8. Obstetrics

Learning Objectives

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

Obstetric Word Parts

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

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Introduction to Obstetrics

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

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Media 8.1. Reproductive System, Part 4 – Pregnancy & Development: Crash Course A&P #43 [Online video]. Copyright 2015 by CrashCourse.

Obstetrics Medical Terms

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Fertilization

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

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

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

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

Stages of Childbirth

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

- cervical dilation
- expulsion of the newborn
- after birth

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

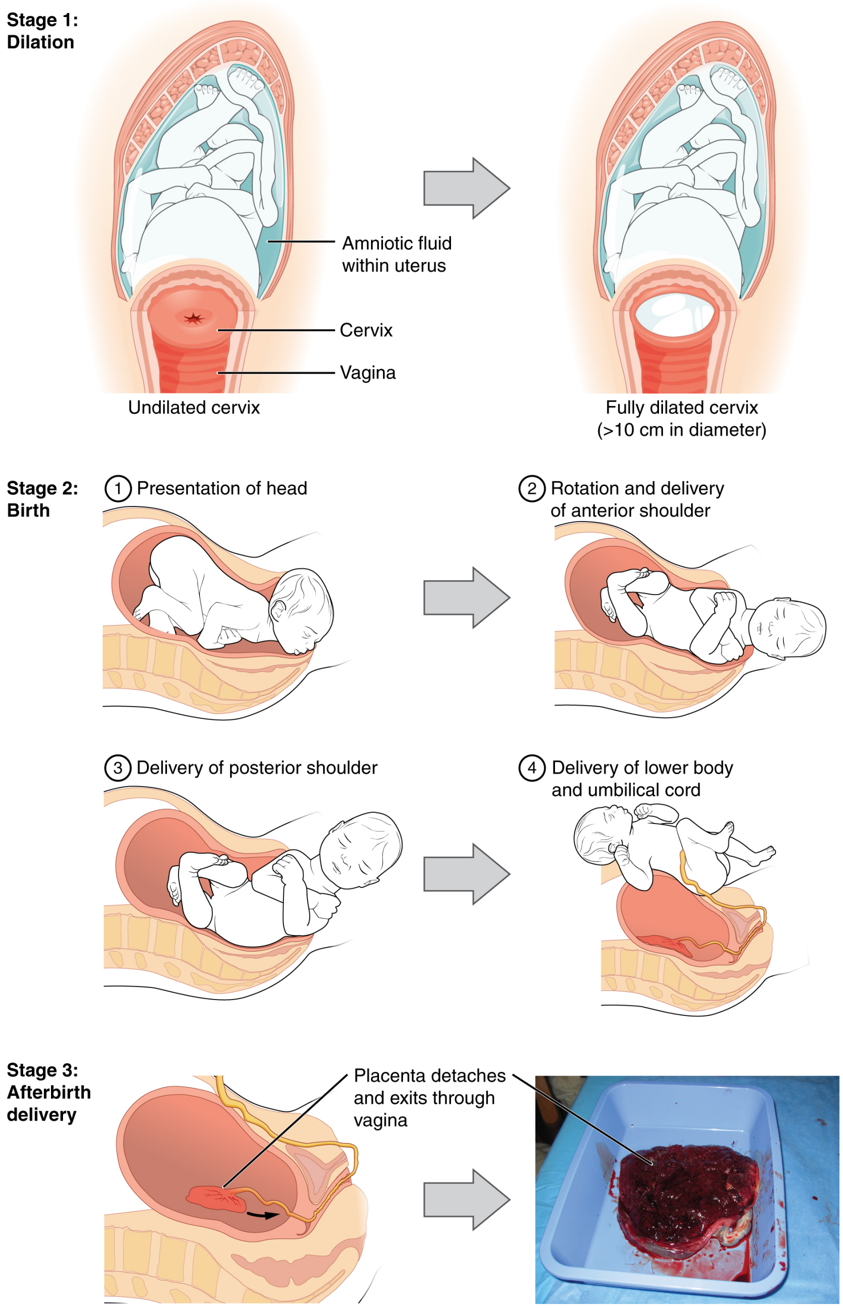

Figure 8.1 Stages of Childbirth. The stages of childbirth include Stage 1, early cervical dilation; Stage 2, full dilation and expulsion of the newborn; and Stage 3, delivery of the placenta and associated fetal membranes. (The position of the newborn's shoulder is described relative to the mother).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

Concept Check

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

Homeostasis in the Newborn: Apgar Score

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

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

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

APGAR Evaluation of newborn infants

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

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

*Response to catheter in nostrils

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

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

Obstetrics Medical Terms not Easily Broken into Word Parts

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Obstetrics Abbreviations

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Medical Terms in Context

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Procedures Related to Obstetrics

In Vitro Fertilization (IVF)

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

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

Test Yourself

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https://nicoletcollege.pressbooks.pub/ltcmedicalterminology/?p=90#h5p-54

References

[CrashCourse]. (2019, November 23). *Reproductive System, Part 4 – Pregnancy & Development: Crash Course A&P #43* [Video]. YouTube. https://youtu.be/BtsSbZ85yiQ

9. Cardiovascular System – Heart

WTCS Learning Objectives

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

Cardiovascular System – Heart Word Parts

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

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Introduction to the Heart

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

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](#).

Cardiovascular System – Heart Medical Terms

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Anatomy of the Heart

Location

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

Concept Check

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

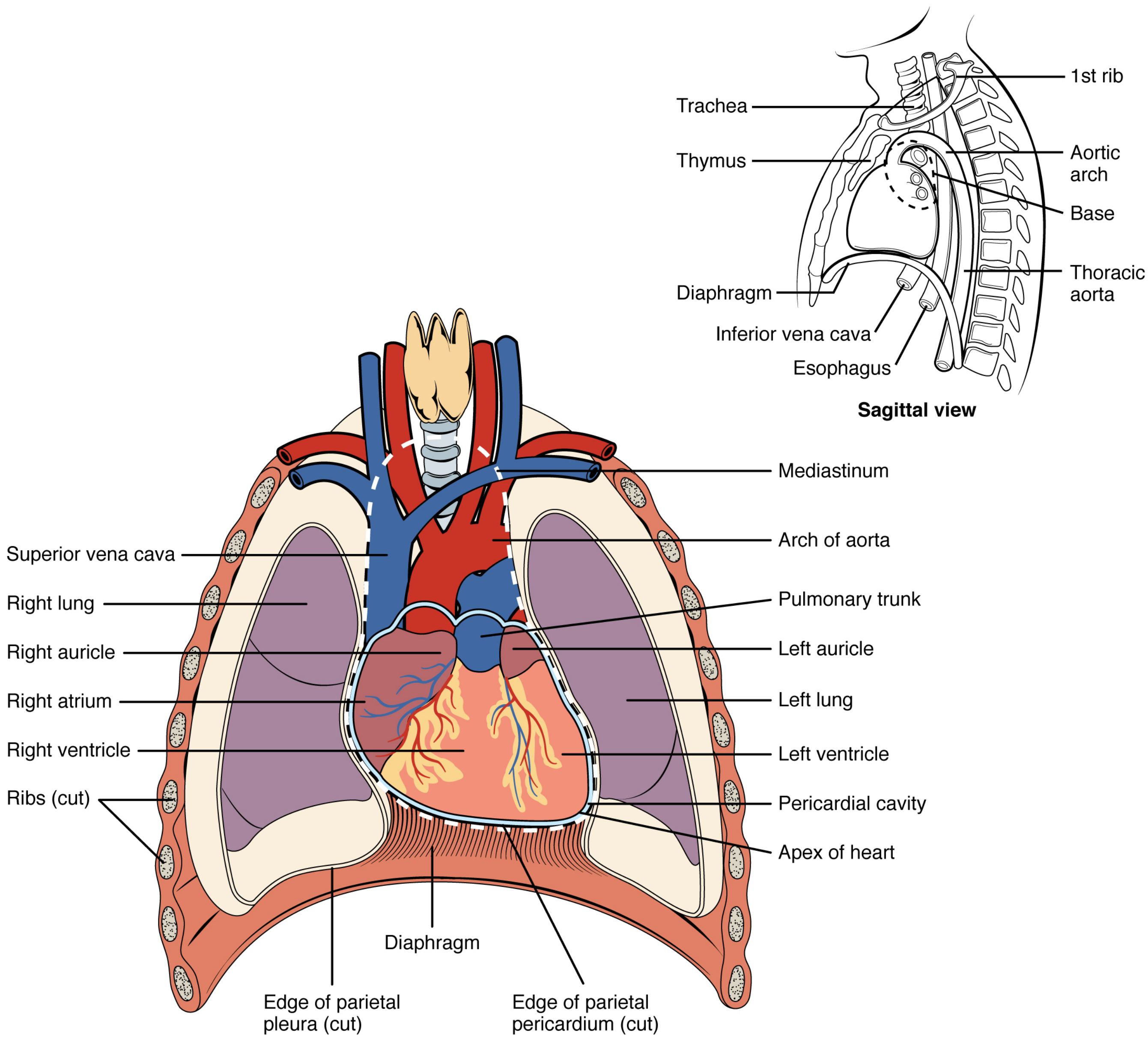

Figure 9.1. Position of the Heart in the Thorax. The heart is located within the thoracic cavity, medially between the lungs in the mediastinum. It is about the size of a fist, is broad at the top, and tapers toward the base. From Betts, et al., 2021. Licensed under [CC BY 4.0](#).

Membranes and Layers of the Heart Walls

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

- The sturdy outer fibrous pericardium is made of tough, dense connective tissue that protects the heart and holds it in position.
- Separated by the **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 is the **myocardium** layer is thicker than the **endocardium** layer?

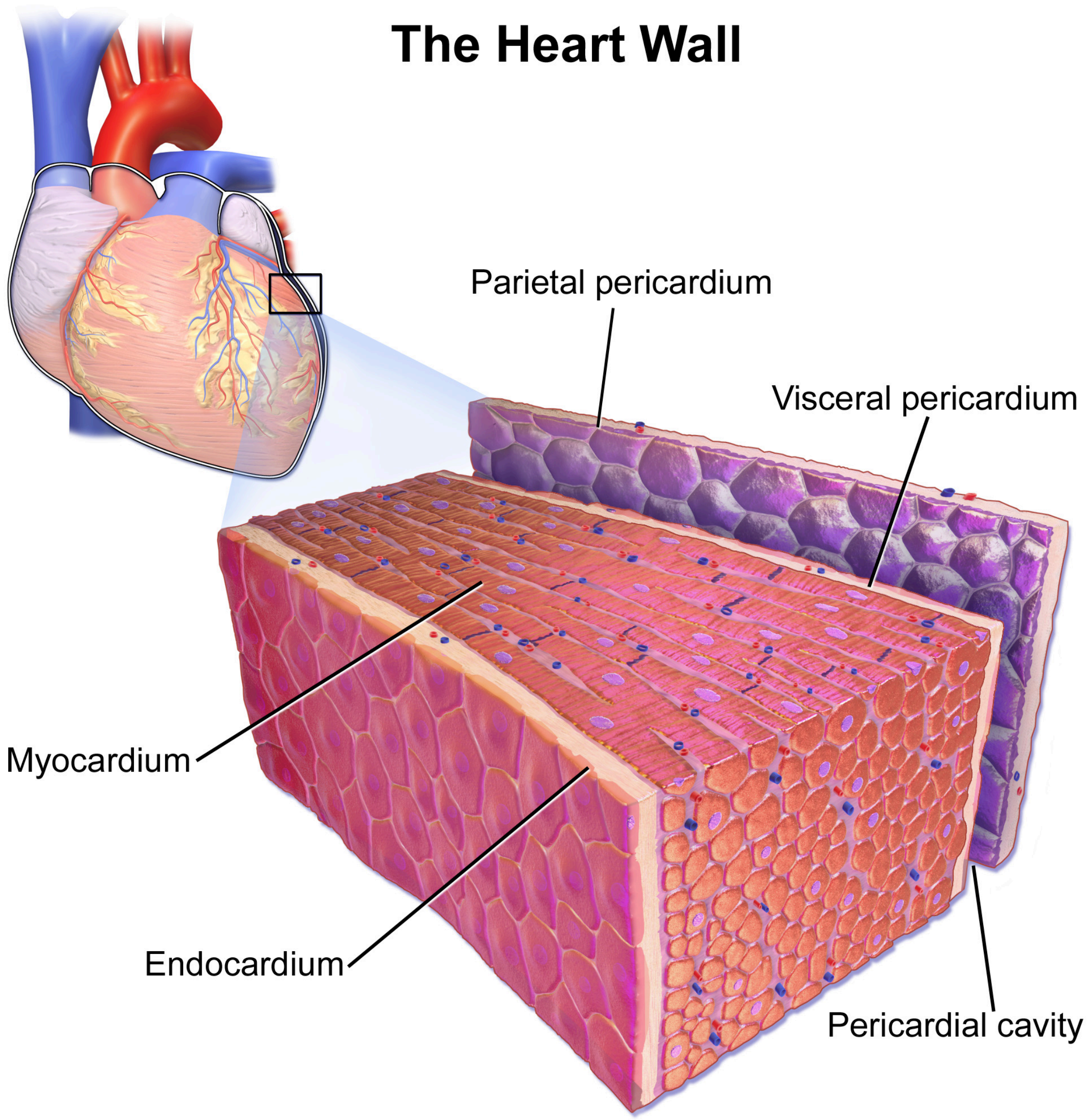

Figure 9.2. Layers of the Heart Wall. The pericardial membrane that surrounds the heart consists of three layers and the pericardial cavity. The heart wall also consists of three layers. The pericardial membrane and the heart wall share the epicardium From [Blausen, 2014](). Licensed under CC BY 3.0.

Internal Structures of the Heart

The heart consists of four chambers:

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

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

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

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

There are also two semilunar valves:

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

Anatomy Labeling Activity

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Physiology of the Heart

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

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

Circulation Through the Heart: The Heart as a Pump

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

Did You Know?

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

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

Pulmonary Circuit

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

Concept Check

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

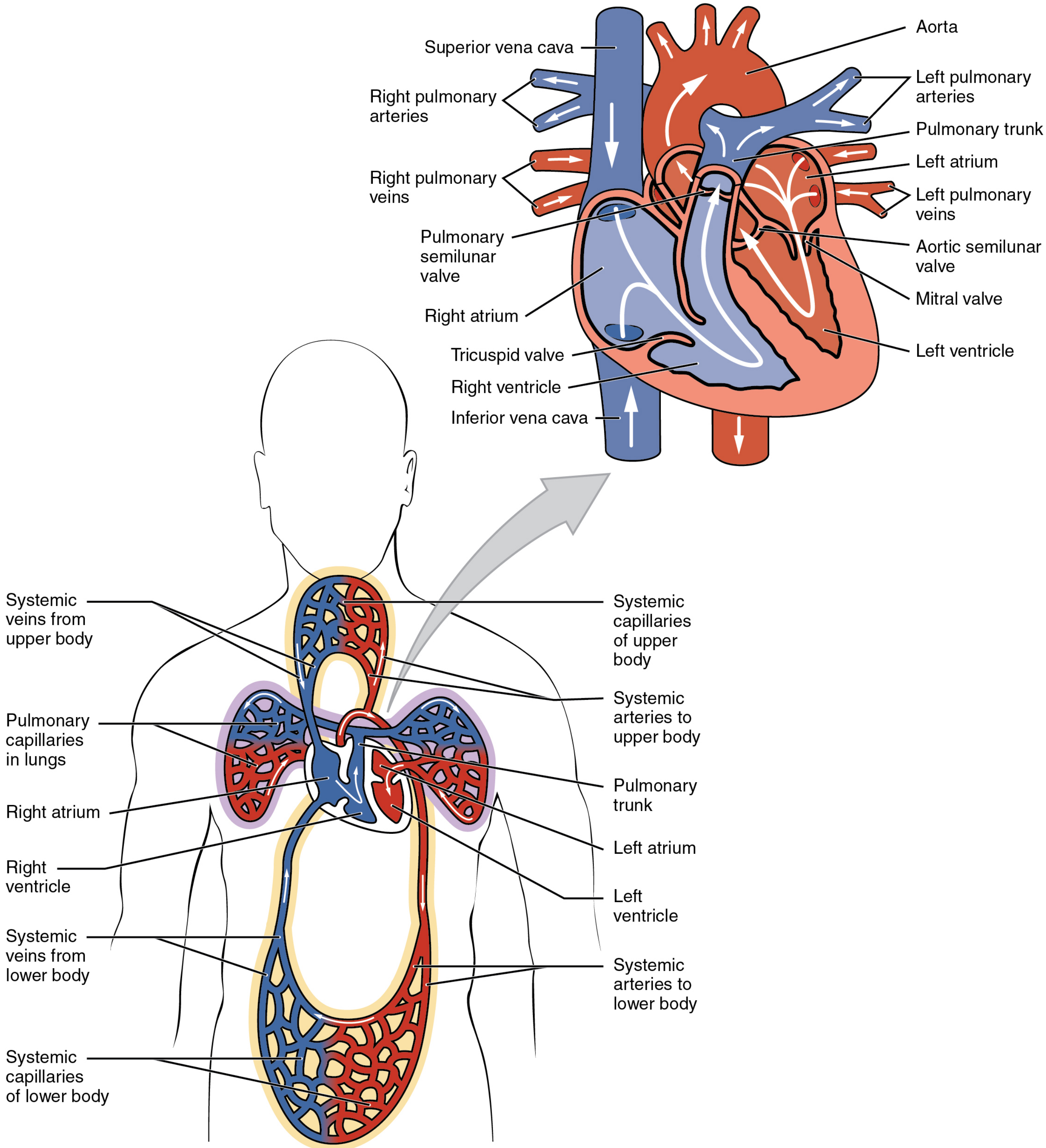

Figure 9.3. Dual System of the Human Blood Circulation. Blood flows from the right atrium to the right ventricle, where it is pumped into the pulmonary circuit. The blood in the pulmonary artery branches is low in oxygen but relatively high in carbon dioxide. Gas exchange occurs in the pulmonary capillaries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

Cardiac Cycle

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

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

Heart Terms not Easily Broken into Word Parts

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Heart Abbreviations

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

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Diseases and Disorders

Cardiomyopathy

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

Other types of cardiomyopathy include:

- **Dilated cardiomyopathy**, which also has an unknown cause and is seen in people of any age. In this disorder, one of the ventricles of the heart is larger than normal.

- **Arrhythmogenic cardiomyopathy**, an inherited condition which results in irregular heart rhythms.
- **Restrictive cardiomyopathy**, which is a complication of other conditions which cause the myocardium to scar or stiffen (Centers for Disease Control and Prevention, 2019).

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

Heart Failure

Heart failure is defined as the inability of the heart to pump enough blood to meet the needs of the body. It is also called **congestive heart failure (CHF).** This condition causes swelling in the lower extremities and shortness of breath, due to a buildup of fluid in the lungs. It may be caused by cardiomyopathy and it may lead to **hypertension** and heart valve disorders (Heart & Stroke, n.d.). To learn more, visit the Heart & Stroke's congestive heart failure web page.

Valvular Heart Disease

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

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

Concept check

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

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

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

Aneurysms

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

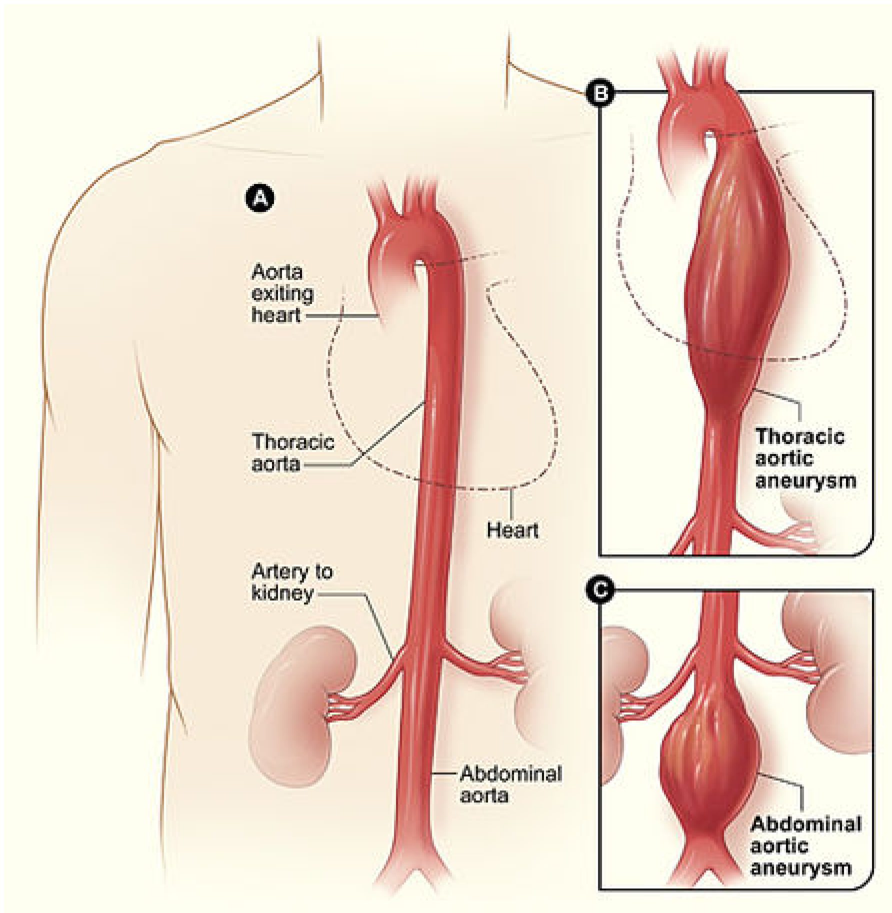

Figure 9.4 Arteries of the Thoracic and Abdominal Regions. The thoracic aorta gives rise to the arteries of the visceral and parietal branches. (Picture: Wikimedia. Aortic aneurysm)

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

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

Heart Defects

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

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

- **Patent ductus arteriosus** is a congenital condition in which the ductus arteriosus fails to close. If untreated, the condition can result in congestive heart failure.
- **Patent foramen ovale** is one type of atrial septal defect (ASD), due to a failure of the hole in the **interatrial septum** to close at birth.
  - As much as 20 – 25 percent of the general population may have a patent foramen ovale, most have the benign, asymptomatic version but in extreme cases a surgical repair is required to close the opening permanently.
- **Tetralogy of Fallot** is a congenital condition that may also occur from exposure to unknown environmental factors; it occurs when there is an opening in the **interventricular septum** caused by blockage of the pulmonary trunk, normally at the pulmonary semilunar valve. This allows blood that is relatively low in oxygen from the right ventricle to flow into the left ventricle and mix with the blood that is relatively high in oxygen.
  - Symptoms include a distinct heart murmur, low blood oxygen percent saturation, **dyspnea**, **polycythemia**, **clubbing of the fingers and toes**, and in children, difficulty in feeding or failure to grow and develop.
  - It is the most common cause of **cyanosis** following birth. Other heart defects may also accompany this condition, which is typically confirmed by **echocardiography** imaging.
- In the case of severe septal defects, including both tetralogy of fallot and patent foramen ovale, failure of the heart to develop properly can lead to a condition commonly known as a **blue baby.** Regardless of normal skin pigmentation, individuals with this condition have an insufficient supply of oxygenated blood, which leads to **cyanosis**, especially when active (Betts, et al., 2021).

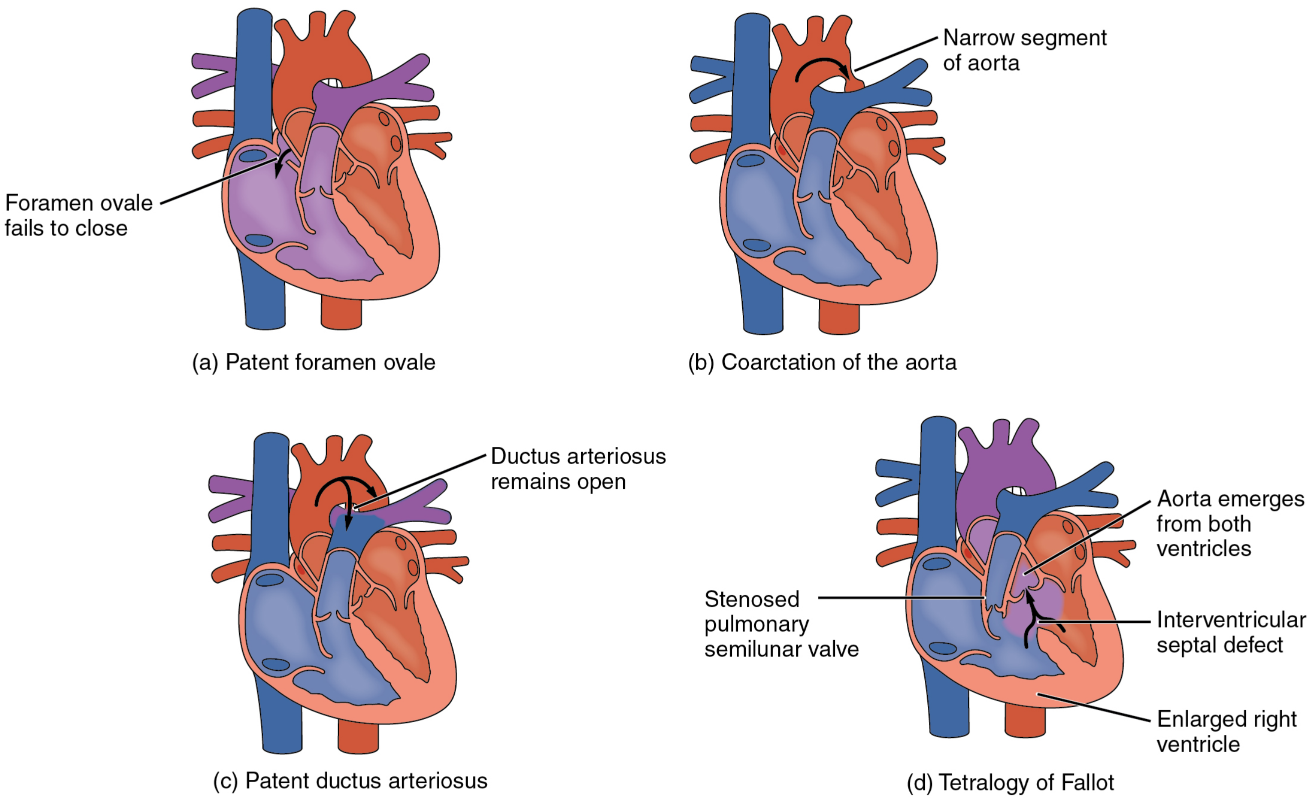

Figure 9.5. Congenital Heart Defects. (a) A patent foramen ovale defect is an abnormal opening in the interatrial septum, or more commonly, a failure of the foramen ovale to close. (b) Coarctation of the aorta is an abnormal narrowing of the aorta. (c) A patent ductus arteriosus is the failure of the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

Diseases of the Coronary Circulation

Coronary Artery Disease (CAD)

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

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

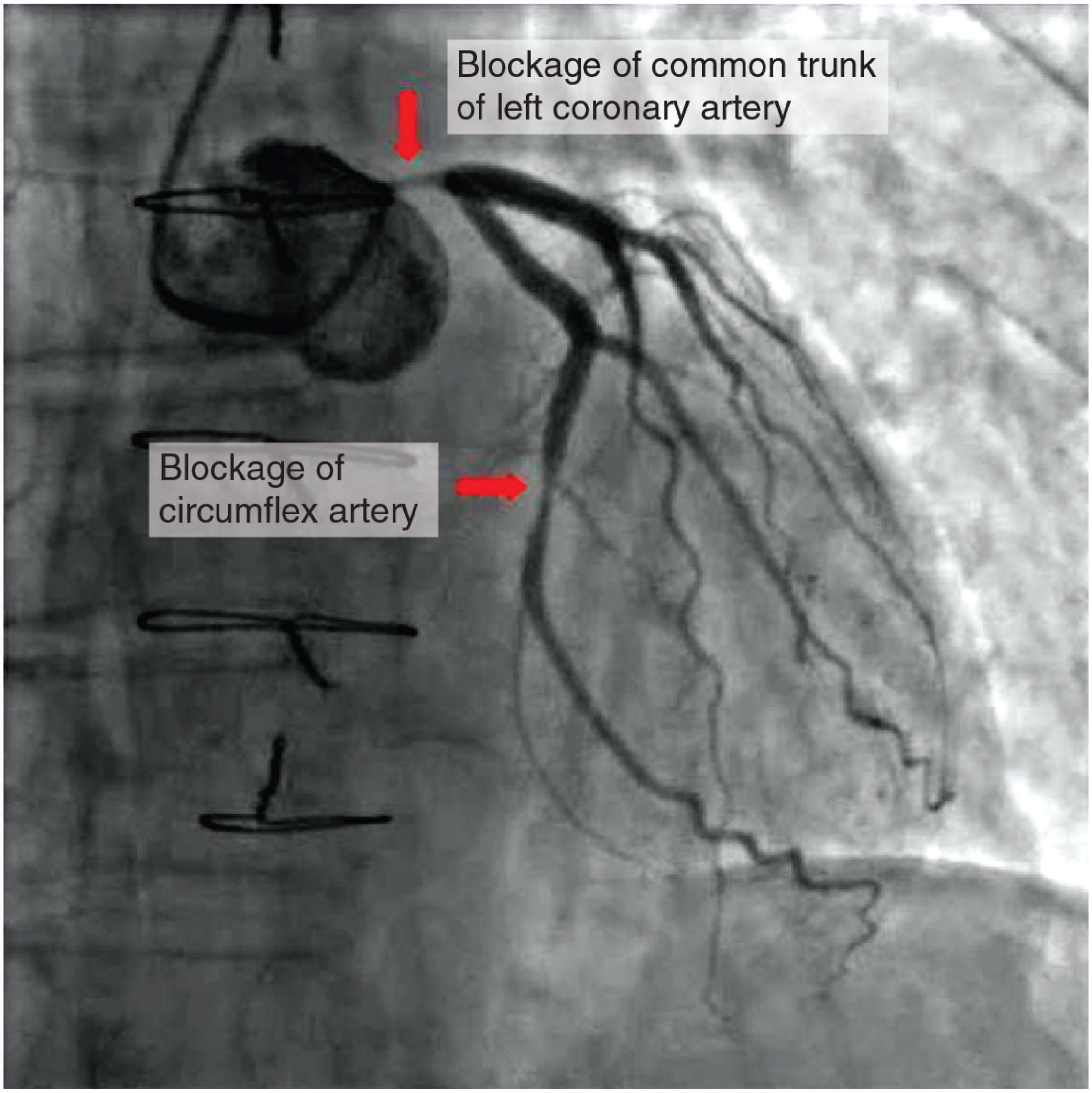

Figure 9.6. Angiogram of Atherosclerotic Coronary Arteries. In this coronary angiogram (X-ray), the dye makes visible two occluded coronary arteries. Such blockages can lead to decreased blood flow (ischemia) and insufficient oxygen (hypoxia) delivered to the cardiac tissues. If uncorrected, this can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

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

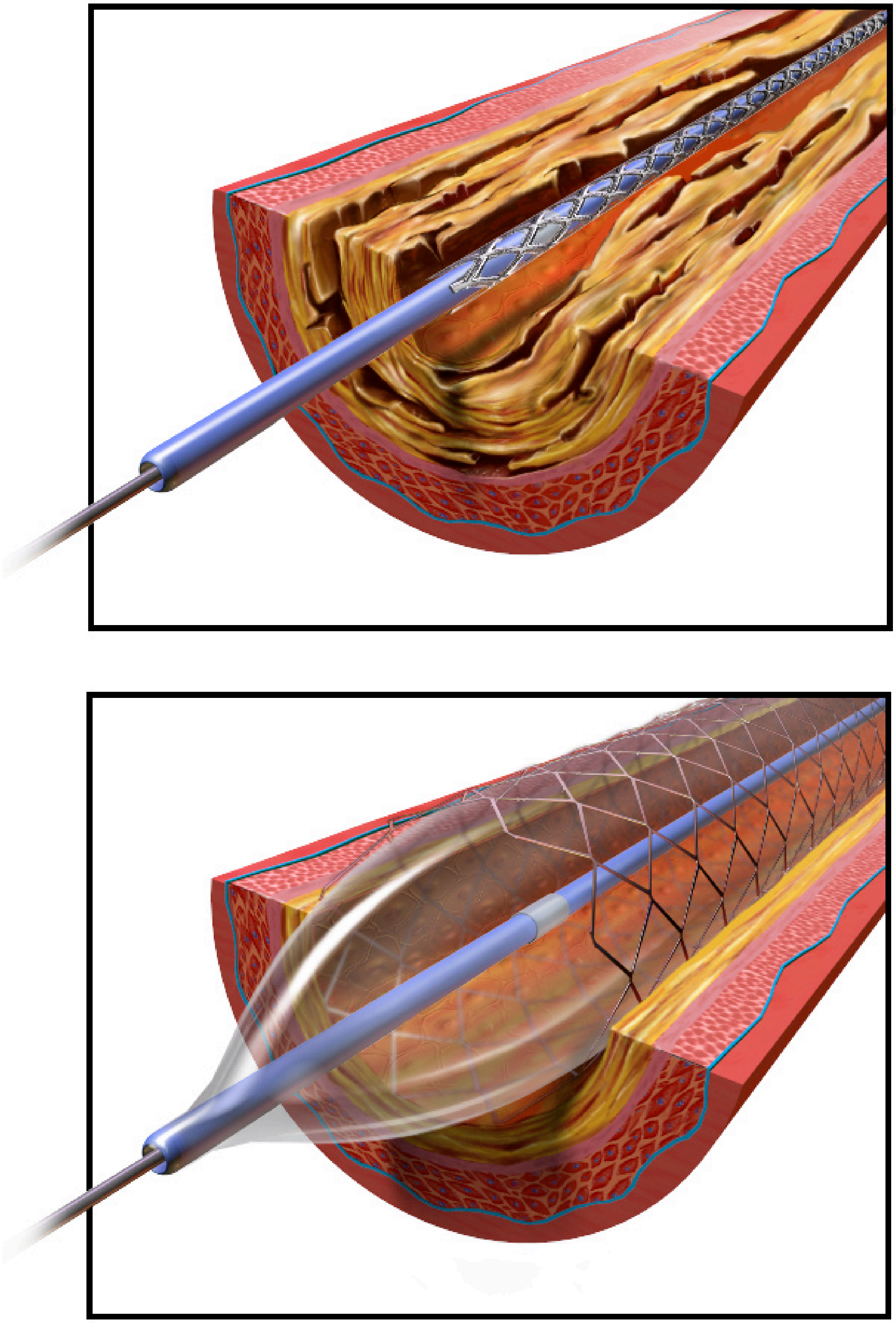

Figure 9.7 Angioplasty-Before and after image of Balloon Inflated with Stent From Blausen, 2014. Licensed under CC BY 3.0.

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

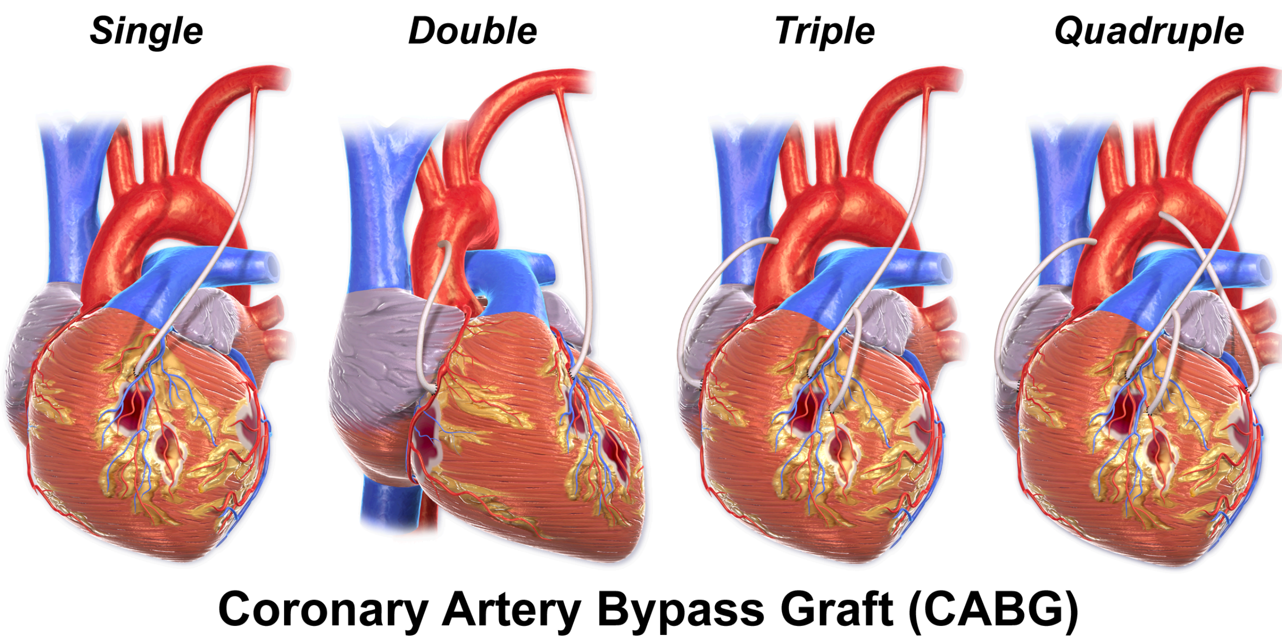

Figure 9.8 Single, Coronary Artery Bypass Graft (CABG). Double, Triple and Quadruple Bypass Image. From Blausen, 2014. Licensed under CC BY 3.0. BY 3.0.

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

Myocardial Infarction

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

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

Did you know?

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

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

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

Other diagnostic tests include:

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

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

Diseases of the (Electrical) Conduction System

Arrhythmia

Did you know?

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

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

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

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

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

too fast, too slow or just irregular.

Abnormal Heart Rates

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

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

Heart Block

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

Medical Terms in Context

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Medical Specialties and Procedures Related to the Heart

Cardiologists and Cardiovascular Surgeons

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

Cardiology Technologists

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

Cardiovascular Perfusionists

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

Test Yourself

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perfusionist/#:~:text=Cardiovascular%20perfusionists%20are%20responsible%20for,patient's%20circulatory%20or%20respiratory%20function
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10. Cardiovascular System – Blood Vessels and Blood

WTCS Learning Objectives

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

Blood Vessels and Blood Word Parts

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

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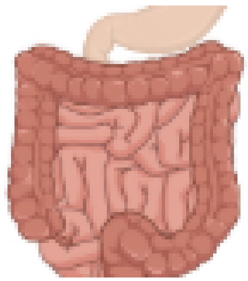
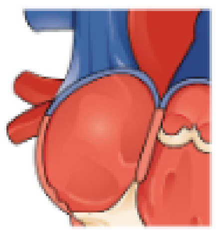
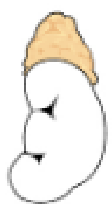
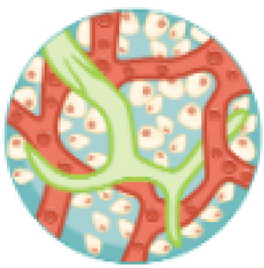
Introduction to the Blood Vessels and Blood

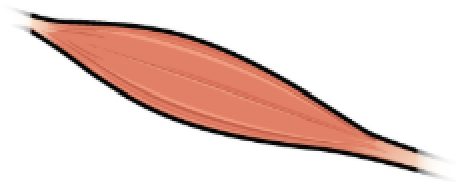
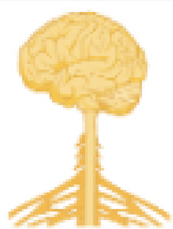
Our large, complex bodies need blood to deliver nutrients to and remove wastes from our trillions of cells. The heart, as discussed in the previous chapter, pumps blood throughout the body in a network of blood vessels. Together, these three components—blood, heart, and vessels—makes up the cardiovascular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

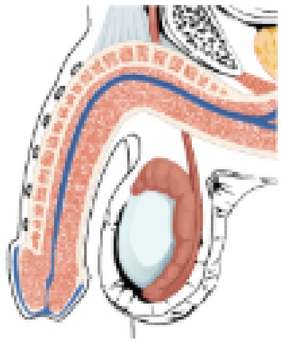
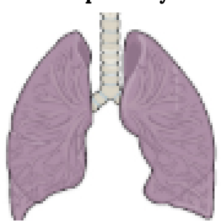
Virtually every cell, tissue, organ, and system in the body is impacted by the circulatory system. This includes the generalized and more specialized functions of transport of materials, capillary exchange, maintaining health by transporting white blood cells and various immunoglobulins (antibodies),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

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

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Digestive  *Digestive System*	Absorbs nutrients and water; delivers nutrients (except most lipids) to liver for processing by hepatic portal vein; provides nutrients essential for hematopoiesis and building hemoglobin.
Endocrine   *Endocrine System*	Delivers hormones: atrial natriuretic hormone (peptide) secreted by the heart atrial cells to help regulate blood volumes and pressures; epinephrine, ANH, angiotensin II, ADH, and thyroxine to help regulate blood pressure; estrogen to promote vascular health in women and men.

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Integumentary  *Integumentary System*	Carries clotting factors, platelets, and white blood cells for hemostasis, fighting infection, and repairing damage; regulates temperature by controlling blood flow to the surface, where heat can be dissipated; provides some coloration of integument; acts as a blood reservoir.
Lymphatic  *Lymphatic System*	Transports various white blood cells, including those produced by lymphatic tissue, and immunoglobulins (antibodies) throughout the body to maintain health; carries excess tissue fluid not able to be reabsorbed by the vascular capillaries back to the lymphatic system for processing.

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Muscular  *Muscular System*	Provides nutrients and oxygen for contraction; removes lactic acid and distributes heat generated by contraction; muscular pumps aid in venous return; exercise contributes to cardiovascular health and helps to prevent atherosclerosis.
Nervous  *Nervous System*	Produces cerebrospinal fluid (CSF) within choroid plexuses; contributes to blood-brain barrier; cardiac and vasomotor centers regulate cardiac output and blood flow through vessels via the autonomic system.

SYSTEM	ROLE OF CIRCULATORY SYSTEM
Reproductive  *Reproductive System*	Aids in erection of genitalia in both sexes during sexual arousal; transports gonadotropic hormones that regulate reproductive functions.
Respiratory  *Respiratory System*	Provides blood for critical exchange of gases to carry oxygen needed for metabolic reactions and carbon dioxide generated as byproducts of these processes.

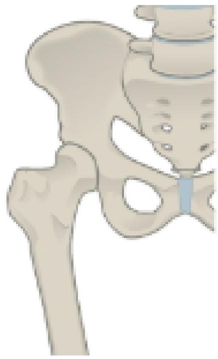
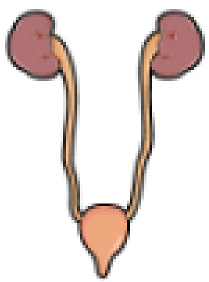
SYSTEM	ROLE OF CIRCULATORY SYSTEM
Skeletal  *Skeletal System*	Provides calcium, phosphate, and other minerals critical for bone matrix; transports hormones regulating buildup and absorption of matrix including growth hormone (somatotropin), thyroid hormone, calcitronins, and parathyroid hormones; erythropoietin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

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

Watch this video:

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

Cardiovascular System – Blood Vessels and Blood Medical Terms

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Anatomy of the Blood Vessels

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

- **Arteries** transport blood away from the heart and branch into smaller vessels, forming arterioles.
- **Arterioles** distribute blood to capillary beds, the sites of exchange with the body tissues.
- A **capillary** is a microscopic channel that supplies blood to the tissues themselves, a process called **perfusion.**
    - Exchange of gases and other substances occurs in the capillaries between the blood and the surrounding cells and their tissue fluid (interstitial fluid).
    - For capillaries to function, their walls must be leaky, allowing substances to pass through.
    - Capillaries lead back to small vessels known as **venules.**
- **Venules** are small **veins** that converge into larger veins.
- A **vein** is a blood vessel that conducts blood toward the heart

- Compared to arteries, veins are thin-walled vessels with large and irregular lumens
- Larger veins are commonly equipped with valves that promote the unidirectional flow of blood toward the heart and prevent backflow toward the capillaries caused by the inherent low blood pressure in veins as well as the pull of gravity
- Other ways in which the body assists the transport of venous blood back to the heart involve contractions of skeletal muscles in the extremities (see figure below), as well as pressure variations caused by breathing motion in the chest.

Concept Check

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

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

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

CHARACTERISTIC	ARTERIES	VEINS
Direction of blood flow	Conducts blood away from the heart	Conducts blood toward the heart
General appearance	Rounded	Irregular, often collapsed
Pressure	High	Low
Wall thickness	Thick	Thin
Relative oxygen concentration	Higher in systemic arteries Lower in pulmonary arteries	Lower in systemic veins Higher in pulmonary veins
Valves	Not present	Present most commonly in limbs and in veins inferior to the heart

The Major Arteries and Veins in the Human Body

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

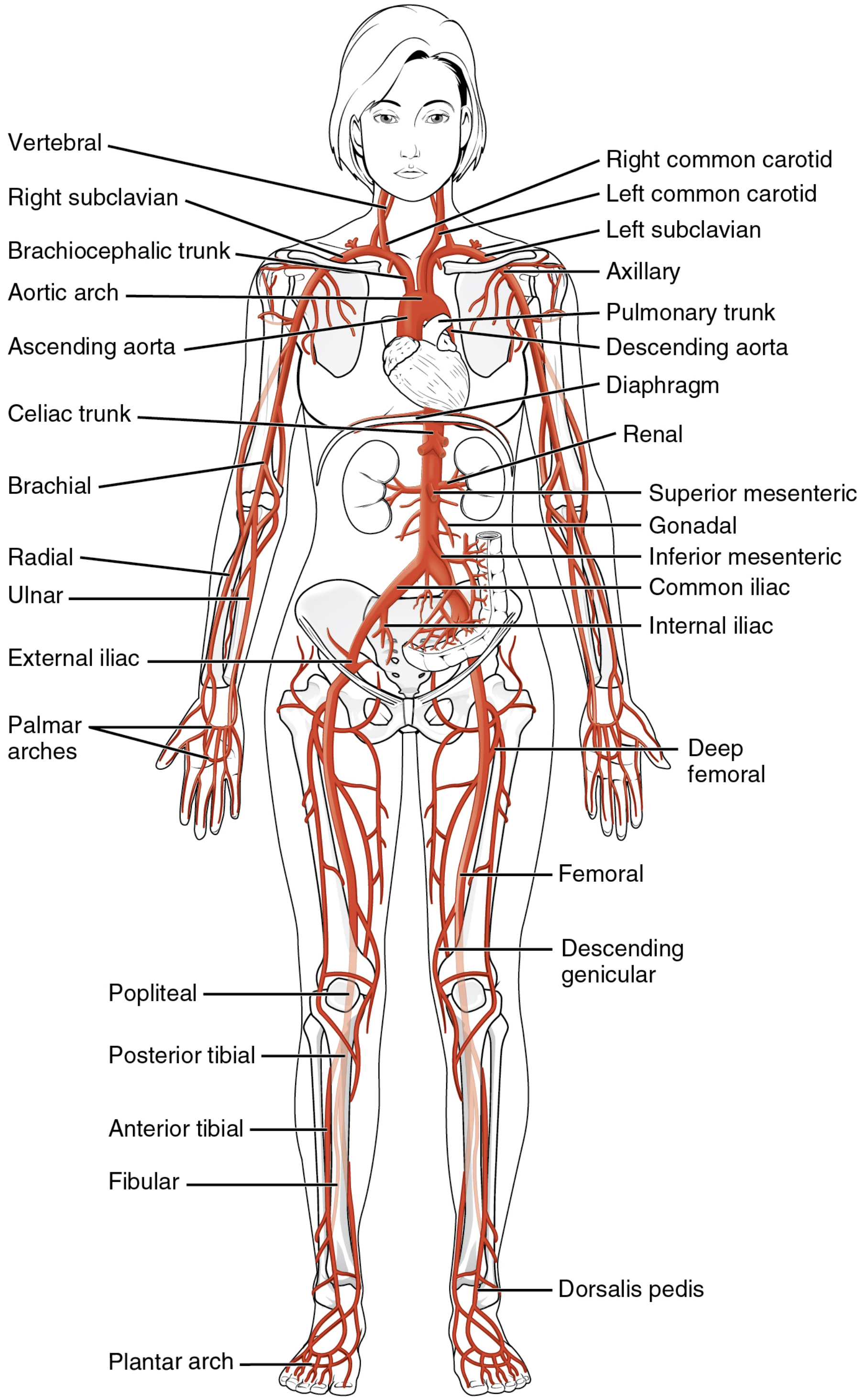


Figure 10.1 Systemic Arteries. The major systemic arteries shown here deliver oxygenated blood throughout the body. From Betts, et al., 2021. Licensed under [CC BY 4.0](#).

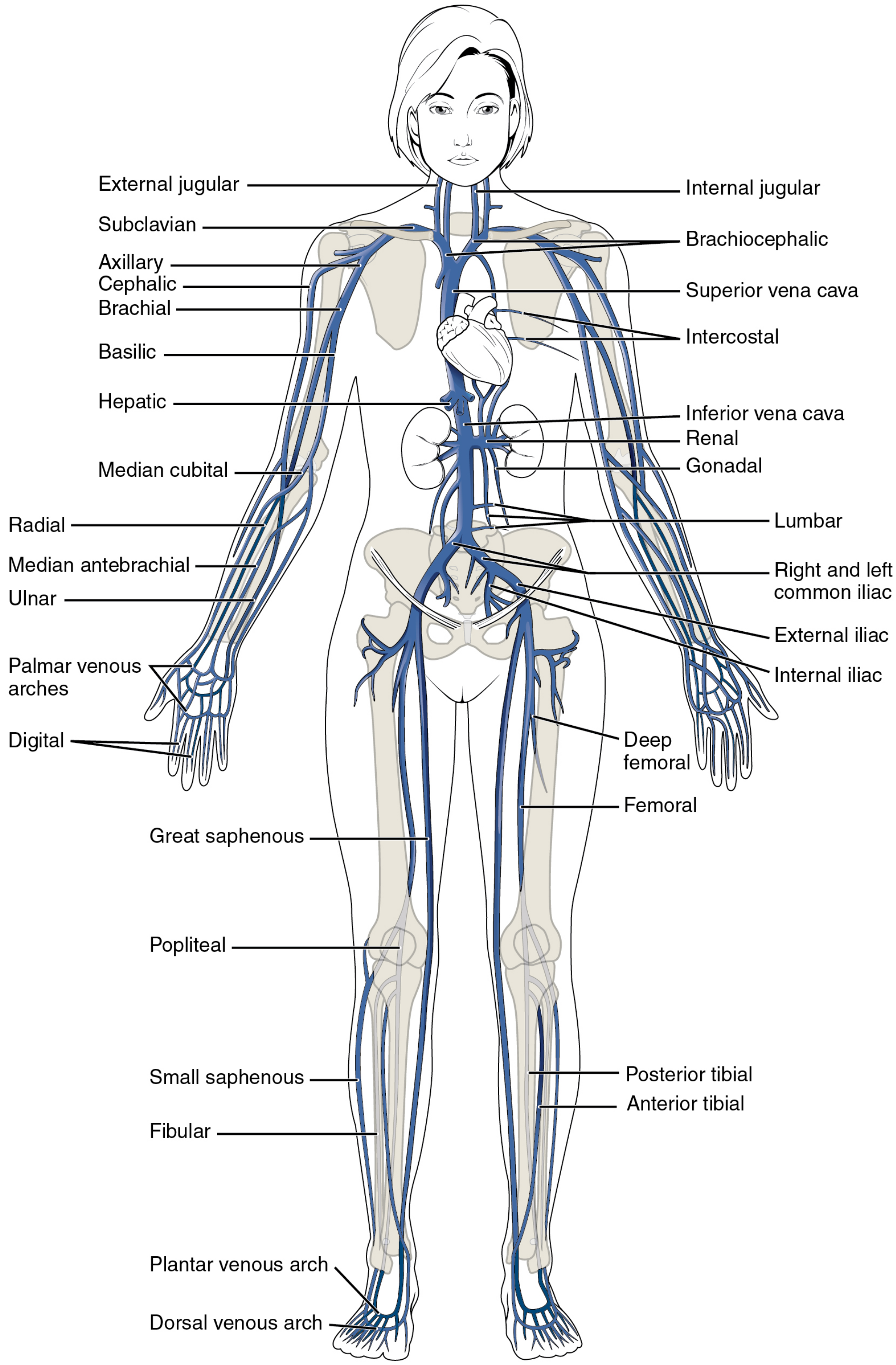


Figure 10.2 Major Systemic Veins of the Body. The major systemic veins of the body are shown here in an anterior view. From Betts, et al., 2021. Licensed under [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Concept Check

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

Physiology of the Blood Vessels

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

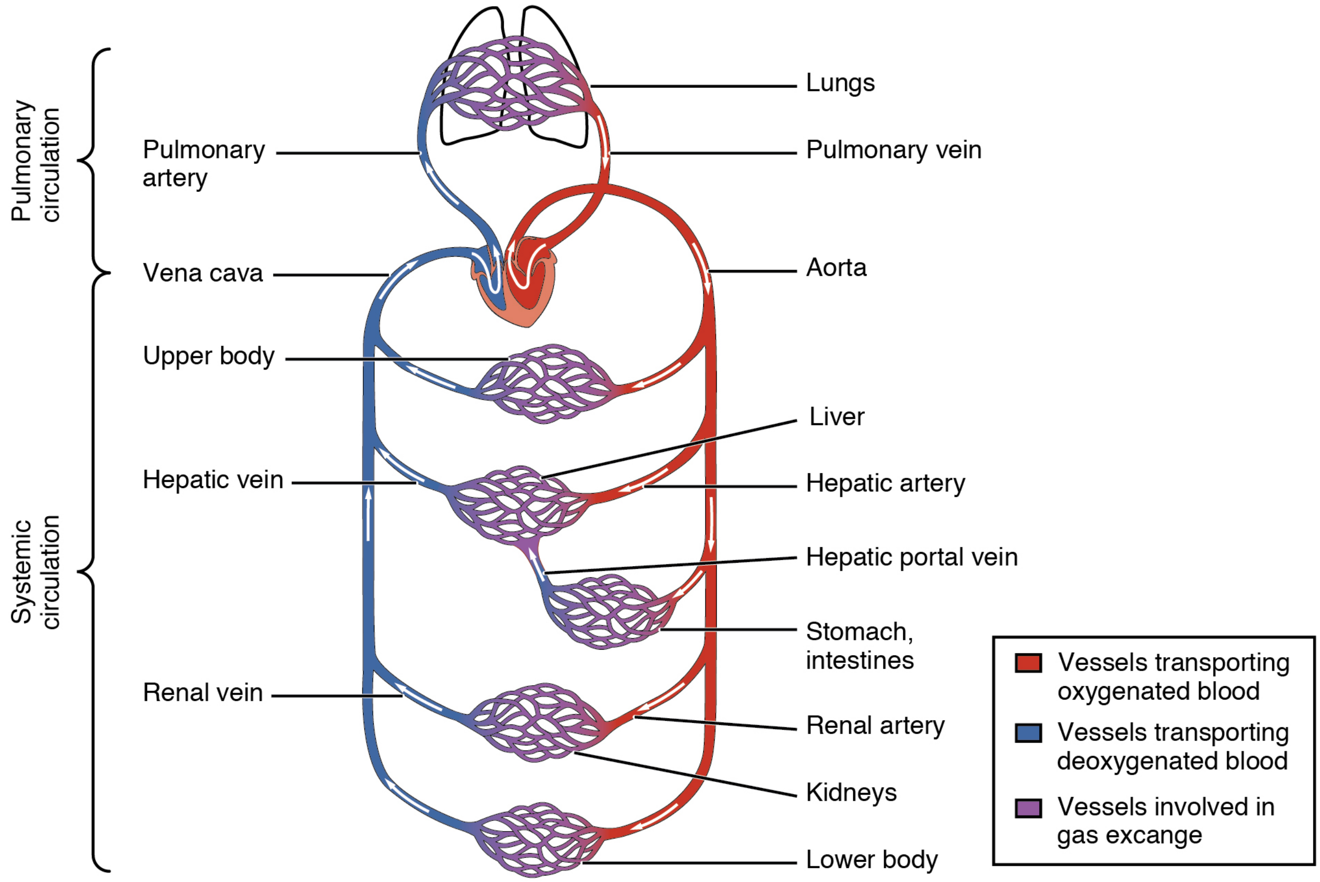


Figure 10.3 Cardiovascular Circulation. The pulmonary circuit moves blood from the right side of the heart to the lungs and back to the heart. The systemic circuit moves blood from the left side of the heart to the head and body and returns it to the right side of the heart to repeat the cycle. The arrows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

Blood Pressure

Blood pressure is the force exerted by blood upon the walls of the blood vessels or the chambers of the heart. Blood pressure may be measured in capillaries and veins, as well as the vessels of the pulmonary circulation; however, the general term 'blood pressure' refers to the pressure of blood flowing in the arteries of the systemic circulation. Blood pressure is one of the critical parameters measured on virtually every patient in every healthcare setting.
The technique used today was developed more than 100 years ago by a pioneering Russian physician, Dr. Nikolai Korotkoff. Turbulent blood flow through the vessels can be heard as a soft ticking while measuring blood pressure; these sounds are known as **Korotkoff sounds**. Blood pressure is measured in mm Hg and is usually obtained from the **brachial artery** using a **sphygmomanometer** and a stethoscope. Blood pressure is recorded as **systolic pressure** over **diastolic pressure.**

Did You Know?

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

Five variables influence blood flow and blood pressure:

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

Pulse

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

Both the rate and the strength of the pulse are important clinically. A high or irregular pulse rate can be caused by physical activity or other temporary factors, but it may also indicate a heart condition. The pulse strength indicates the strength of ventricular contraction and cardiac output. If the pulse is strong, then systolic pressure is high. If it is weak, systolic pressure has fallen, and medical intervention may be warranted.

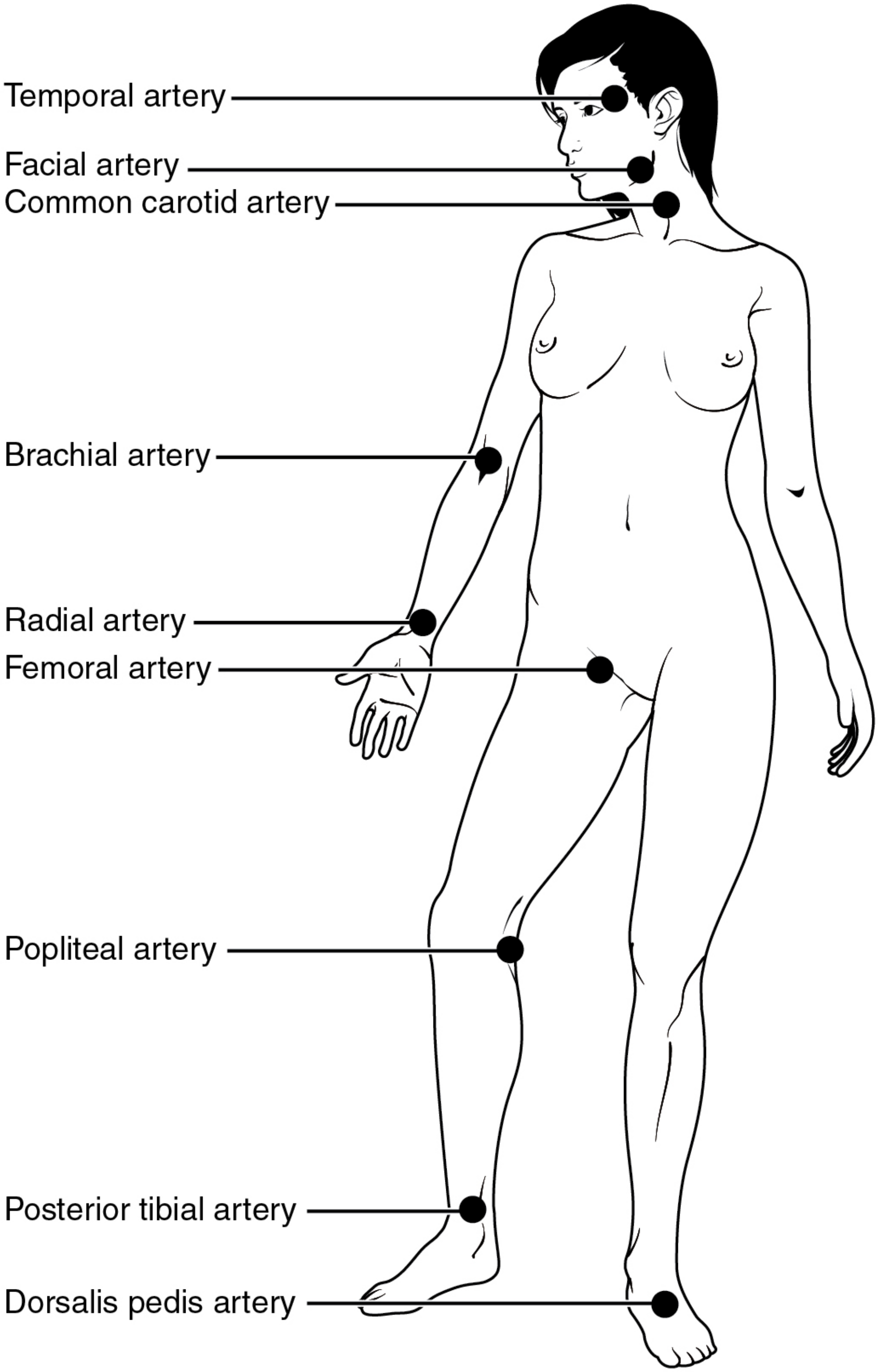


Figure 10.4 Pulse Sites. The pulse is most readily measured at the radial artery, but can be measured at any of the pulse points shown. From Betts, et al., 2021. Licensed under [CC BY 4.0]().

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

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

Did You Know?

Blood constitutes approximately 8% of adult body weight.

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

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

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

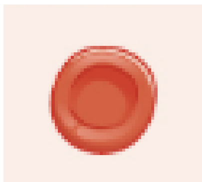
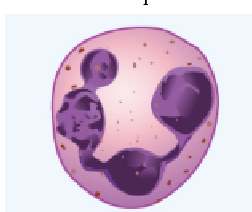
Blood Plasma

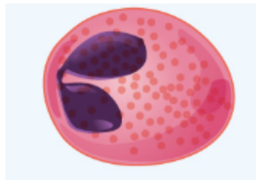
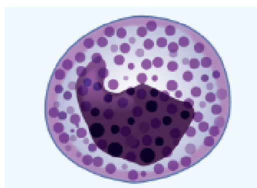
Like other fluids in the body, plasma is composed primarily of water. In fact, it is about 92% water. Dissolved or suspended within this water is a mixture of substances, most of which are proteins. The major components of plasma and their functions are summarized in the table below.

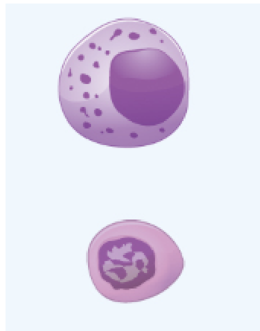
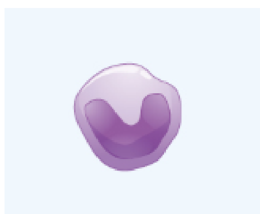
Formed Elements (Erythrocytes, Leukocytes, Thrombocytes)

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

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

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (μL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
Erythrocytes (red blood cells)  *Red Blood Cell*	n/a	5.2 million (4.4-5.0 million)	Flattened biconcave disk; no nucleus; pale red colour	Transport oxygen and some carbon dioxide between tissues and lungs	Lifespan of approximately 120 days
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  *Platelete Cells*	n/a	350,000 (150,000 – 500,000)	Cellular fragments surrounded by a plasma membrane and containing granules; purple stain	Hemostasis plus release growth factors for repair and healing of tissue	Formed from megakaryocytes that remain in the red bone marrow and shed platelets into circulation

Erythrocytes

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

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

Leukocytes

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

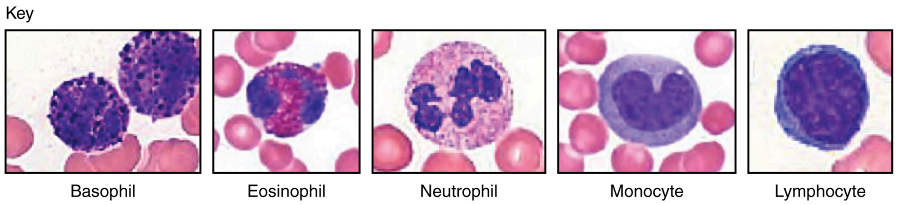


Figure 10.7 Leukocytes. (Micrographs provided by the Regents of University of Michigan Medical School © 2012). From Betts, et al., 2021. Licensed under [CC BY 4.0.](#)

Concept Check

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

Lymphocytes

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

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

Platelets

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

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

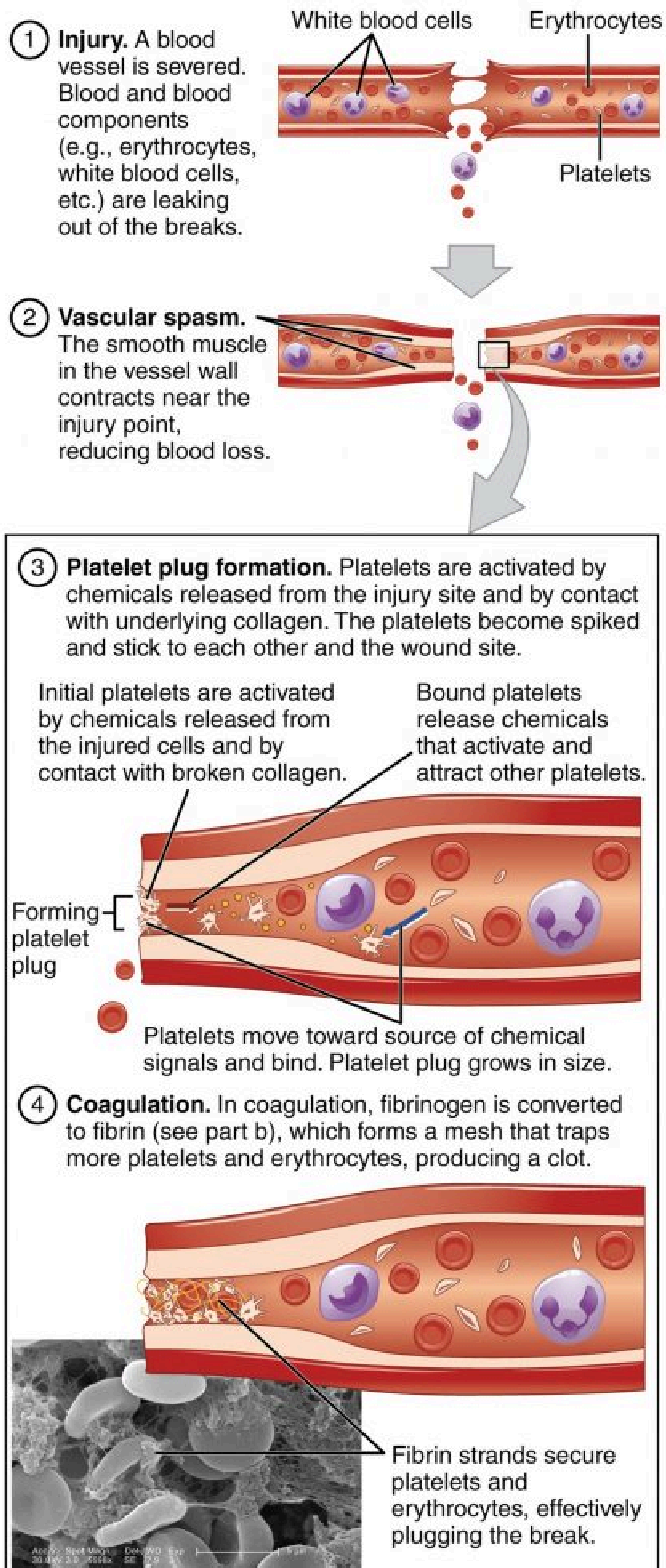

1 Injury. A blood vessel is severed. Blood and blood components (e.g., erythrocytes, white blood cells, etc.) are leaking out of the breaks.
White blood cells
Erythrocytes
Platelets
2 Vascular spasm. The smooth muscle in the vessel wall contracts near the injury point, reducing blood loss.
3 Platelet 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.
Forming platelet plug
Platelets move toward 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.
Fibrin strands secure platelets and erythrocytes, effectively plugging the break.

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

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

Concept Check

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

Physiology of Blood

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

Transportation

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

Defense

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

Homeostasis

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

Concept Check

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

- Hemostasis
- Homeostasis
- Hematopoiesis

Blood Types

In order to understand blood types, it is important to understand several terms that relate to the body's **immune** functions (discussed in detail in the next chapter)

- **Antigens** are substances that the body does not recognize as belonging to itself ("self") and that therefore trigger a **defensive response** from the leukocytes of the immune system. Many people have antigens on the surfaces of their red blood cells. More than 50 antigens have been identified on erythrocyte membranes, but the most significant in terms of their potential harm to patients are classified in two groups: the ABO blood group and the

Rh blood group.

- **Antibodies** are proteins which are produced by **plasma cells** in response to a "non-self" antigen being present in the body. Antibodies attach to the antigens on the plasma membranes of the erythrocytes in a blood transfusion and cause them to adhere to one another.
- Agglutination refers to the resulting clumps of red blood cells that are formed in such an antigen-antibody reaction. These clumps can block small blood vessels, thereby cutting of the supply of oxygen and nutrients to the tissues.
- **Hemolysis**, or the breakdown of the erythrocyte's cell membrane, takes place as the clumps of red cells start to degrade. The resulting release of the cell's contents, mainly hemoglobin, into the bloodstream can cause kidney failure.

ABO Blood Group

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

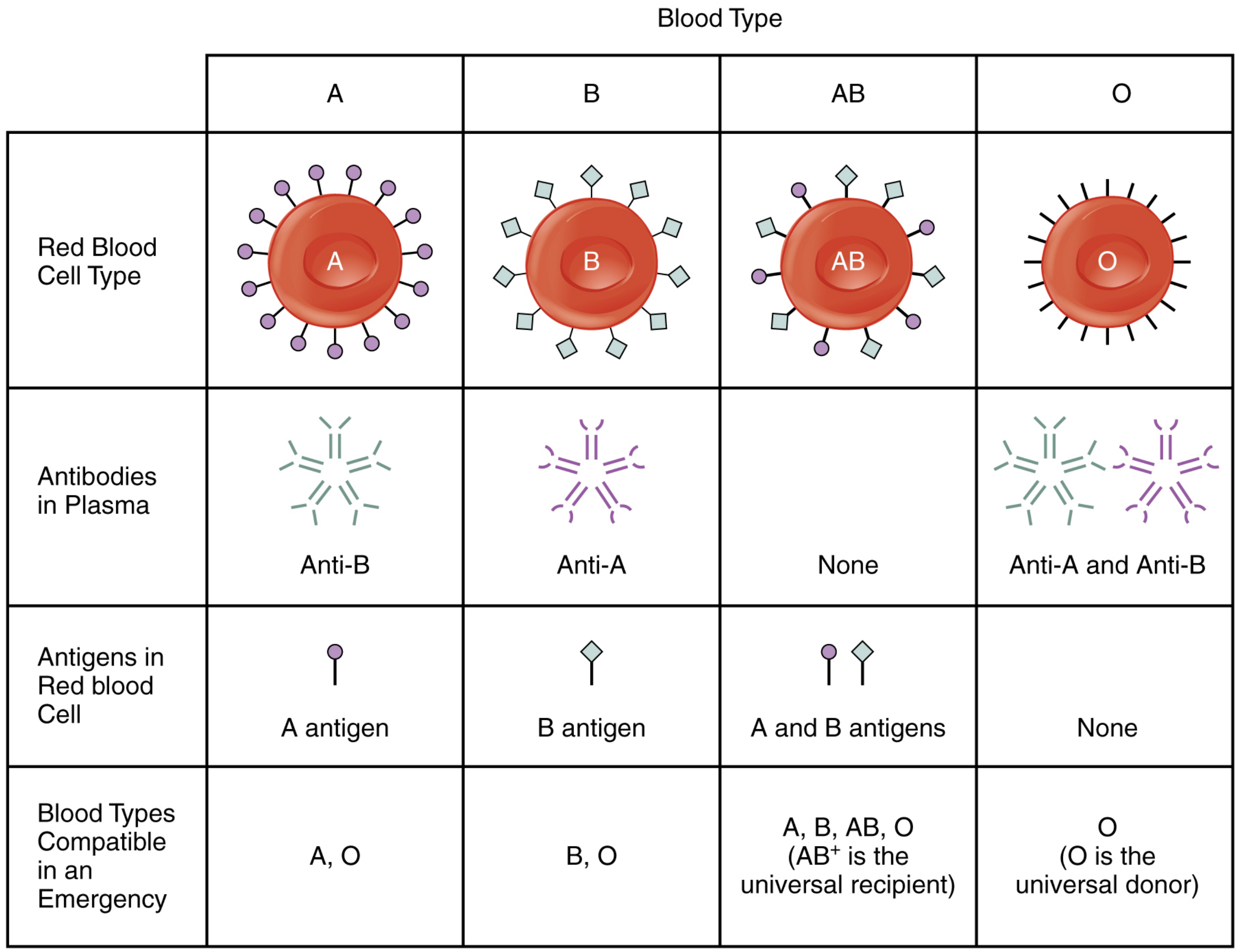


Figure 10.9 ABO Blood Groups. From Betts, et al., 2021. Licensed under CC BY 4.0.

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

Rh Blood Group

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

Hemolytic Disease of the Newborn (HDN)

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

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

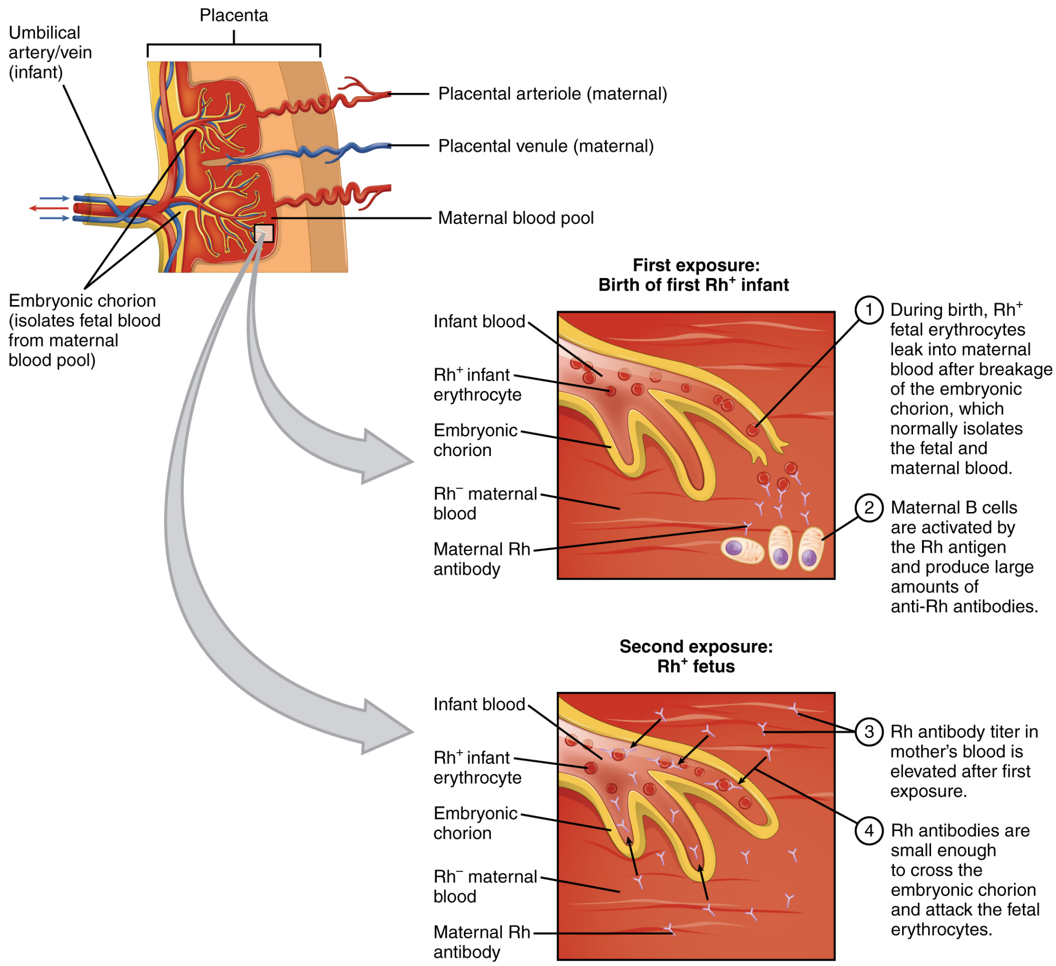


Figure 10.10 Erythroblastosis Fetalis. The first exposure of an Rh− mother to Rh+ erythrocytes during pregnancy induces sensitization. Anti-Rh antibodies begin to circulate in the mother's bloodstream. A second exposure occurs with a subsequent pregnancy with an Rh+ fetus in the uterus. Maternal anti-Rh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

Blood Transfusions

Figure 10.11 is an example of a commercially produced "bedside" card which enables quick typing of both a recipient's and donor's blood before transfusion. The card contains three reaction sites or wells. One is coated with an anti-A antibody, one with an anti-B antibody, and one with an anti-D antibody (tests for the presence of Rh factor D). Mixing a drop of blood and saline into each well enables the blood to interact with a preparation of type-specific antibodies, also called anti-seras. Agglutination of RBCs in a given site indicates a positive identification of the blood antigens, in this case A and Rh antigens for blood type A+. To avoid serious and potentially fatal immune reactions, the donor's and recipient's blood types must match

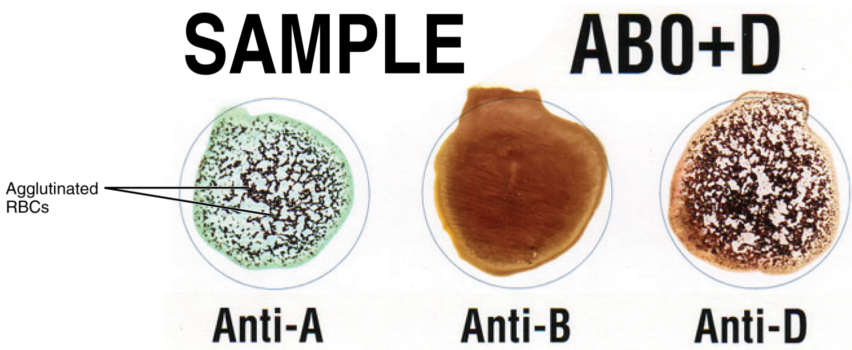


Figure 10.11. Cross Matching Blood Types. From Betts, et al., 2013. Licensed under [CC BY 4.0.](https://creativecommons.org/licenses/by/4.0/)

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

Blood Vessel Medical Terms Not Easily Broken into Word Parts

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

Common Diseases and Disorders of Blood Vessels and/or Blood

Arteriosclerosis

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

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

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

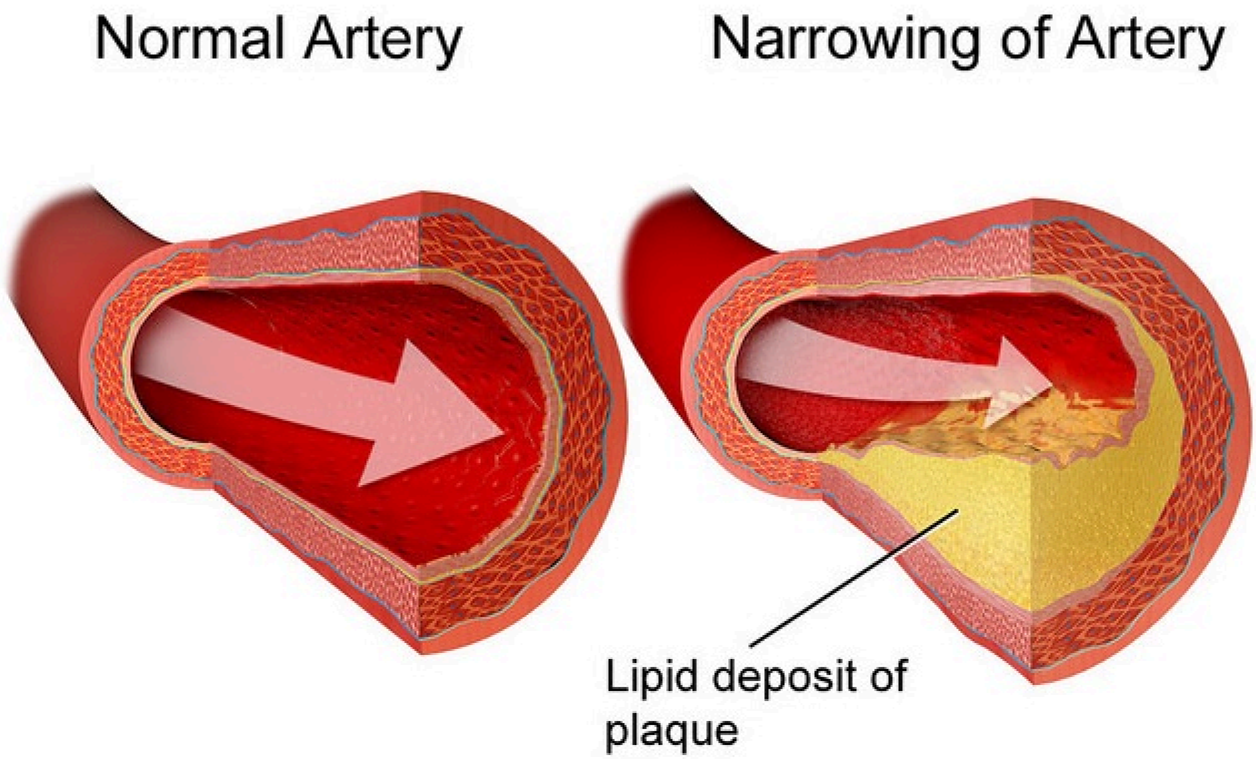


Figure 10.12 Atherosclerosis. This is an example of how build up of lipids (fat) in the artery prevents blood from flowing. From Blausen.com staff courtesy of Oregon State University, CC BY-SA 2.0, via Wikimedia Commons.

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

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

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

Edema and Varicose Veins

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

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

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

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

Hypertension

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

Hemorrhage

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

Circulatory Shock

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

There are several recognized forms of shock:

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

Blood Disorders

Erythrocyte Disorders

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

Anemia

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

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

Blood Loss Anemias:

Did You Know?

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

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

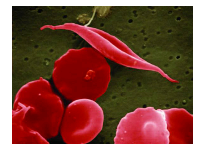


Figure 10.14 Sickle Cell Disease. (credit: NIH Image Gallery). From Flickr. Licensed under CC BY-NC 2.0.

Polycythemia

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

Platelet Disorders/Clotting Disorders

Thrombocytosis

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

Thrombophilia

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

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

Thrombocytopenia

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

Hemophilia

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

Leukocyte Disorders

Leukopenia

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

Leukocytosis

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

Leukemia

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

Lymphoma

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

Other Conditions Related to Abnormal Leukocyte Counts

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

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

Bone Marrow Biopsy/Bone Marrow Transplant

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

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

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

Common Cardiovascular System – Blood, Abbreviations

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

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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 (Betts, et al., 2021; Society for Vascular Surgery, n.d.). For more information, please visit Society for Vascular Surgery website.

Hematologists

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

Vascular Sonographer

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

Phlebotomist

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

Medical Laboratory Scientist/Technician

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

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

Test Yourself

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11. Lymphatic and Immune Systems

WTCS Learning Objectives

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

Word Parts for the Lymphatic and Immune Systems

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

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Introduction to the Lymphatic and Immune Systems

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

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

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

Lymphatic and Immune Systems Medical Terms

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Anatomy and Physiology of the Lymphatic System

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

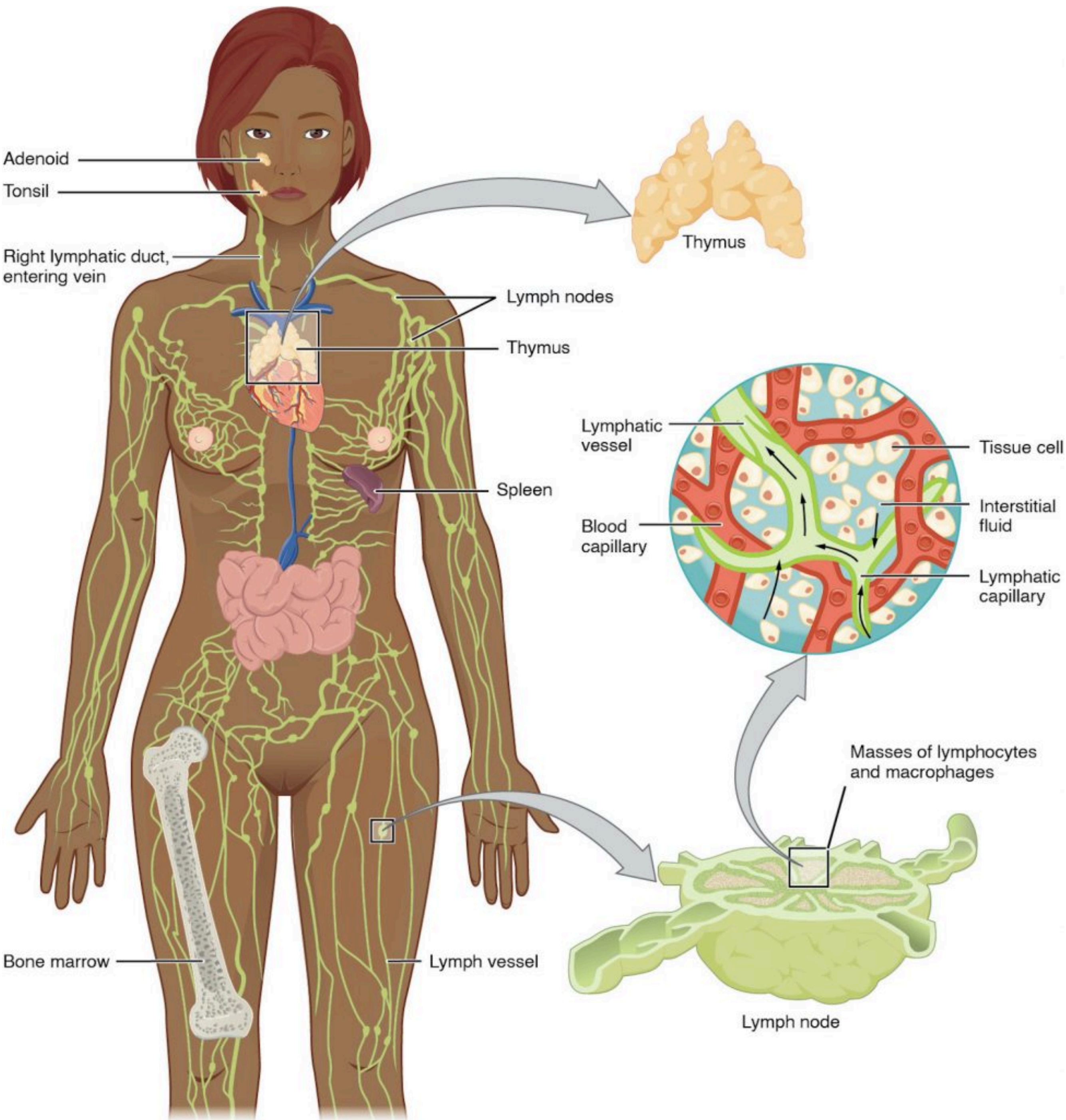

Figure 11.1 Anatomy of the Lymphatic System. Lymphatic vessels in the arms and legs convey lymph to the larger lymphatic vessels in the torso. From Betts, et al., 2021. Licensed under [CC BY 4.0](CC BY 4.0).

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.

Did you know?

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

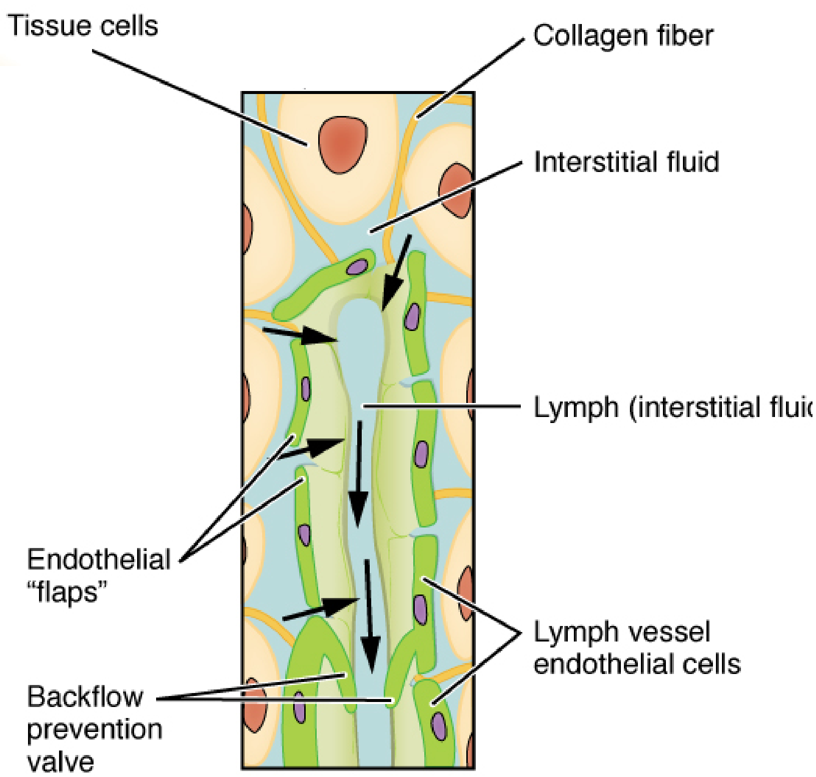

Figure 11.2 Lymphatic Capillaries. Lymphatic capillaries are interlaced with the arterioles and venules of the cardiovascular system. Collagen fibers anchor a lymphatic capillary in the tissue. Interstitial fluid slips through spaces between the overlapping endothelial cells that compose the lymphatic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

Larger Lymphatic Vessels, Trunks, and Ducts

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

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

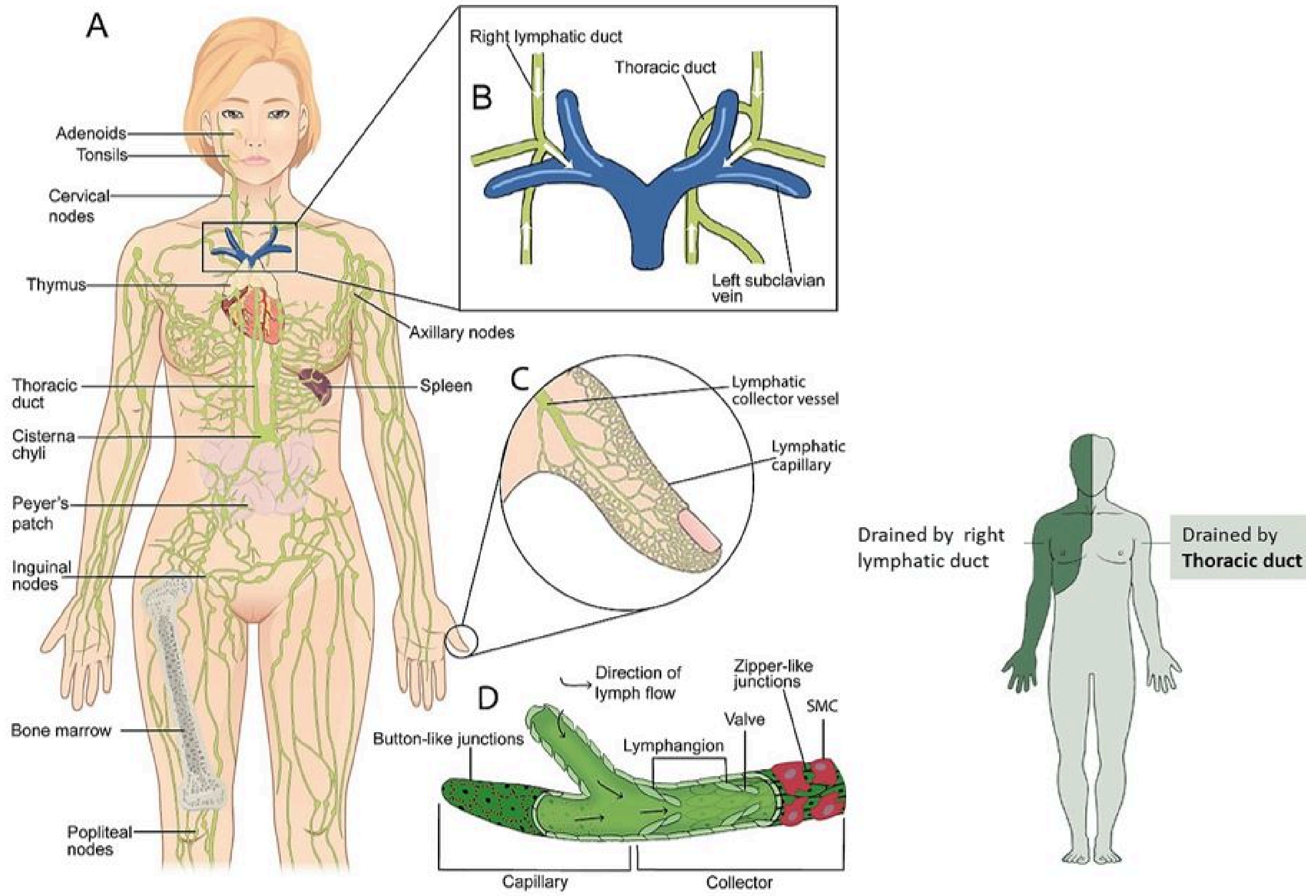

Figure 11.3 Lymphatic System. (A) The lymphatic system includes the primary and secondary lymphoid organs and a series of lymphatic vessels, providing a one-way drainage route from all tissues back ultimately to the blood circulation via the great veins in the neck. In the primary lymphoid organs (bone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

Primary Lymphoid Organs

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

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

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

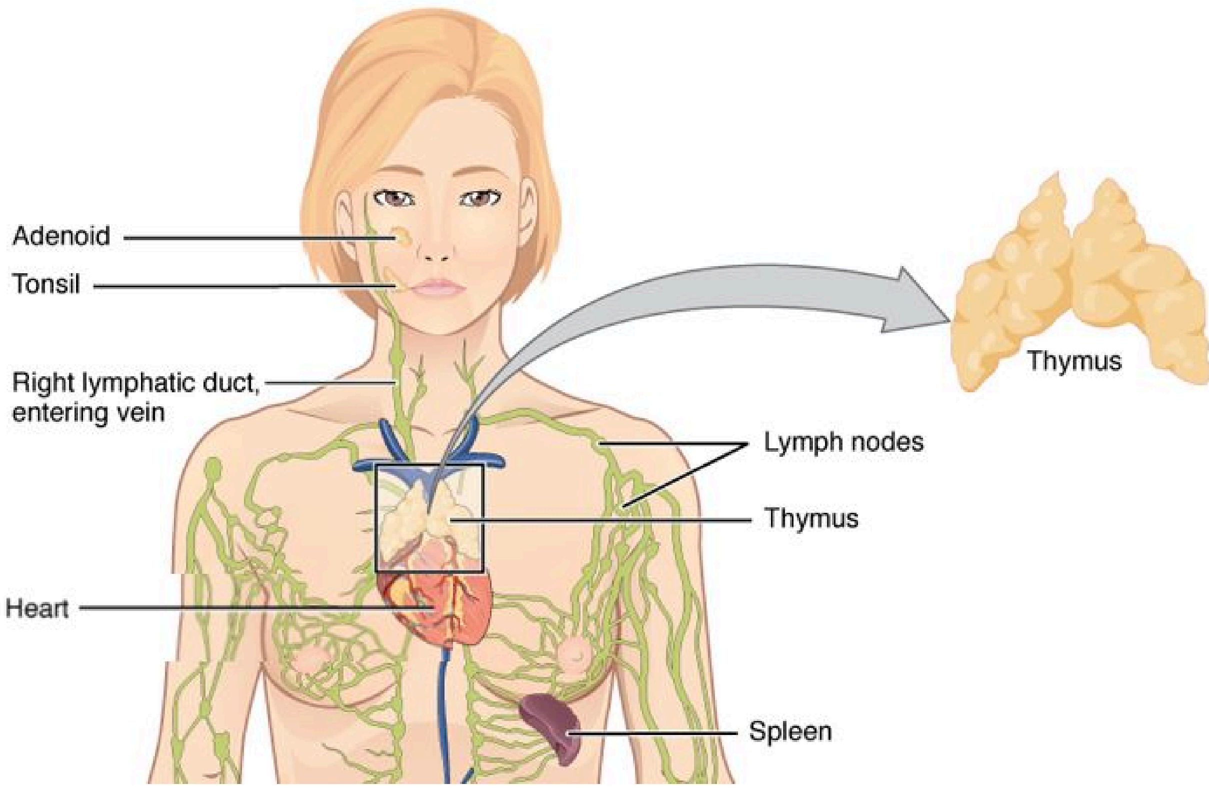

Figure 11.4 Location and Structure of the Thymus. Modified from Anatomy & Physiology, OpenStax. Licensed under CC BY 3.0, via Wikimedia Commons.

Concept Check

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

Secondary Lymphoid Organs

Did You Know?

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

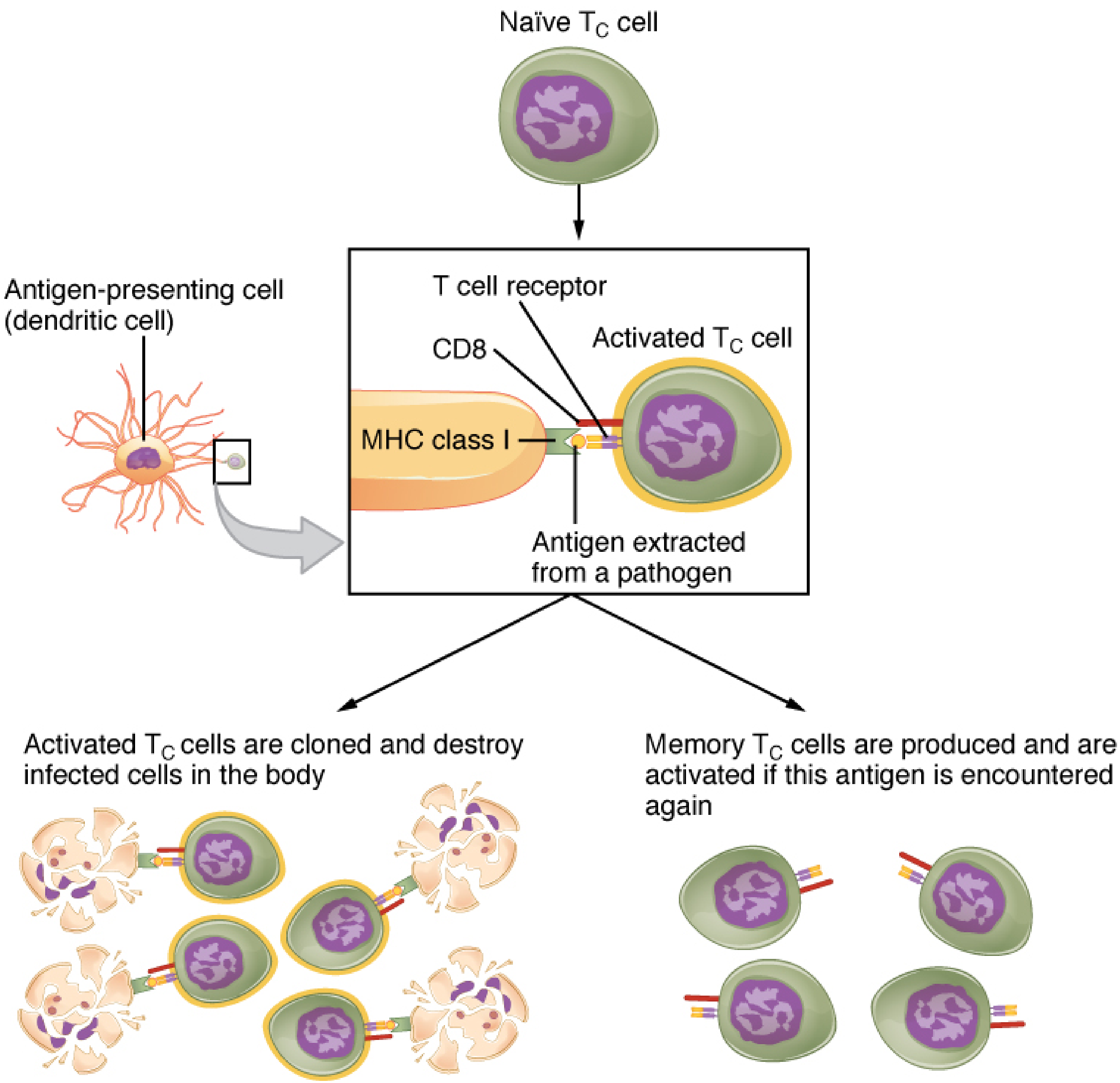

Figure 11.5 Clonal Selection and Expansion of T Lymphocytes. Stem cells differentiate into T cells with specific receptors, called clones. The clones with receptors specific for antigens on the pathogen are selected for and expanded. From Betts, et al., 2021. Licensed under CC BY 4.0.

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

Lymph Nodes

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

Spleen

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

Did You Know?

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

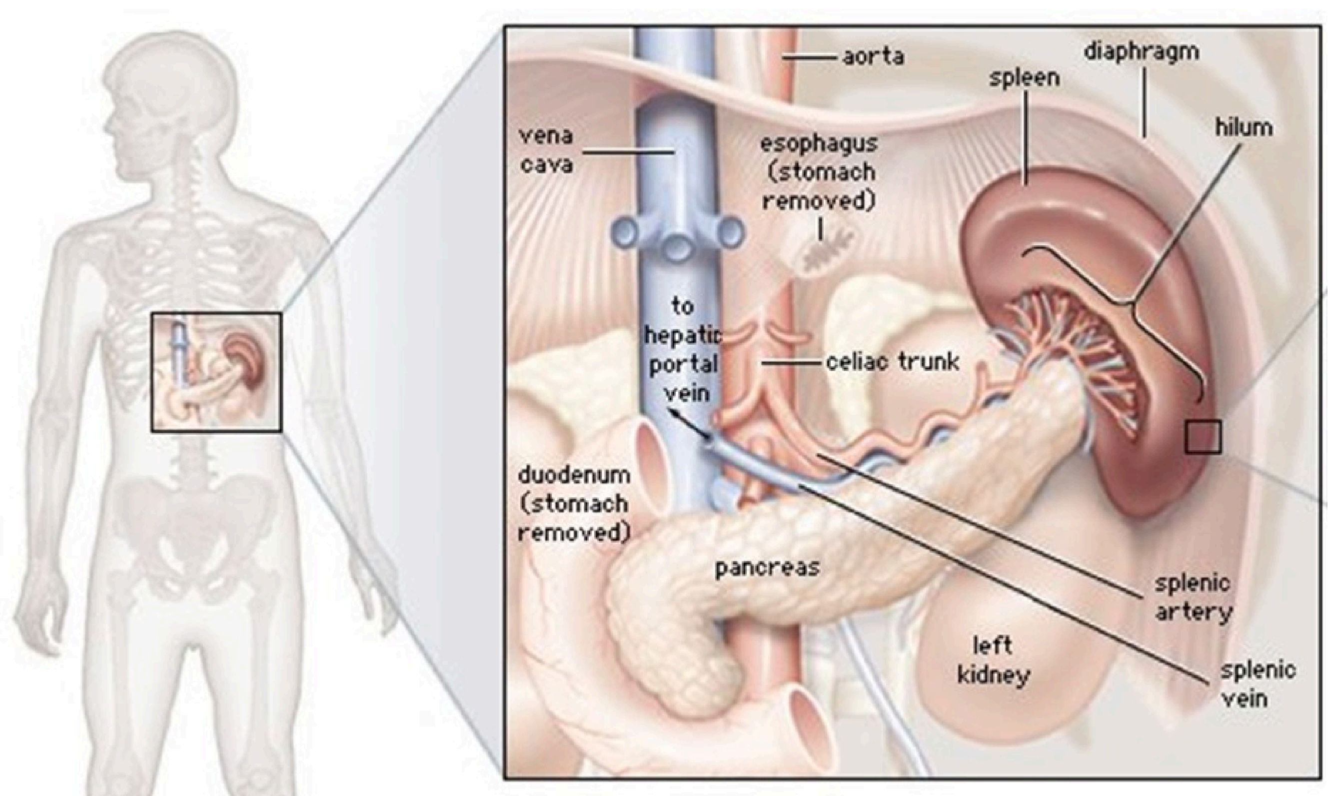

Figure 11.6 Spleen. The spleen is located in the left side of the abdominal cavity under the diaphragm. It is about the size of a fist and is well supplied with blood. The spleen is the primary filtering element for the blood. From Britannica Encyclopedia (2021). https://www.britannica.com/science/spleen-anatomy

Lymphoid Nodules

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

Tonsils are lymphoid nodules located along the inner surface of the pharynx and are important in developing immunity to oral pathogens (see Figure 11.7). The tonsil located at the back of the throat, the pharyngeal tonsil, is sometimes referred to as the adenoid when swollen. Such swelling is an indication of an active immune response to infection. Tonsils have deep grooves called **crypts**, which accumulate all sorts of materials taken into the body through eating and breathing and actually "encourage" pathogens to penetrate deep into the tonsillar tissues where they are eliminated. A major function of tonsils is to help children's bodies recognize, destroy, and develop immunity to common environmental pathogens so that they will be protected in their later lives. Tonsils are often removed in children who have recurring throat infections since swollen palatine tonsils can interfere with breathing and/or swallowing.

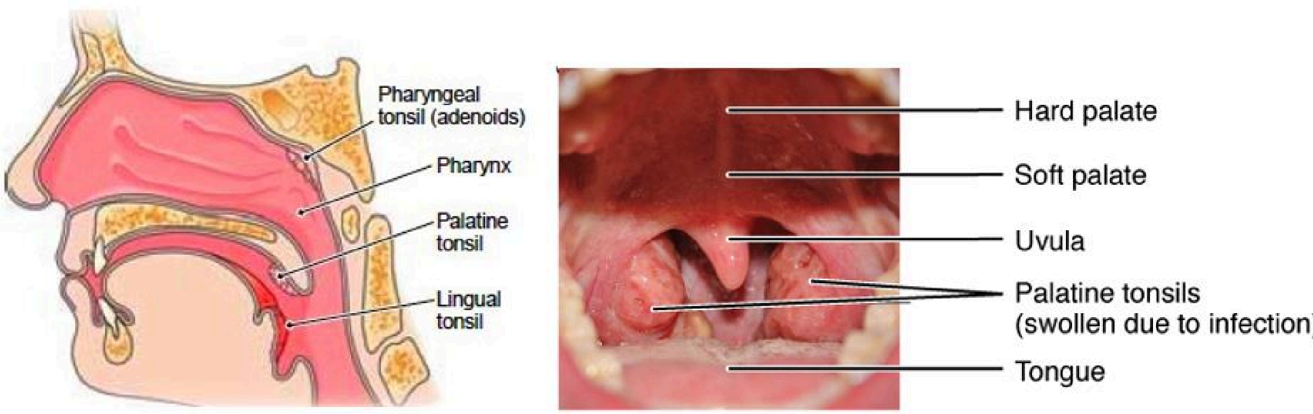

Figure 11.7. Locations of the Tonsils. (a) The pharyngeal tonsil is located on the roof of the posterior superior wall of the nasopharynx. The palatine tonsils lay on each side of the pharynx. Modified From Betts, et al., 2021. Licensed under CC BY 4.0.

Concept Check

Tonsils are named after their locations.

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

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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 Cells

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

Concept Check

Do you know the difference between these terms?

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

Cytokines and Chemokines

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

Early Induced Proteins

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

Inflammatory Response

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

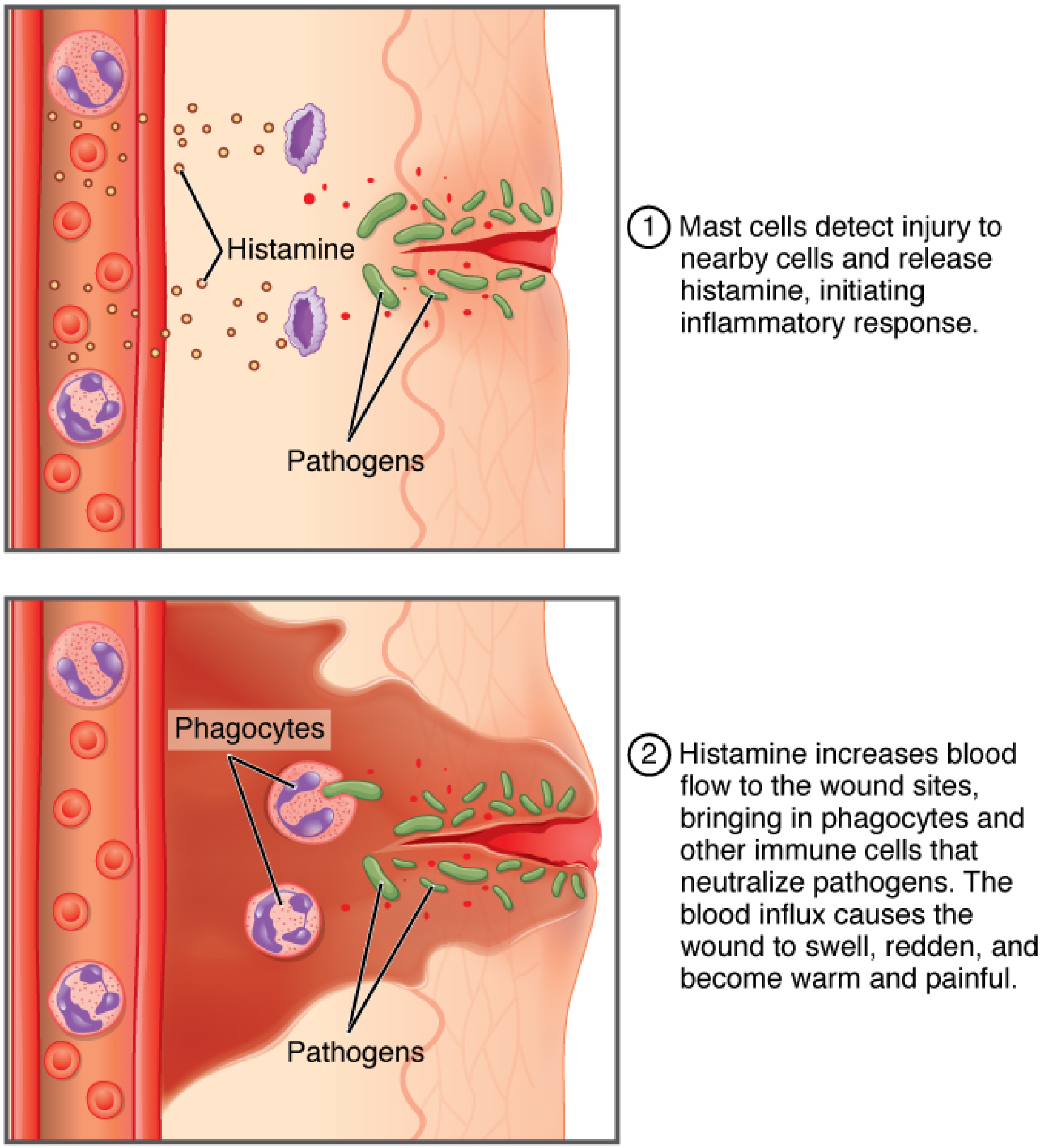

Figure 11.8 Inflammatory Response. From Betts, et al., 2021. Licensed under [CC BY 4.0.](https://creativecommons.org/licenses/by/4.0/)

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

- The released contents of injured cells stimulate the release of substances from **mast cells** including histamine, leukotrienes, and prostaglandins.
- **Histamine** increases blood flow to the area by **vasodilation**, resulting in **heat** and **redness**. Histamine also increases the permeability of local capillaries, causing plasma to leak out and form interstitial fluid, resulting in **swelling**
- **Leukotrienes** attract neutrophils from the blood by **chemotaxis**.
  When local infections are severe, neutrophils are attracted to the sites of infections in large numbers, and as they phagocytose the pathogens and subsequently die, their accumulated cellular remains are visible as pus at the infection site.

- **Prostaglandins** cause vasodilation by relaxing vascular smooth muscle and are a major cause of the **pain** associated with inflammation. Nonsteroidal anti-inflammatory drugs such as aspirin and ibuprofen relieve pain by inhibiting prostaglandin production.

Concept Check

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

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

Phase 3: Adaptive Immune Response

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

Benefits of the Adaptive Immune Response

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

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

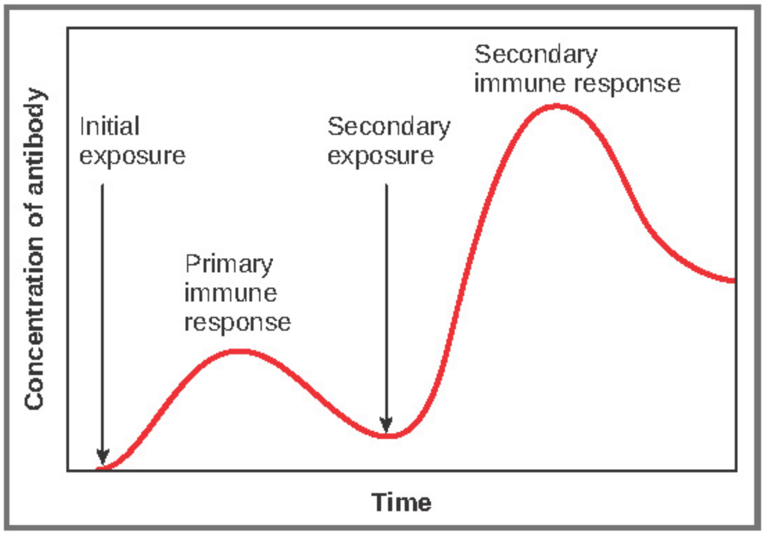

Figure 11.9 Primary and Secondary Antibody Responses. Antigen A is given once to generate a primary response and later to generate a secondary response. When a different antigen is given for the first time, a new primary response is made. From Betts, et al., 2021. Licensed under [CC BY 4.0.](#)

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

Lymphocytes: B Cells, T Cells, Plasma Cells

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

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

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

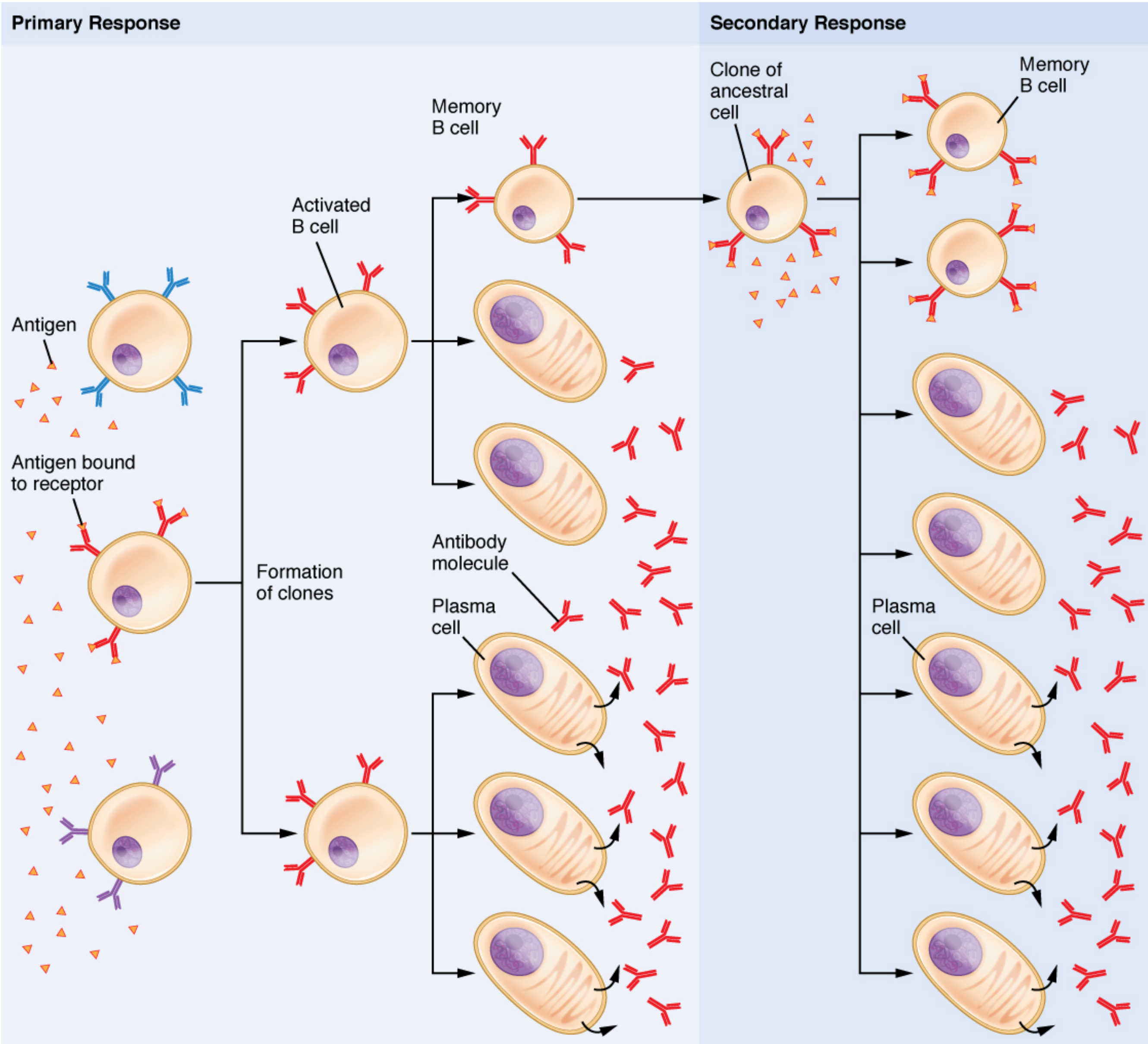

Figure 11.10 Clonal Selection of B Cells. During a primary B cell immune response, both antibody-secreting plasma cells and memory B cells are produced. These memory cells lead to the differentiation of more plasma cells and memory B cells during secondary responses. From Betts, et al., 2021. Licensed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

Active Versus Passive Immunity

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

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

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

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

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

Evasion of the Immune System by Pathogens

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

- **Protective adaptations**: It is important to keep in mind that although the immune system has evolved to be able to control many pathogens, pathogens themselves have evolved ways to evade the immune response. An example is in *Mycobactrium tuberculosis*, which has evolved a complex cell wall that is resistant to the digestive enzymes of the macrophages that ingest them, and thus persists in the host, causing the chronic disease tuberculosis.
- **Multiple strains**: Bacteria sometimes evade immune responses because they exist in multiple strains, each having different surface antigens and requiring individual adaptive immune responses. One example is a small group of strains of **S. *aureus***, called methicillin-resistant *Staphylococcus aureus* (MRSA), which has become resistant to multiple antibiotics..
- **Antigen mutation:** Because viruses' surface molecules mutate continuously, viruses like influenza change enough each year that the flu vaccine for one year may not protect against the flu common to the next. New vaccine formulations must be derived for each flu season.
- **Genetic recombination:** An example is the influenza virus, which contains gene segments that can recombine when two different viruses infect the same cell. Recombination between human and pig influenza viruses led to the 2010 H1N1 swine flu outbreak.
- **Immunosuppression**: Pathogens, especially viruses, can produce immunosuppressive molecules that impair

immune function.

Tissue Transplantation

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

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

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

Immune Responses Against Cancer

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

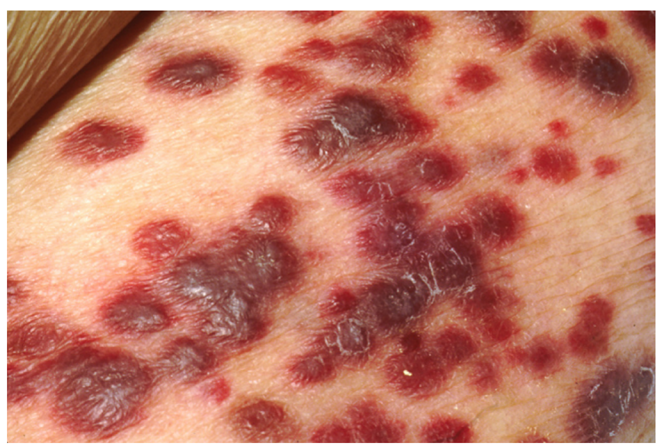

Figure 11.11 Kaposi's Sarcoma Lesions. (credit: National Cancer Institute). From Betts, et al., 2021. Licensed under [CC BY 4.0.](#)

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

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

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

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

Immune Responses and Stress

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

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

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

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

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

Anatomy Labeling Activity

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Medical Terms not Easily Broken into Word Parts

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Lymphatic and Immune System Abbreviations

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Diseases and Disorders of the Lymphatic and Immune Systems

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

Underactive Immune System: Immunodeficiencies

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

Inherited Immunodeficiencies/SCID

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

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

Acquired Immunodeficiency/HIV and AIDS

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

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

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

Overactive Immune System: Hypersensitivities and Autoimmune Diseases

Hypersensitivities

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

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

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

Autoimmune Responses

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

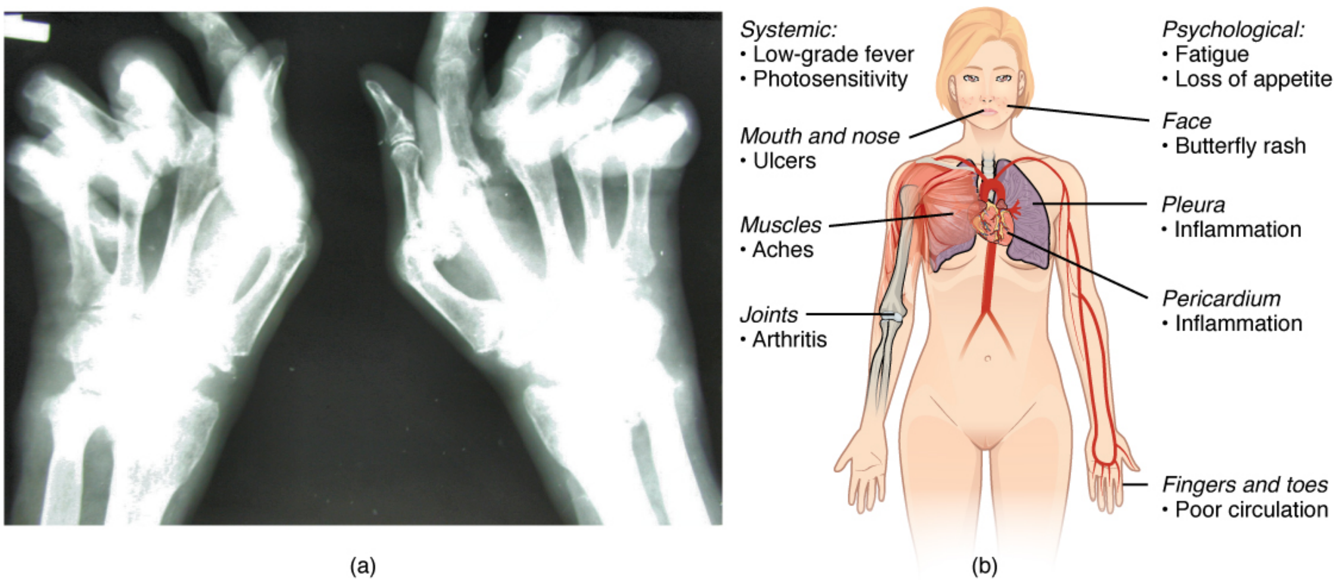

Figure 11.12 Autoimmune Disorders: Rheumatoid Arthritis and Lupus. (a) Extensive damage to the right hand of a rheumatoid arthritis sufferer is shown in the x-ray. (b) The diagram shows a variety of possible symptoms of systemic lupus erythematosus. From Betts, et al., 2021. Licensed under CC BY 4.0.

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

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

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

Lymphoma

Lymphoma was briefly discussed in the previous chapter.

Medical Terms in Context

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Medical Specialties and Procedures Related to the Lymphatic and Immune Systems

Clinical Immunology/Allergy is a medical specialty that diagnoses and treats diseases of the immune system (American

Academy of Allergy Asthma and Immunology, 2021). For more information, please visit the 'About Careers in Allergy/Immunology' page from the American Academy of Allergy Asthma and Immunology.

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

Test Yourself

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12. Digestive System

WTCS Learning Objectives

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

Digestive System Word Parts

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

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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 12.1).

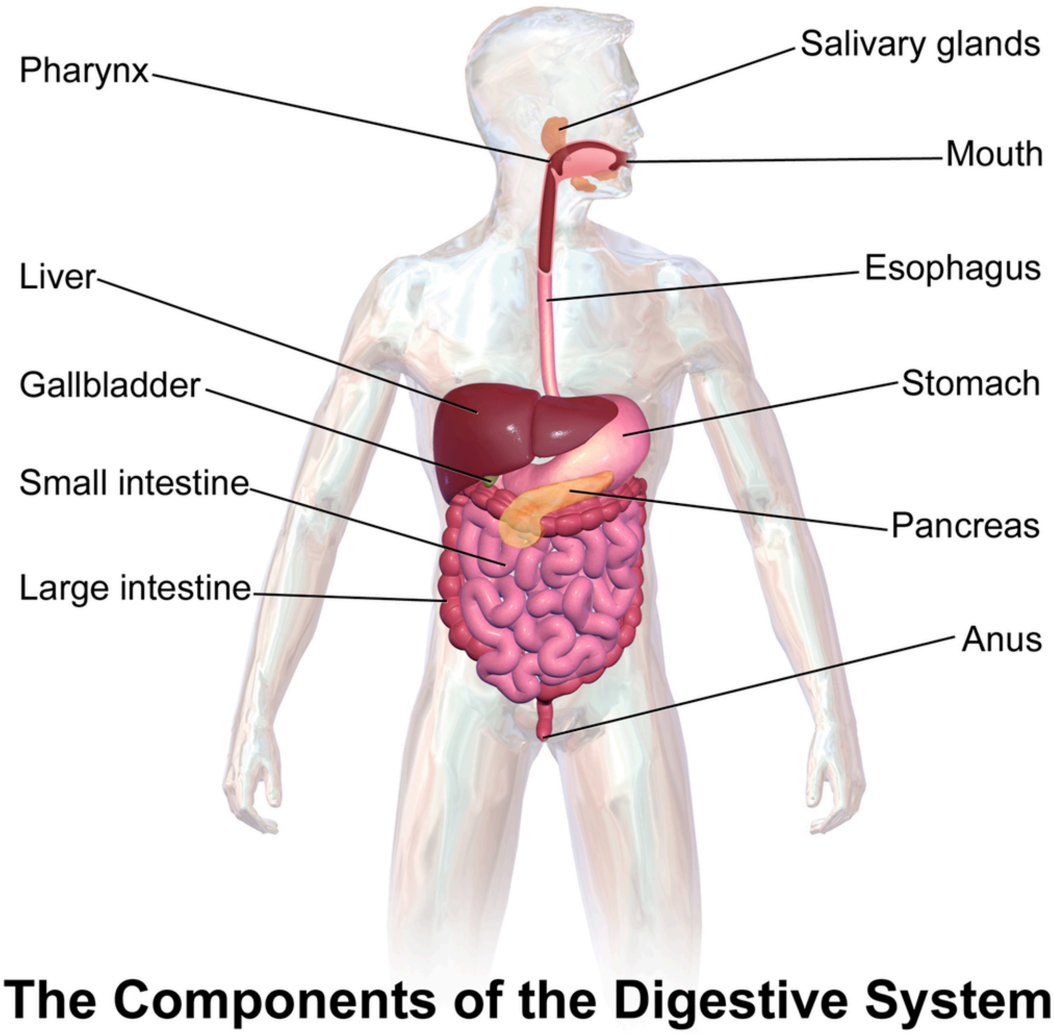

Figure 12.1 Components of the Digestive System. All digestive organs play integral roles in the life-sustaining process of digestion. Medical gallery of Blausen Medical 2014. ISSN 2002-4436., CC BY 3.0, via Wikimedia Commons.

Watch this video:

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Media 12.1 How your digestive system works – Emma Bryce. Copyright 2017 by Ted-Ed.

Digestive System Medical Terms

Now that you have memorized the word parts see if you can break down the following Digestive terms and define them.

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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

> *Did You Know?*
>
> You can eat upside down. Food doesn't need gravity to reach your stomach. Peristalsis, a wave-like muscle movement, pushes food along.

also called the **oral cavity** (or buccal cavity). The structures of the mouth are illustrated in Figure 12.2.

The pocket-like part of the mouth that is framed on the inside by the gums and teeth, and on the outside by the cheeks and lips is called the **oral vestibule**. The main open area of the mouth, or oral cavity proper, runs from the gums and teeth to the fauces.

When you are chewing, you do not find it difficult to breathe simultaneously. The next time you have food in your mouth, notice how the arched shape of the roof of your mouth allows you to handle both digestion and respiration at the same time. This arch is called the palate. The anterior region of the palate serves as a wall (or septum) between the oral and nasal cavities as well as a rigid shelf against which the tongue can push food. It is created by the maxillary and palatine bones of the skull and, given its bony structure, is known as the hard palate. If you run your tongue along the roof of your mouth, you'll notice that the hard palate ends in the posterior oral cavity, and the tissue becomes fleshier. This part of the palate, known as the **soft palate**, is composed mainly of skeletal muscle. You can therefore manipulate, subconsciously, the soft palate—for instance, to yawn, swallow, or sing (see Figure 12.2).

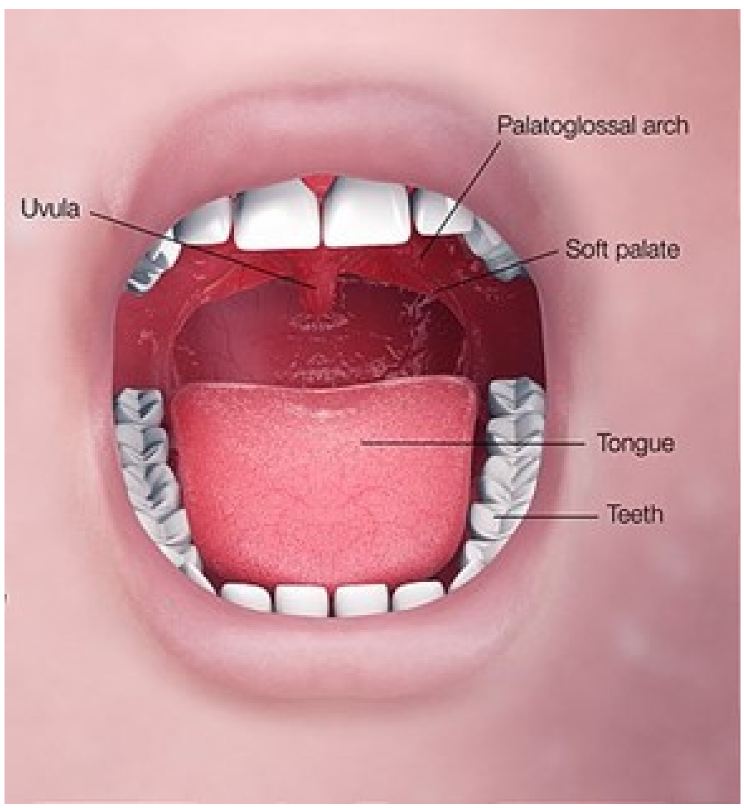

Figure 12.2 3D Medical Animation Mouth. Including uvula, teeth, tongue, soft palate, and palatoglossal arch. https://www.scientificanimations.com, [CC BY 4.0.](#) via Wikimedia Commons

A fleshy bead of tissue called the **uvula** drops down from the center of the posterior edge of the soft palate. Although some have suggested that the uvula is a vestigial organ, it serves an important purpose. When you swallow, the soft palate and uvula move upward, helping to keep foods and liquid from entering the **nasal cavity**. Unfortunately, it can also contribute to the sound produced by snoring. Two muscular folds extend downward from the soft palate, on either side of the uvula. Between these two folds are the **palatine tonsils**, clusters of lymphoid tissue that protect the pharynx. The **lingual tonsils** are located at the base of the tongue.

Tongue

Perhaps you have heard it said that the **tongue** is the strongest muscle in the body. Those who stake this claim cite its strength proportionate to its size. Although it is difficult to quantify the relative strength of different muscles, it remains indisputable that the tongue is a workhorse, facilitating **ingestion**, **mechanical digestion**, **chemical digestion** (lingual lipase), sensation (of taste, texture, and temperature of food), swallowing, and vocalization.

The top and sides of the tongue are studded with papillae (see Figure 12.3).

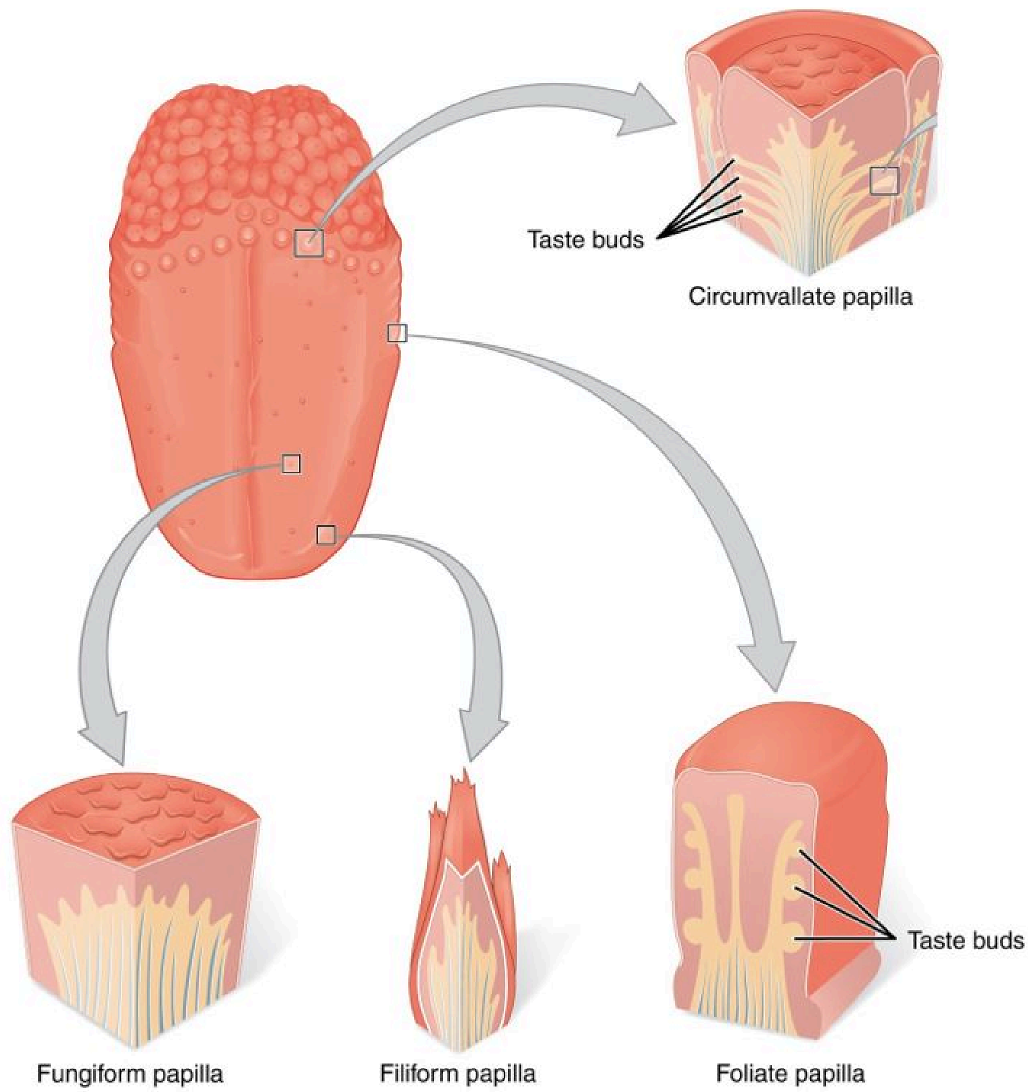

Figure 12.3 The Tongue. This view of the tongue shows the locations and types of papillae. OpenStax, CC BY 4.0, via Wikimedia Commons.

Salivary Glands

Many small **salivary glands** are housed within the mucous membranes of the mouth and tongue. These minor **exocrine** glands are constantly secreting **saliva**, either directly into the oral cavity or indirectly through ducts, even while you sleep. In fact, an average of 1 to 1.5 liters of saliva is secreted each day. Usually just enough saliva is present to moisten the mouth and teeth. Secretion increases when you eat, because saliva is essential to moisten food and initiate the chemical breakdown of **carbohydrates**. Small amounts of saliva are also secreted by the **labial glands** in the lips. In addition, the **buccal glands** in the cheeks, palatal glands in the palate, and lingual glands in the tongue help ensure that all areas of the mouth are supplied with adequate saliva.

Concept Check

- Describe how the **anatomy** of the **mouth** permits breathing and chewing at the same time
- Explain the role **saliva** performs in the digestive system

Pharynx

The pharynx (throat) is involved in both digestion and respiration. It receives food and air from the mouth, and air from the nasal cavities. When food enters the pharynx, involuntary muscle contractions close off the air passageways. A short tube of skeletal muscle lined with a **mucous membrane**, the pharynx runs from the posterior oral and nasal cavities to the opening of the esophagus and larynx. It has three subdivisions. The most superior, the nasopharynx, is involved only in breathing and speech. The other two subdivisions, the **oropharynx** and the **laryngopharynx**, are used for both breathing and digestion. The oropharynx begins inferior to the nasopharynx and is continuous below with the laryngopharynx. The inferior border of the laryngopharynx connects to the esophagus, whereas the anterior portion connects to the larynx, allowing air to flow into the bronchial tree.

Esophagus

The esophagus is a muscular tube that connects the pharynx to the stomach. It is approximately 25.4 cm (10 in) in length, located posterior to the trachea, and remains in a collapsed form when not engaged in swallowing. As you can see in Figure 12.4, 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.

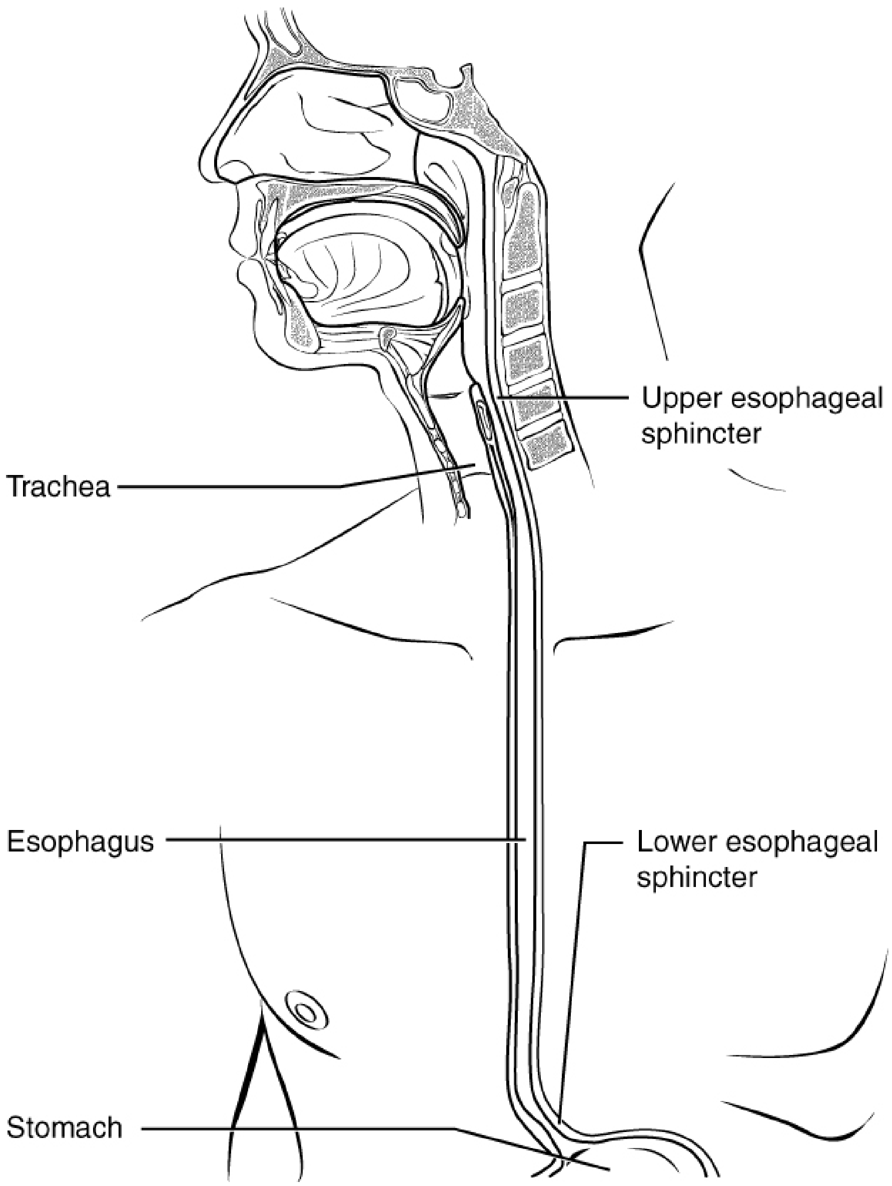

Figure 12.4 Esophagus. The upper esophageal sphincter controls the movement of food from the pharynx to the esophagus. The lower esophageal sphincter (LES) controls the movement of food from the esophagus to the stomach. From Betts, et al., 2021. Licensed under [CC BY 4.0.](#)

Passage of Food Through the Esophagus

The upper **esophageal sphincter**, controls the movement of food from the pharynx into the esophagus. The upper two-thirds of the esophagus consists of both smooth and skeletal muscle fibers. A series of contractions called **peristalsis** push food through the esophagus and into the stomach. Just before the opening to the stomach is an important ring-shaped muscle called the lower esophageal sphincter (LES). Recall that sphincters are muscles that surround tubes and serve as valves, closing the tube when the sphincters contract and opening it when they relax. This sphincter opens to let food pass into the stomach and closes to keep it there.

Stomach

There are four main regions in the **stomach**: the cardia, fundus, body, and pylorus (see Figure 12.5). The **cardia** (or cardiac region) is the point where the esophagus connects to the stomach and through which food passes into the stomach. Located inferior to the diaphragm, above and to the left of the cardia, is the dome-shaped **fundus**. Below the fundus is the **body**, the main part of the stomach. The funnel-shaped **pylorus** connects the stomach to the duodenum.

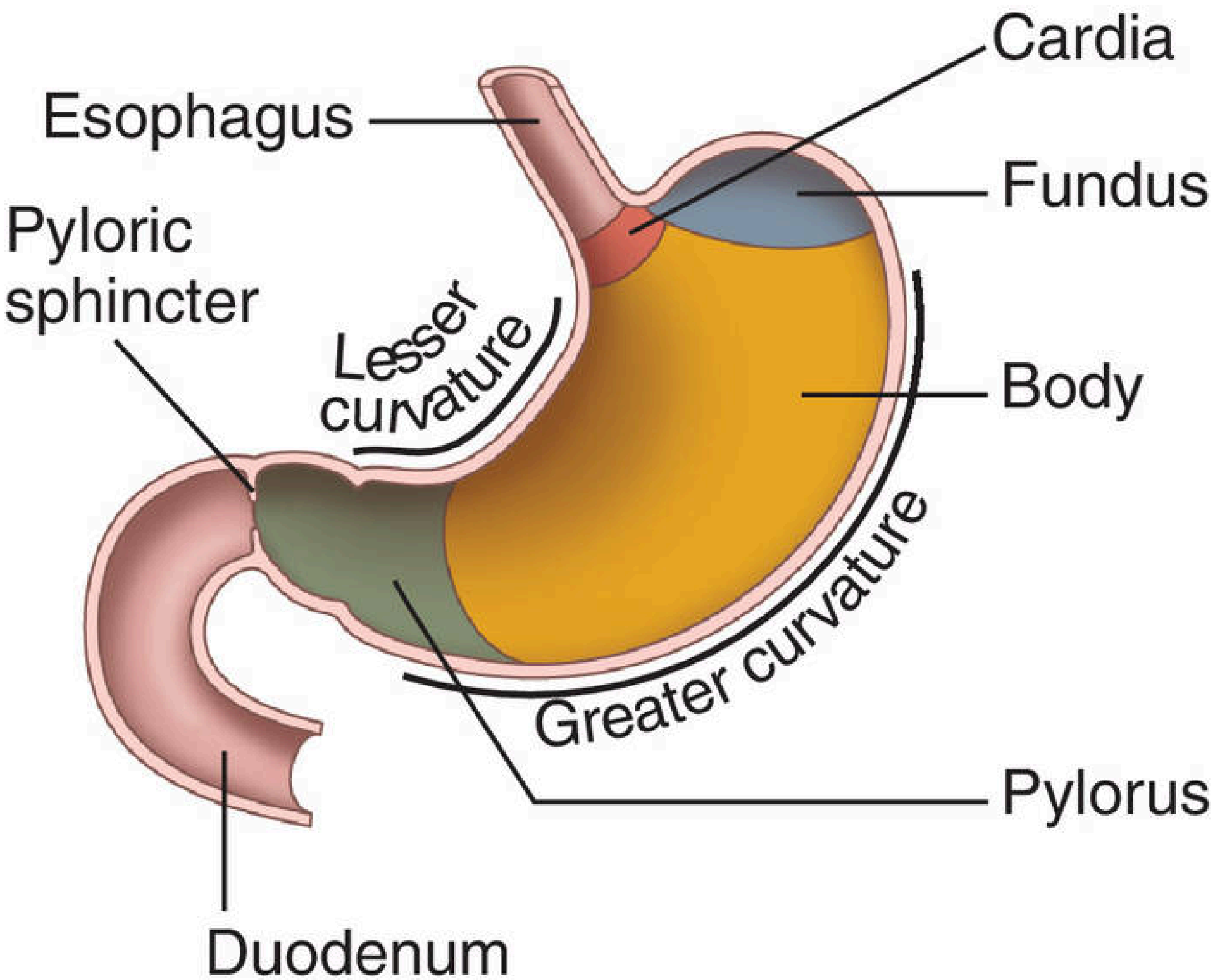

Figure 12.5 Regions of the Stomach. The stomach has four major regions: the cardia, fundus, body, and pylorus. From Farlex, 2021.

Small Intestines

Did You Know?

Your body absorbs 90 per cent of our nutrients through the **small intestine**, into your blood.

Chyme released from the stomach enters the **small intestine**, which is the primary digestive organ in the body. Not only is this where most digestion occurs, it is also where practically all absorption occurs. The longest part of the **alimentary canal**, the small intestine is about 3.05 meters (10 feet) long in a living person (but about twice as long in a cadaver due to the loss of muscle tone). Since this makes it about five times longer than the large intestine, you might wonder why it is called "small." In fact, its name derives from its relatively smaller diameter of only about 2.54 cm (1 in), compared with 7.62 cm (3 in) for the large intestine. As we'll see shortly, in addition to its length, the folds and projections of the lining of the small intestine work to give it an enormous surface area, more than 100 times the surface area of your skin. This large surface area is necessary for complex processes of digestion and absorption that occur within it.

The coiled tube of the small intestine is subdivided into three regions. From **proximal** (at the stomach) to **distal**, these are the duodenum, jejunum, and ileum (see Figure 12.6).

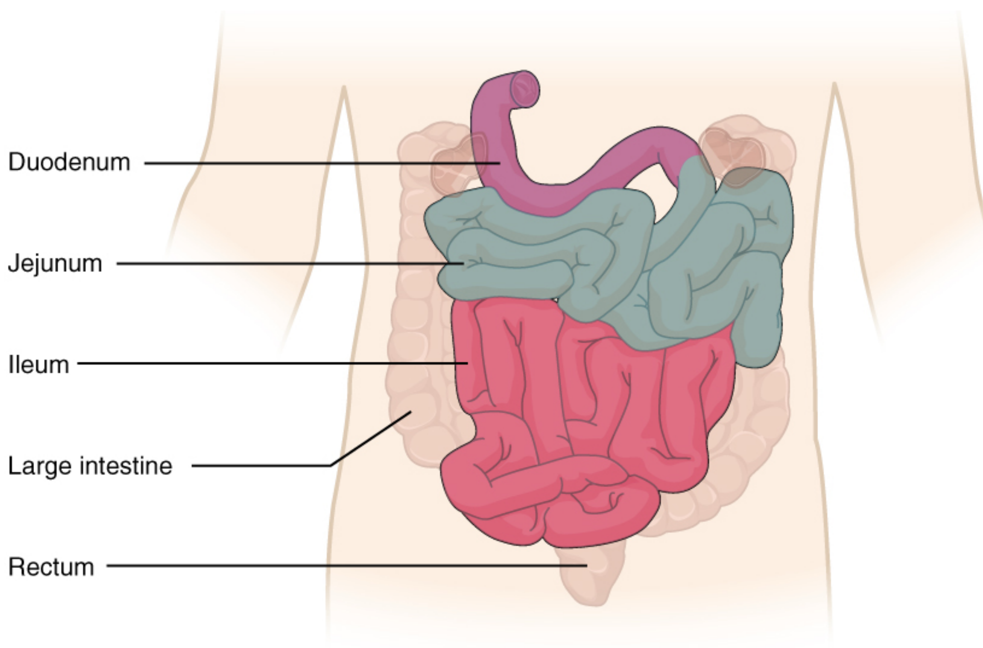

Figure 12.6 Small Intestine. The three regions of the small intestine are the duodenum, jejunum, and ileum. From Betts, et al., 2021. Licensed under [CC BY 4.0.]

Large Intestines

The **large intestine** is the terminal part of the alimentary canal. The primary function of this organ is to finish absorption of nutrients and water, synthesize certain vitamins, form feces, and eliminate feces from the body.

The large intestine runs from the appendix to the anus. It frames the small intestine on three sides. Despite its being about one-half as long as the small intestine, it is called large because it is more than twice the diameter of the small intestine, about 3 inches.
The large intestine is subdivided into four main regions: the cecum, the colon, the rectum, and the anus. The ileocecal valve, located at the opening between the ileum and the large intestine, controls the flow of **chyme** from the small intestine to the large intestine.

Cecum

The first part of the large intestine is the **cecum**, a sac-like structure that is suspended inferior to the ileocecal valve. It is about 6 cm (2.4 in) long, receives the contents of the ileum, and continues the absorption of water and salts. The **appendix** (or vermiform appendix) is a winding tube that attaches to the cecum. Although the 7.6-cm (3-in) long appendix contains **lymphoid** tissue, suggesting an immunologic function, this organ is generally considered vestigial. However, at least one recent report assumes a survival advantage conferred by the appendix: In diarrheal illness, the appendix may serve as a bacterial reservoir to repopulate the enteric bacteria for those surviving the initial phases of the illness. Moreover, its twisted anatomy provides a haven for the accumulation and multiplication of enteric bacteria.

Colon

The cecum blends seamlessly with the **colon**. Upon entering the colon, the food residue first travels up the **ascending colon** on the right side of the abdomen. At the inferior surface of the liver, the colon bends to become the **transverse colon**. The region defined as hindgut begins with the last third of the transverse colon and continues on. Food residue passing through the transverse colon travels across to the left side of the abdomen. From there, food residue passes through the **descending colon**, which runs down the left side of the posterior abdominal wall. After entering the pelvis inferiorly, it becomes the s-shaped **sigmoid colon**, which extends medially to the midline (see Figure 12.7). The ascending and descending colon, and the rectum (discussed next) are located in the retroperitoneum.

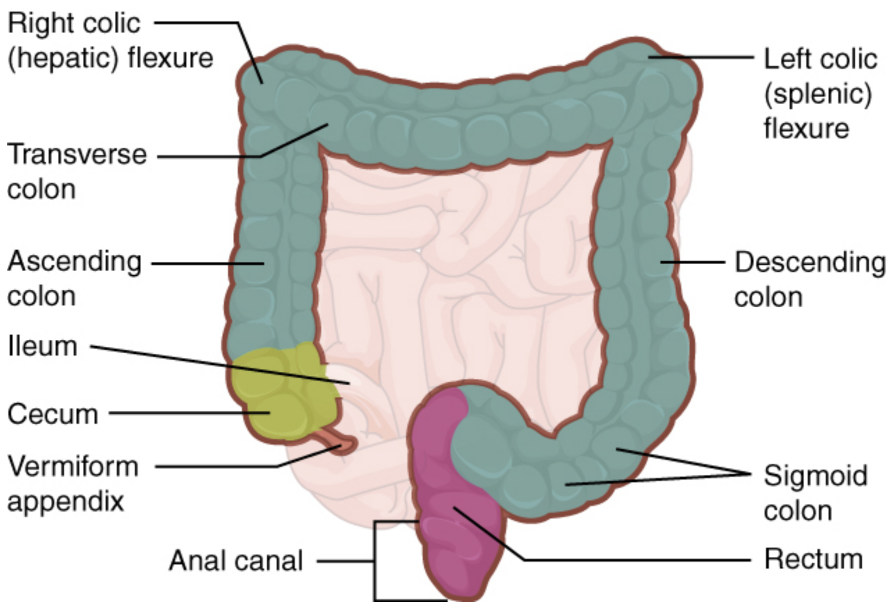

Figure 12.7 Large Intestine. The large intestine includes the cecum, colon, and rectum. From Betts, et al., 2021. Licensed under CC BY 4.0.

Accessory Organs of Digestion

Chemical digestion in the small intestine relies on the activities of three accessory digestive organs: the liver, pancreas, and gallbladder (see Figure 12.8). The digestive role of the liver is to produce bile and export it to the duodenum. The gallbladder primarily stores, concentrates, and releases bile. The pancreas produces pancreatic juice, which contains digestive enzymes and **bicarbonate** ions, and delivers it to the duodenum.

Concept Check

On the Figure 12.8 diagram locate the following **anatomical organs** and consider how these organs **support** the digestive process

- Liver
- Pancreas
- Gallbladder

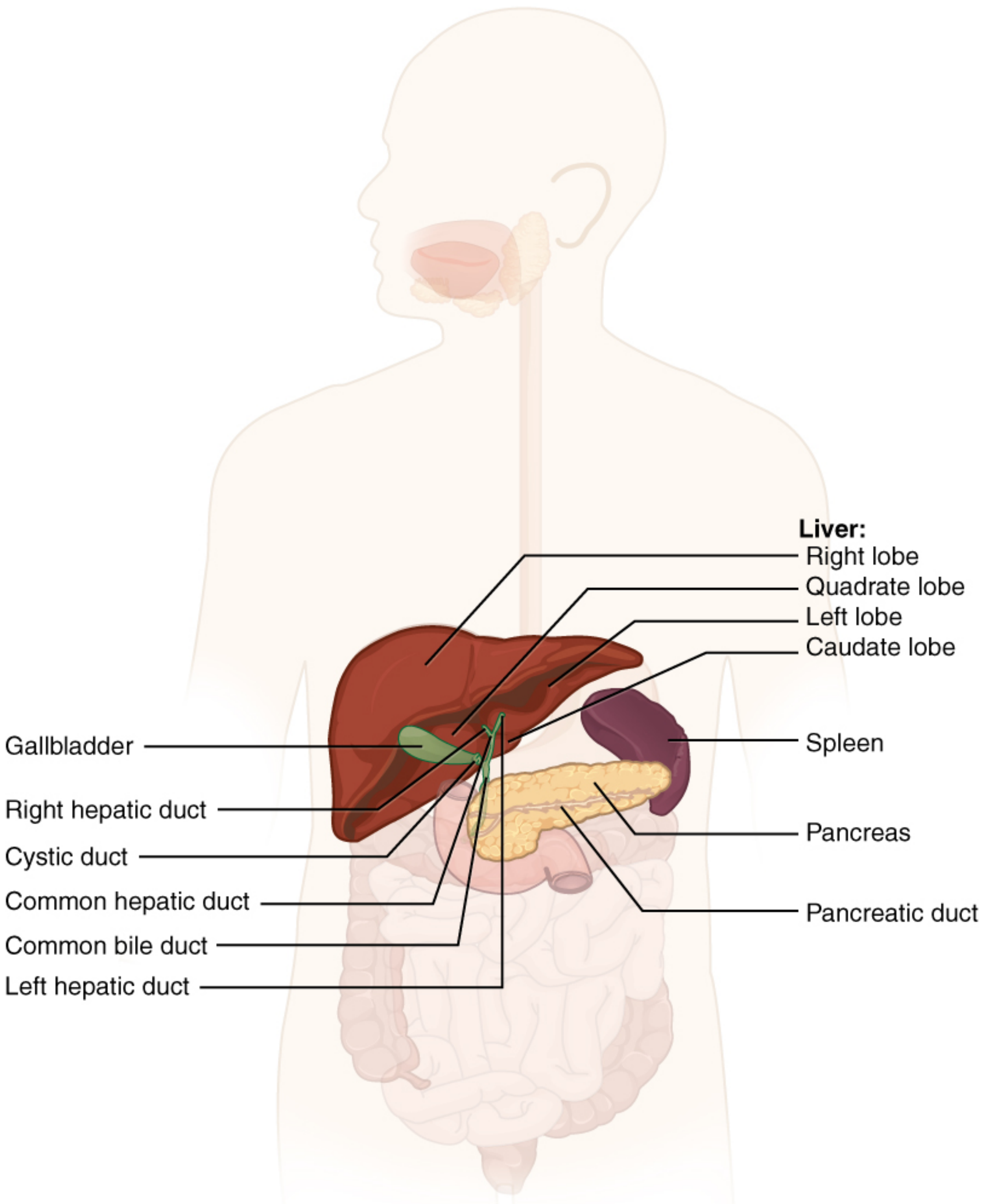

Figure 12.8 Accessory Organs. The liver, pancreas, and gallbladder are considered accessory digestive organs, but their roles in the digestive system are vital. From Betts, et al., 2021. Licensed under [CC BY 4.0.](#)

Liver

The **liver** is the largest gland in the body, weighing about three pounds in an adult. It is also one of the most important organs. In addition to being an accessory digestive organ, it plays a number of roles in metabolism and regulation. The liver lies inferior to the diaphragm in the right upper quadrant of the abdominal cavity and receives protection from the surrounding ribs. The liver is divided into two primary lobes: a large right lobe and a much smaller left lobe.

The hepatic portal vein delivers partially deoxygenated blood containing nutrients absorbed from the small intestine and actually supplies more oxygen to the liver than do the much smaller hepatic arteries. In addition to nutrients, drugs and toxins are also absorbed. After processing the bloodborne nutrients and toxins, the liver releases nutrients needed by other cells back into the blood, which drains into the central vein and then through the hepatic vein to the inferior vena cava. With this **hepatic** portal circulation, all blood from the alimentary canal passes through the liver. This largely explains why the liver is the most common site for the metastasis of cancers that originate in the alimentary canal.

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 12.9).

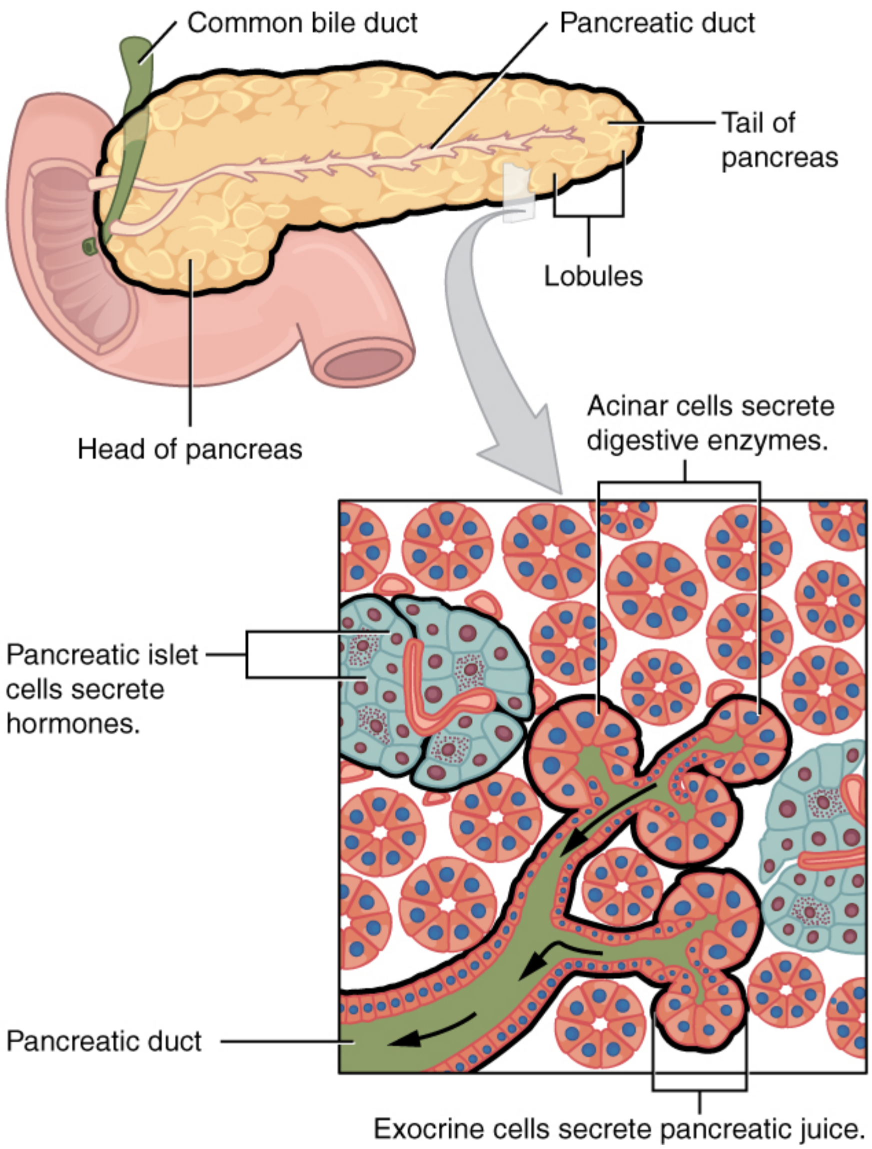

Figure 12.9 Exocrine and Endocrine Pancreas. The pancreas has a head, a body, and a tail. It delivers pancreatic juice to the duodenum through the pancreatic duct. From Betts, et al., 2021. Licensed under [CC BY 4.0.](#)

Gallbladder

The **gallbladder** is 8–10 cm (~3–4 in) long and is nested in a shallow area on the posterior aspect of the right lobe of the liver. This muscular sac stores, concentrates, and, when stimulated, propels the bile into the duodenum via the common bile duct. It is divided into three regions. The **fundus** is the widest portion and tapers medially into the **body**, which in turn narrows to become the **neck**.

Anatomy Labeling Activity

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Physiology (Function) of the Digestive System

The main functions of the digestive system are:

- Ingesting food
- Digesting food
- Absorbing nutrients
- Elimination of waste products

Digestive Processes

The processes of digestion include six activities: ingestion, **propulsion**, mechanical or physical digestion, chemical digestion, absorption, and **defecation**.

The first of these processes, **ingestion**, refers to the entry of food into the alimentary canal through the mouth. There, the food is chewed and mixed with saliva, which contains enzymes that begin breaking down the carbohydrates in the food plus some lipid digestion via lingual lipase. Chewing increases the surface area of the food and allows an appropriately sized bolus to be produced.

Food leaves the mouth when the tongue and pharyngeal muscles propel it into the esophagus. This act of swallowing, the last voluntary act until defecation, is an example of **propulsion**, which refers to the movement of food through the digestive tract. It includes both the voluntary process of swallowing and the involuntary process of peristalsis. **Peristalsis** consists of sequential, alternating waves of contraction and relaxation of alimentary wall smooth muscles, which act to propel food along (see Figure 12.10). These waves also play a role in mixing food with digestive juices. Peristalsis is so powerful that foods and liquids you swallow enter your stomach even if you are standing on your head.

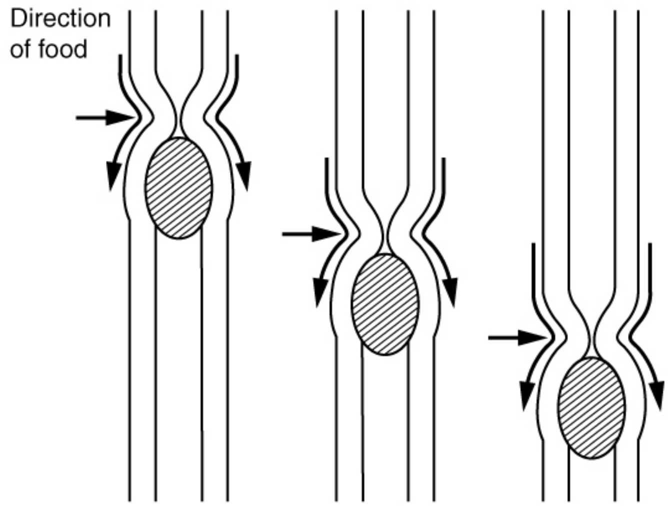

Figure 12.10. Peristalsis. Peristalsis moves food through the digestive tract with alternating waves of muscle contraction and relaxation. From Betts, et al., 2021. Licensed under CC BY 4.0.

Digestion includes both mechanical and chemical processes. **Mechanical digestion** is a purely physical process that does not change the chemical nature of the food. Instead, it makes the food smaller to increase both surface area and mobility. It includes **mastication**, or chewing, as well as tongue movements that help break food into smaller bits and mix food with saliva. Although there may be a tendency to think that mechanical digestion is limited to the first steps of the digestive process, it occurs after the food leaves the mouth, as well. The mechanical churning of food in the stomach serves to further break it apart and expose more of its surface area to digestive juices, creating an acidic "soup" called **chyme**.

In **chemical digestion**, starting in the mouth, digestive secretions break down complex food molecules into their chemical building blocks (for example, proteins into separate amino acids). These secretions vary in composition, but typically contain water, various enzymes, acids, and salts. The process is completed in the small intestine.

Food that has been broken down is of no value to the body unless it enters the bloodstream and its nutrients are put to work. This occurs through the process of **absorption**, which takes place primarily within the small intestine.

In **defecation**, the final step in digestion, undigested materials are removed from the body as feces.

Digestive System: From Appetite Suppression to Constipation

Age-related changes in the digestive system begin in the mouth and can affect virtually every aspect of the digestive system. Taste buds become less sensitive, so food isn't as appetizing as it once was. A slice of pizza is a challenge, not a treat, when you have lost teeth, your gums are diseased, and your salivary glands aren't producing enough saliva. Swallowing can be difficult, and ingested food moves slowly through the alimentary canal because of reduced strength and tone of muscular tissue.

Pathologies that affect the digestive organs—such as **hiatal** hernia, **gastritis**, and **peptic ulcer** disease—can occur at greater frequencies as you age. Problems in the small intestine may include duodenal ulcers, **maldigestion**, and **malabsorption**. Problems in the large intestine include hemorrhoids, diverticular disease, and constipation. Conditions that affect the function of accessory organs—and their abilities to deliver pancreatic enzymes and bile to the small intestine—include jaundice, acute pancreatitis, cirrhosis, and gallstones.

In some cases, a single organ is in charge of a digestive process. For example, ingestion occurs only in the mouth and defecation only in the anus. However, most digestive processes involve the interaction of several organs and occur gradually as food moves through the alimentary canal (see Figure 12.11).

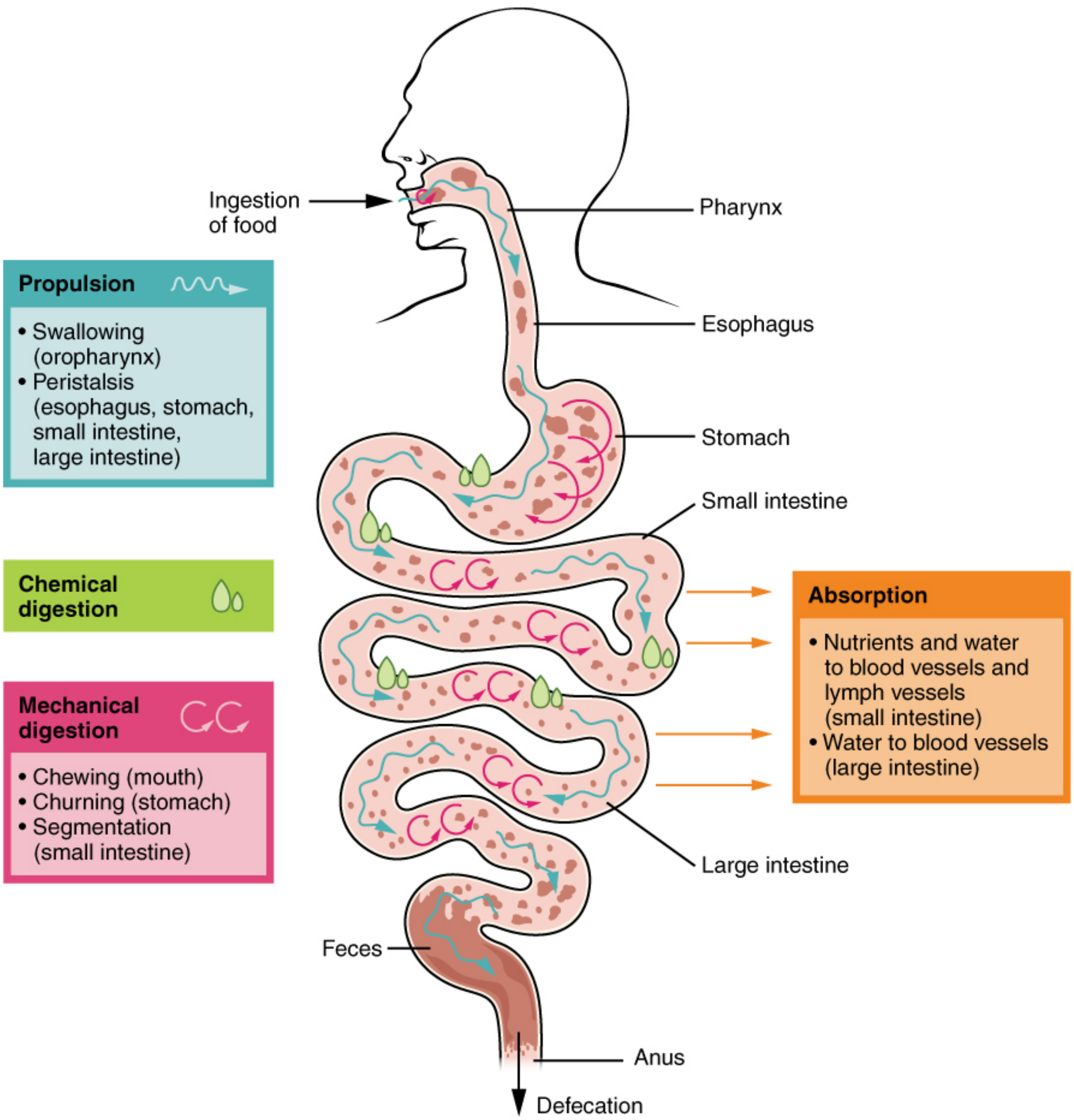

Figure 12.11. Digestive Processes. The digestive processes are ingestion, propulsion, mechanical digestion, chemical digestion, absorption, and defecation. From Betts, et al., 2021. Licensed under [CC BY 4.0.](https://creativecommons.org/licenses/by/4.0/)

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

Medical Terms not Easily Broken into Word Parts

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Common Digestive Abbreviations

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Diseases and Disorders of the Digestive System

Gastroesophageal Reflux Disease

This condition is largely caused by gastric acid flowing upwards from the stomach into the esophagus. Those suffering from the condition will often feel a burning sensation radiating near the top of the stomach. (Mayo Clinic Staff, 2020). To learn more about GERD visit the Mayo Clinic's Gastroesophageal Reflux Disease (GERD) page.

Cholecystitis

This condition is known as inflammation of the gall bladder. Gall stone development can block the gall bladder's release of bile leading to an inflammatory response. Surgical removal (cholecystectomy) or laser stone crushing known as lithotripsy are often the treatment options ("Cholecystitis", 2019). To learn more about cholecystitis visit the Radiology Info's cholecystitis web page.

Cirrhosis

Cirrhosis is condition whereby the liver scars. Advanced cirrhosis is life threatening. It generally can not be reversed. It is caused by different forms of liver disease and chronic alcoholism. (Mayo Clinic Staff, 2018).

Cirrhosis often has no signs or symptoms until liver damage is extensive and may include:

- Fatigue

- Easily bleeding or bruising
- Loss of appetite
- Nausea
- Edema
- Weight loss
- Itchy skin
- Jaundice
- Ascitis (Mayo Clinic Staff, 2018)

To learn more about Cirrhosis visit the Mayo Clinic's Cirrohsis web page .

Esophageal Cancer

This is cancer of the esophagus. The cancer can occur anywhere along the esophageal tube, and can be caused by factors including tobacco use, alcohol, and chronic acid reflux (American Cancer Society medical and editorial team, 2020a). To learn more about esophageal cancer, visit the American Cancer Society's Esophageal Cancer web page.

Hepatitis A, B and C

Inflammation of the liver is referred to as hepatitis. This condition can by caused by several factors such as viruses, alcohol consumption, toxins, and drug interactions. In some cases it can also be caused by an autoimmune response in the body. There are five types of viral hepatitis, A, B, C, D, and E (Booth, 2018). To learn more, visit Healthline's article on Hepatitis.

Celiac Sprue (Celiac Disease)

Individuals who posses celiac disease have an immune sensitivity reaction occurring in the small intestines when they consume gluten. Typically people with this condition are genetically pre-disposed to the condition. Damage to the small intestine will occur if continued consumption of gluten occurs. Individuals once diagnosed eat a gluten free diet as a best approach for management of the condition. (Celiac Disease Foundation, n.d.). To learn more, visit the Celiac Disease Foundation's *What is Celiac Disease?* article .

Crohn's Disease and Ulcerative Colitis

Crohn's disease and ulcerative colitis are chronic inflammatory bowel diseases (IBD) whereby a section or segments of the digestive tract experience inflammation. Crohn's disease can occur anywhere along the digestive tract from the mouth to the anus, although it is most often found in the small intestines. This often leads to malabsorption of nutrients from food. Ulcerative colitis is localized inflammation and ulcers in the colon (UCLA Health, n.d.). To learn more, visit UCLA Health's page about inflammatory bowel diseases.

Colon Cancer

Cancer formation in the colon portion of the digestive tract. It is typically found in older adults. Colon cancer is often diagnosed through a colonoscopy. (American Cancer Society medical and editorial team, 2020b). To learn more, visit the American Cancer Society's page on colon cancer.

Hernia

A hernia occurs when an organ or fatty tissue squeezes through a weak spot in a surrounding muscle or connective tissue. A hiatal hernia is found in the upper stomach region.

Irritable Bowel Syndrome

Irritable bowel syndrome (IBS) is a common disorder affecting the large intestines. IBS often involves abdominal pain as sensitive nerve tissue within the colon react to movement of food and waste through the digestive tract. Along with the abdominal pain individuals often experience gas and bloating. Diet and lifestyle modifications often help in the management of the condition. (American College of Gastroenterology, 2021a). To learn more about irritable bowel syndrome, visit the American College of Gastroenterology's web page on IBS.

Polyps

A polyp is a small growth of tissue protruding outward from the intestinal wall. Some cancers in the intestines start off as a polyp. Typically, they are found in people over the age of 50. Polyps start as a small collection of cells found within the colon. Most are harmless but can transition over time into a cancerous growth (Mayo Clinic Staff, 2019). To learn more about polyps review the Mayo Clinic's patient information page on polyps.

Medical Terms in Context

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