buildup of fluid in the abdomen that may cause swelling.
Bicarbonate
A by-product of the body's metabolism.
Carbohydrates
Molecules composed of carbon, hydrogen, and oxygen. Carbohydrates are found in plant-based foods and dairy products and are an important fuel source.
Celiac
Pertaining to the abdomen.
Cholangioma
Tumor of the bile duct.
Cholangiography
Radiographic imaging of the bile duct.
Cholecystectomy
Excision of the gallbladder.
Cholecystitis
Inflammation of the gallbladder.
Choledocholithiasis
Condition of gallstones in the common bile duct.
Cholelithiasis
Condition of gallstones.
Cirrhosis
A type of chronic, progressive liver disease in which liver cells are replaced by scar tissue.
Colectomy
Excision of the colon.
Colitis
Inflammation of the colon.
Colonoscope
A thin, tube-like instrument used to examine the inside of the colon.
Colonoscopy
Examination of the inside of the colon using a colonoscope, inserted into the rectum.
Colorectal
Pertaining to the colon or rectum.

Colostomy
An opening into the colon from the outside of the body.
CT colonography
A method to examine the inside of the colon by taking a series of x-rays.
Distal
A position in a limb that is farther from the point of attachment or the trunk of the body.
Diverticulitis
Inflammation of one or more pouches or sacs that bulge out from the wall of a hollow organ, such as the colon.
Diverticulosis
A condition marked by small sacs or pouches in the walls of a hollow organ, such as the colon.
Dysentery
Acute inflammation of the intestine presenting with abdominal pain and bloody diarrhea.
Dysphagia
Difficulty swallowing.
Dyspepsia
Upset stomach.
Emesis
Vomiting.
Emulsification
The process of breaking down the fat into smaller blood cells, which makes it easy for enzymes to function and digest food.
Endoscope
A thin, tube-like instrument used to look at tissues inside the body.
Endoscopy
A procedure that uses an endoscope to examine the inside of the body.
Esophageal
Pertaining to the esophagus.
Esophagitis
Inflammation of the esophagus.
Esophagoscopy
Examination of the esophagus using an esophagoscope.
Exocrine gland
A gland whose secretions leave through a duct that opens directly, or indirectly, to the external environment.
Feces
Semisolid waste product of digestion.
Flatus
Gas in the intestine.
Fundus
The part of a hollow organ that is across from, or farthest away from, the organ's opening.
Gastrectomy
Stomach removal.
Gastric
Pertaining to the stomach.
Gastritis
Inflammation of the lining of the stomach.
Gastroenteritis
Inflammation of the lining of the stomach and the intestines.
Gastroenterologist

A doctor who has special training in diagnosing and treating disorders of the digestive system.

Gastroenterology

A subspecialty of internal medicine concerned with the study of the physiology and diseases of the digestive system and related structures.

Gastrojejunostomy

A surgical procedure that connects part of the stomach to the jejunum.

Gastroplasty

Surgical repair of the stomach.

Gastroscope

A thin, tube-like instrument used to examine the inside of the stomach.

Gastroscopy

Examination of the inside of the stomach using a gastroscope passed through the mouth and esophagus.

Gastrostomy

Creation of an artificial opening in the stomach.

Gingivectomy

Excision of the gums.

Gingivitis

Inflammation of the gums.

Glossitis

Inflammation of the tongue.

Hemorrhoid

An enlarged or swollen blood vessel, usually located near the anus or the rectum.

Hepatitis

Disease of the liver causing inflammation.

Hepatoma

Tumor of the liver.

Hepatomegaly

Enlarged liver.

Herniorrhaphy

Suturing of a hernia.

Ileostomy

A procedure in which the ileum is brought through the abdominal wall.

Labia

Lips of the mouth.

Lacteals

The lymphatic vessels of the small intestine which absorb digested fats.

Laparoscope

A thin, tube-like instrument used to look at tissues and organs inside the abdomen.

Laparoscopy

A procedure that uses a laparoscope, inserted through the abdominal wall, to examine the inside of the abdomen.

Laparotomy

A surgical incision made in the wall of the abdomen.

Lingual tonsil

Lymphoid tissue located at the base of the tongue.

Lymphoid

Referring to lymphocytes or tissue in which lymphocytes develop.

Melena

Black, tarry feces containing blood.

Nasal cavity

The inside of your nose.

Nasogastric

Describes the passage from the nose to the stomach.

Nausea

A feeling of sickness or discomfort in the stomach that may come with an urge to vomit.

Obesity

A common, chronic disease marked by an abnormally high, unhealthy amount of body fat.

Omentum

A fold of the peritoneum (the thin tissue that lines the abdomen) that surrounds the stomach and other organs in the abdomen.

Oral

By or pertaining to the mouth.

Palatine tonsils

A pair of soft tissue masses located at the rear of the throat (pharynx).

Palpation

Examination by pressing on the surface of the body to feel the organs or tissues underneath.

Pancreatic

Pertaining to the pancreas.

Pancreatitis

Inflammation of the pancreas.

Peritoneal

Having to do with the parietal peritoneum (the tissue that lines the abdominal wall and pelvic cavity) and visceral peritoneum (the tissue that covers most of the organs in the abdomen, including the intestines).

Peritonitis

Inflammation of the peritoneum.

Polyp

A growth that protrudes from a mucous membrane.

Polypectomy

Excision of polyps.

Polyposis

The development of numerous polyps.

Proctoscope

A thin, tube-like instrument used to look inside the anus and rectum.

Proctoscopy

A procedure that uses a proctoscope to look inside the anus and rectum.

Proximal

A position in a limb that is nearer to the point of attachment or the trunk of the body.

Pyloric sphincter

A band of smooth muscle at the junction between the pylorus of the stomach and the duodenum of the small intestine.

Pyloromyotomy

Incision into the pyloric muscle (used to correct pyloric stenosis).

Rectal

By or pertaining to the rectum.

Rectocele

Herniation of the rectum into the vagina.

Reflux

The backward flow of liquid from the stomach into the esophagus.