Course Title: Cardiopulmonary Medical Terminology

chapter list:-

Medical Terminology for Healthcare Professions
(chapters 1, 2, 9, 10 & 12)

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1. Word Parts and Rules

Learning Objectives

- Identify word parts in medical terms.
- Examine the rules for building medical terms.

Word Parts

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

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Identifying Word Parts in Medical Terms

By the end of this book, you will have identified hundreds of word parts within medical terms. Let's start with some common medical terms that many non-medically trained people may be familiar with.

Examples

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

arthr/o is a **combining form** that means joint
-itis is a **suffix** that means inflammation

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

Notice, when breaking down words that you place slashes between word parts and a slash on each side of a combining form vowel.

Language Review

Before we begin analyzing the rules let's complete a short language review that will assist with pronunciation and spelling.

Short Vowels
a, e, i, o, u, and sometimes y are indicated by lower case.

Long Vowels
A, E, I, O, U are indicated by upper case.

Consonants
Consonants are all of the other letters in the alphabet. b, c, d, f, g, h, j, k, l, m, n, p, q, r, s, t, v, w, x, and z.

Language Rules

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

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

Language Rules for Building Medical Terms

1. When combining two **combining forms**, you keep the **combining form vowel**.

2. When combining a **combining form** with a **suffix** that begins with a consonant, you keep the **combining form vowel**.

Examples

Gastr/o/enter/o/logy – The study of the stomach and the intestines

- Following **rule 1,** when we join combining form gastr/o (meaning stomach) with the combining form enter/o (meaning intestines) we keep the combining form vowel o.
- Following **rule 2**, when we join the combining form enter/o (meaning intestines) with the suffix -logy (that starts with a suffix and means the study of) we keep the combining form vowel o.

3. When combining a **combining form** with a **suffix** that begins with a vowel, you drop the **combining form vowel**.
4. A **prefix** goes at the beginning of the word and no **combining form vowel** is used.

Examples

Intra/ven/ous – Pertaining to within the vein

- Following **rule 3**, notice that when combining the combining form ven/o (meaning vein) with the suffix -ous (that starts with a vowel and means pertaining to) we drop the combining form vowel o.
- Following **rule 4**, the prefix intra- (meaning within) is at the beginning of the medical term with no combining form vowel used.

5. When defining a medical word, start with the **suffix** first and then work left to right stating the word parts. You may need to add **filler** words. As long as the filler word does not change the meaning of the word you may use it for the purpose of building a medical vocabulary. Once you start to apply the word in the context of a sentence it will be easier to decide which filler word(s) to choose.

Examples

Intra/ven/ous – Pertaining to within the vein or Pertaining to within a vein.

- Following **rule 5**, notice that I start with the suffix -ous (that means pertaining to) then we work left to right starting with the prefix Intra- (meaning within) and the combining form ven/o (meaning vein).
- Notice that we have used two different definitions that mean the same thing.
- In these examples we do not have the context of a full sentence. For the purpose of building a medical terminology foundation either definition is accepted.

2. Prefixes and Suffixes

Learning Objectives

- Understand the difference between a prefix and a suffix.
- Differentiate prefixes that deal with body parts, color, and direction.
- Distinguish suffixes that deal with procedures.

Prefixes

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

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

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

Common Prefixes

PREFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
A-, An-	Without; Lacking	**Anemia**
Andr/o-	Male	**Androgen**
Anti-	Against	**Anticholinergic drugs**
Auto-	Self	**Autocrine**
Bio-	Life	**Biology**
Chem/o-	Chemistry	**Chemotherapy**
Contra-	Against	**Contraception**
Cyt/o-	Cell	**Cytokine**
Dis-	Separation; Taking apart	**Dissection**
Dys-	Difficult; Abnormal	**Dyspnea**
Eu-	Good; Well	**Eupnea**
Fibr/o-	Fiber	**Fibrosis**
Gluco-, Glyco-	Glucose; Sugar	**Glycogen**
Gyn/o-, Gynec-	Female	**Gynecology**
Hydr/o-	Water	**Hydrocephalus**
Idio-	Self; One's own	**Idiopathic**
Lyso-, Lys-	Break down; Destruction; Dissolving	**Lysosome**
Mal-	Bad; Abnormal	**Malignant**
Myc/o-	Fungus	**Mycetoma**
Necr/o-	Death	**Necrosis**
Neo-	New	**Neonate**
Oxy-	Sharp; Acute; Oxygen	**Oxytocin**
Pan-, Pant/o-	All or everywhere	**Pancytopenia**
Pharmaco-	Drug; Medicine	**Pharmacist**
Re-	Again; Backward	**Rejuvenation**
Somat/o-, Somatico-	Body; Bodily	**Somatic cell**

Body Part Prefixes

PREFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
Acous/o-	Hearing	**Acoustic meatus**
Aden/o-	Gland	**Adenoid**
Adip/o-	Fat	**Adipocyte**
Adren/o-	Gland	**Adrenal cortex**
Angi/o-	Blood vessel	**Angioplasty**
Arteri/o-	Artery	**Arteriole**
Arthr/o-	Joint	**Arthroplasty**
Bucc/o-	Cheek	**Buccal cavity**
Bronch/i-	**Bronchus**	**Bronchioles**
Burs/o-	**Bursa**	**Bursa**
Carcin/o-	Cancer	**Basal cell carcinoma**
Cardi/o-	Heart	**Cardiology**
Cephal/o-	Head	**Cephalic flexure**
Chol-	Bile	**Cholesterol**
Chondri-	Cartilage	**Chondrosarcoma**
Coron-	Heart	**Coronary arteries**
Cost-	Rib	**Costal cartilage**
Crani/o-	Brain	**Cranium**
Cutane-	Skin	**Cutaneous**
Cyst/o-, Cysti-	Bladder or sac	**Cystoscopy**
Derm-, Dermat/o-	Skin	**Dermatologist**
Duoden/o-	**Duodenum**	**Duodenitis**
Gastr-	Stomach	**Gastrectomy**
Gloss-	Tongue	**Glossectomy**
Hem-, Hema-, Hemat-, Hemo-, Hemat/o-	Blood	**Hematopoiesis**
Hepat/o-, Hepatico-	Liver	**Hepatic portal system**
Hist/o-, Histio-	Tissue	**Histology**
Hyster/o-	Uterus	**Hysterectomy**
Ileo-	**Ileum**	**Ileostomy**
Ischi/o-	**Ischium**	**Ischial tuberosity**
Kerat/o-	Corena (eye or skin)	**Keratin**
Lacrim/o-	Tear (from your eyes)	**Lacrimal fluid**
Lact/o-, Lacti-	Milk	**Lactose**

Laryng/o-	**Larynx**	**Laryngitis**
Lingu/o-	Tongue	**Lingual tonsil**
Lip/o-	Fat	**Lipolysis**
Lymph/o-	Lymph	**Lymphocyte**
Mamm-, Mast/o-	Breast	**Mammary glands**
Mening/o-	**Meninges**	**Meningitis**
Muscul/o-	Muscle	**Musculoskeletal**
My/o-	Muscle	**Myocardium**
Myel/o-	Spinal cord or bone marrow	**Myelin**
Nephr/o-	Kidney	**Nephron**
Neur/i-, Neur/o-	Nerve	**Neuron**
Oculo-	Eye	**Oculomotor nerve**
Onco-	Tumor; Bulk; Volume	**Oncogene**
Onych/o-	Fingernail; Toenail	**Onychodystrophy**
Oo-	Egg; Ovary	**Oocyte**
Oophor/o-	Ovary	**Oophorectomy**
Op-, Opt-	Vision	**Optic nerve**
Ophthalm/o-	Eye	**Ophthalmic artery**
Orchid/o-, Orchio-	Testis	**Orchidectomy**
Orth/o-	Straight; Normal; Correct	**Orthostatic**
Osseo-	Bony	**Osseous tissue**
Ossi-	Bone	**Ossicles**
Ost-, Oste/o-	Bone	**Osteoporosis**
Ot/o-	Ear	**Otolaryngologist**
Ovar/i-, Ovario-, Ovi-, Ovo-	Ovary	**Ovarian follicle**
Phalang-	**Phalanx**	**Phalanges**
Pharyng/o-	Pharynx; Throat	**Pharyngeal tonsil**
Phleb/o-	Vein	**Phlebotomist**
Phren/i-, Phreno-, Phrenico-	Diaphragm	**Phrenic nerve**
Pleur-, Pleur/a-, Pleur/o-	Rib, **pleura**	**Pleural cavity**
Pneum/a- Pneumat/o-	Air; Lung	**Pneumonia**
Proct/o-	Anus; Rectum	**Proctoscopy**

Prostat-	Prostate	**Prostatectomy**
Pseudo-	False	**Pseudostratified**
Psych/o-, Psyche-	Mind	**Psychiatrist**
Radio-	Radiation; Radius	**Radioisotopes**
Ren/o-	Kidney	**Renal cortex**
Retin-	Retina (of the eye)	**Retinitis pigmentosa**
Rhin/o-	Nose	**Rhinoscope**
Salping/o-	Tube	**Salpingo-oophorectomy**
Sarco-	Muscular; Flesh-like	**Sarcomere**
Schiz/o-	Split; Cleft	**Schizophrenia**
Sclera-, Sclero-	Hardness	**Sclerosis**
Sigmoid/o-	Sigmoid colon	**Sigmoidoscopy**
Sperma-, Spermo-, Spermato-	Sperm	**Spermatocyte**
Splen/o-	Spleen	**Splenomegaly**
Sten/o-	Narrowed; Blocked	**Stenosis**
Stern-	**Sternum**	**Sternoclavicular joint**
Stom/a-, Stomat/o-	Mouth	**Stomatitis**
Thorac/o-, Thoracico-	Chest	**Thoracic cavity**
Thromb/o-	Blood clot	**Thrombolytic**
Thyr/o-	Thyroid gland	**Thyroiditis**
Trache/o-	**Trachea**	**Trachealis**
Tympan/o-	Eardrum	**Tympanic membrane**
Ur/o-	Urine	**Urologist**
Vagin-	Vagina	**Vaginal**
Varic/o-	Duct; Blood vessel	**Varicose veins**
Vasculo-	Blood vessel	**Vasculitis**
Ven/o-	Vein	**Venae cavae**
Vertbr-	Vertebra; Spine	**Vertebral column**

Color Prefixes

PREFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
Chlor/o-	Green	**Chlorophyll**
Chrom-, Chromato-	Color	**Chromosome**
Cyano-	Blue	**Cyanosis**
Erythr/o-	Red	**Erythrocyte**
Leuk/o-	White	**Leukocyte**
Melan/o-	Black	**Melanin**

Physical Property and Shape Prefixes

PREFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
Cry/o-	Cold	**Cryotherapy**
Elect-	Electrical activity	**Electrocardiogram**
Kin/o-, Kine-, Kinesi/o-	Movement	**Kinetic energy**
Kyphy/o-	Humped	**Kyphosis**
Rhabd/o-	Rod-shaped; Striated	**Rhabdomyosarcoma**
Phot/o-	Light	**Photoreceptor**
Reticul/o-	Net	**Reticulocytes**
Scoli/o-	Twisted	**Scoliosis**
Therm/o-	Heat	**Thermotherapy**

Direction and Position Prefixes

PREFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
Ab-, Abs-	Away from	**Abductor**
Ad-	Towards	**Adductor**
Ante-	Before; Forward	**Antenatal**
Circum-	Around	**Circumcision**
Cycl-	Circle; Cycle	**Cyclic neutropenia**
De-	Away from; Ending	**Dehydration**
Dia-	Across; Through	**Diagnosis**
Ect/o-, Exo-	Outer; Outside	**Exocrine gland**
End/o-, Ent-, Enter/o-	Within; Inner	**Endocrine gland**
Epi-	Upon; Outside of	**Epidermis**
Ex-, Extra-	Beyond	**Expiration**
Infra-	Beneath; Below	**Infratemporal fossa**
Inter-	Between	**Interstitial fluid**
Intra-	Within	**Intracellular fluid**
Meso-	Middle	**Mesoderm**
Meta-	Beyond; Change	**Metabolism**
Para-	Alongside; Abnormal	**Parathyroid glands**
Path/o-	Disease	**Pathologist**
Peri-	Around	**Pericardium**
Post-	Behind; After	**Postpartum**
Pre-	Before; In front	**Precancerous**
Retro-	Backward; Behind	**Retroperitoneum**
Sub-	Under	**Subcutaneous layer**
Super-	Above	**Superior**
Supra-	Above; Upon	**Supraglottis**
Sy-, Syl-, Sym-, Syn-, Sys-	Together	**Syndrome**
Trans-	Across; Through	**Transdermal**

Quantity Prefixes

PREFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
Bi-	Two	**Biceps**
Brady-	Slow	**Bradycardia**
Diplo-	Double	**Diploid**
Hemi-	Half	**Hemihypertrophy**
Hetero-	Other; Different	**Heterogeneous**
Homo-	Same	**Homozygous genotype**
Hyper-	Above; Beyond; Excessive	**Hypertension**
Hypo-	Under; Deficient	**Hypotension**
Iso-	Equal; Like	**Isointense**
Macro-	Large; Long; Big	**Macrophage**
Mic-, Micro-	Small	**Microglia**
Mon-, Mono-	One	**Monocyte**
Olig/o-	Few; Little	**Oliguria**
Poly-	Many; Excessive	**Polyuria**
Quadri-	Four	**Quadriceps**
Semi-	Half	**Semilunar valves**
Tachy-	Fast	**Tachycardia**
Tetra-	Four	**Tetralogy of Fallot**
Tri-	Three	**Triceps**
Uni-	One	**Unicellular**

Concept Check

- Do you know the difference between the prefixes **inter-**, **infra-**, and **intra-**?
- What color is an erythrocyte? A leukocyte?
- Which prefixes could you use to indicate something is:
    - around something else?

- within something else?
- below something else?

Suffixes

Suffixes are word parts that are located at the end of words. Suffixes can alter the meaning of medical terms. It is important to spell and pronounce suffixes correctly.

Suffixes in medical terms are common to English language suffixes. Suffixes are not always explicitly stated in the definition of a word. It is common that suffixes will not be explicitly stated when defining a medical term in the workplace. However, when transcribing or reading medical reports the suffix is always clearly written. In order to properly spell and pronounce medical terms, it is helpful to learn the suffixes.

Common Suffixes

SUFFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
-ac	Pertaining to	**Cardiac**
-blast, -blasto, -blastic	Bud; Germ	**Myeloblast**
-cyte, -cytic	Cell	**Thrombocyte**
-dynia	Pain; Swelling	**Thoracodynia**
-eal, -ial	Pertaining to	**Esophageal**
-ectasis	Expansion; Dilation	**Atelectasis**
-emia	Blood condition	**Anemia**
-ia	Condition	**Hemophilia**
-iasis	Condition; Formation of	**Psoriasis**
-ism	Condition	**Hypothyroidism**
-ites, -itis	Inflammation	**Arthritis**
-ity	Pertaining to	**Immunity**
-ium	Structure or tissue	**Epithelium**
-lysis, -lytic	Break down; Destruction; Dissolving	**Osteolytic**
-malacia	Softening	**Osteomalacia**
-megaly	Enlargement	**Acromegaly**
-oid	Resembling	**Arachnoid trabeculae**
-oma	Tumor	**Angiosarcoma**
-osis	Condition; Usually abnormal	**Endometriosis**
-ous	Pertaining to	**Aqueous**
-pathy	Disease	**Lymphadenopathy**
-penia	Deficiency; Lack of	**Thrombocytopenia**
-phagia, -phagy	Eating; Swallowing	**Dysphagia**
-phasia	Speech	**Aphasia**
-plasia, -plastic	Growth	**Hyperplasia**
-plegia	Paralysis	**Hemiplegia**
-pnea	Breathing	**Sleep apnea**
-poiesis	Production	**Hemopoiesis**
-ptosis	Falling; Drooping	**Apoptosis**
-rrhage, -rrhagic	Bleeding	**Hemorrhage**
-rrhea	Flow or discharge	**Diarrhea**

-sclerosis	Hardening	**Arteriosclerosis**
-sis	Condition	**Agranulocytosis**
-stasis	Level; Unchanging	**Homeostasis**
-trophy	Growth	**Hypertrophy**
-uria	In the urine	**Anuria**

Procedure Suffixes

SUFFIX	MEANING	EXAMPLE OF USE IN MEDICAL TERMS
-centesis	Surgical puncture to remove fluid	**Thoracentesis**
-desis	Surgical binding	**Pleurodesis**
-ectomy	Cut out; Removal	**Mastectomy**
-gram	Record; Picture	**Electrocardiogram**
-graph	Instrument used to create a record or picture	**Electrocardiograph**
-graphy	To record or take a picture	**Echocardiography**
-meter	Device used for measuring	**Sphygmomanometer**
-opsy	Visual examination	**Biopsy**
-ostomy	Opening	**Colostomy**
-otomy	Incision	**Laparotomy**
-pexy	Surgical fixation	**Oophoropexy**
-plasty	Surgical reconstruction	**Vertebroplasty**
-scope	For examining	**Endoscope**
-scopy	Examine	**Endoscopy**

Concept Check

- Do you know the difference between the suffixes **-gram**, **-graph**, and **-graphy?**
- Which suffixes denote a condition or disease?

9. Cardiovascular System

Learning Objectives

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

Cardiovascular System Word Parts

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

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Introduction to the Cardiovascular System

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

Watch this video:

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.uwf.edu/medicalterminology/?p=92#oembed-1

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

Practice Medical Terms Related to the Cardiovascular System

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Anatomy of the Heart

Location

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

Concept Check

- On the diagram below (Figure 1), locate the **mediastinum**, the **pericardial cavity**, the **base** of the heart and the **apex** of the heart.
- Locate the largest vein in the body, the **superior vena cava**.

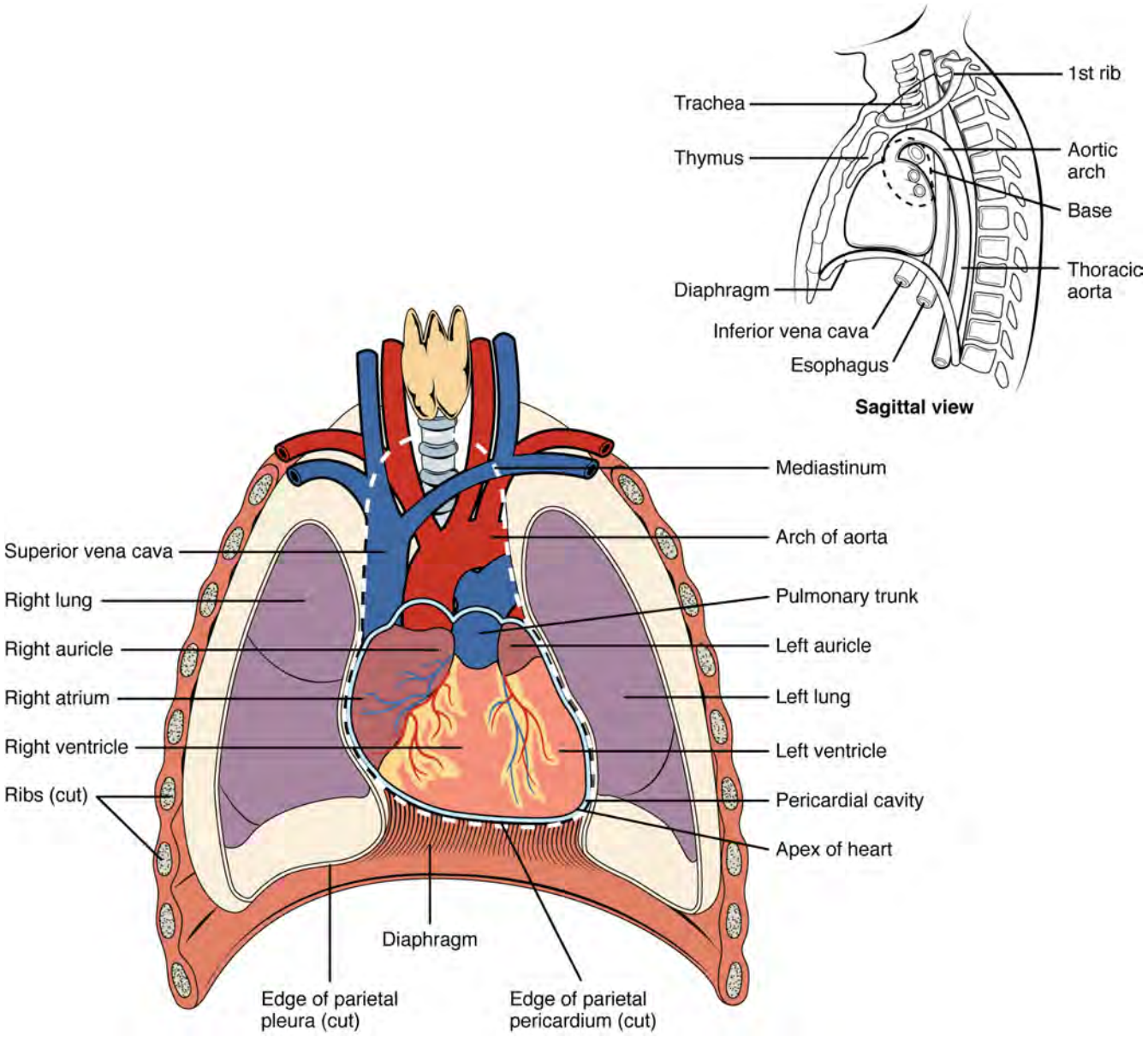

Figure 9.1. Position of the Heart in the Thorax. The heart is located within the thoracic cavity, medially between the lungs in the mediastinum. It is about the size of a fist, is broad at the top, and tapers toward the base. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Membranes and Layers of the Heart Walls

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

- The sturdy outer fibrous pericardium is made of tough, dense connective tissue that protects the heart and holds it in position.
- Separated by the **pericardial cavity** and containing pericardial fluid the inner **serous** pericardium consists of two layers:

    - the outer **parietal pericardium**, which is fused to the fibrous pericardium.
    - the inner **visceral pericardium**, or **epicardium**, which is fused to the heart and forms the outer layer of the heart wall.

The walls of the heart consist of three layers:

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

Concept Check

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

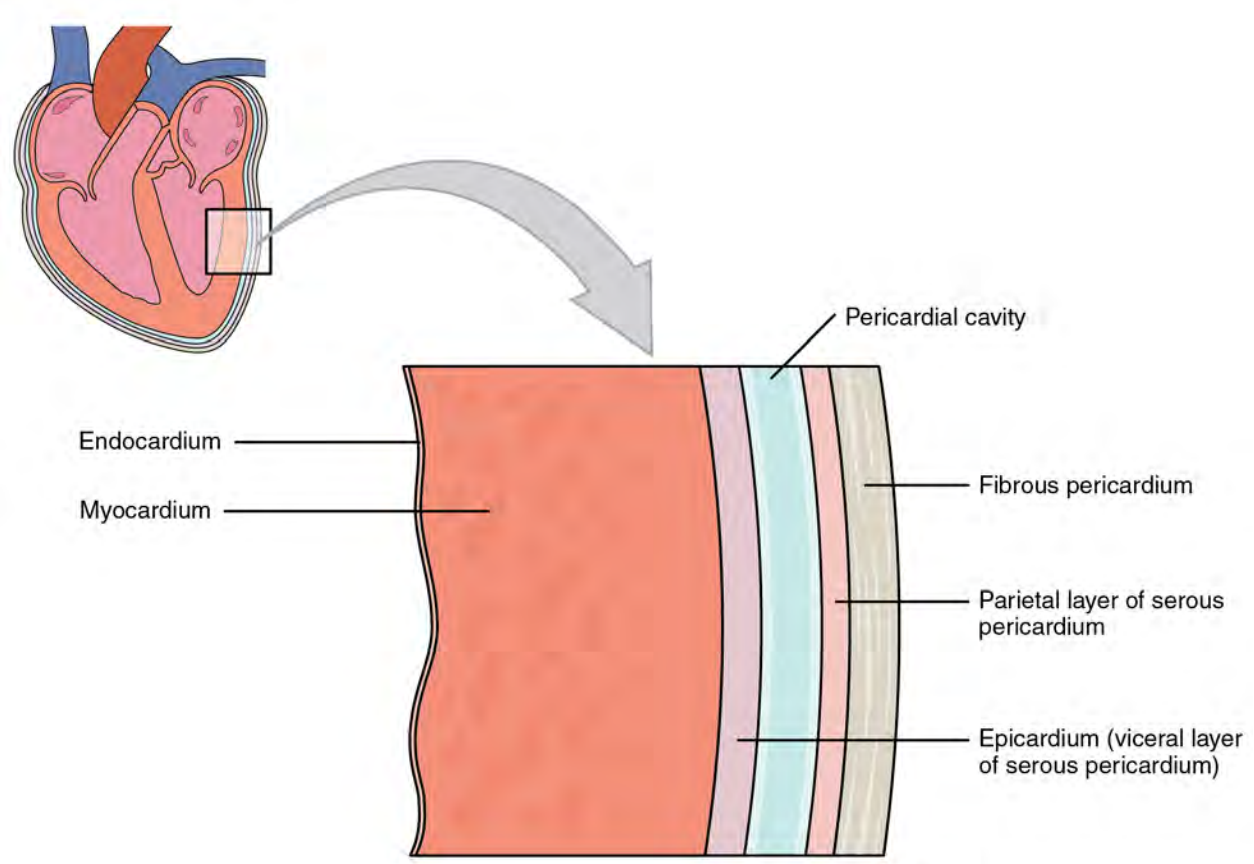

Figure 9.2. Pericardial Membranes and Layers of the Heart Wall. The pericardial membrane that surrounds the heart consists of three layers and the pericardial cavity. The heart wall also consists of three layers. The pericardial membrane and the heart wall share the epicardium From Betts et al., 2013.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

Internal Structures of the Heart

The heart consists of four chambers:

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

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

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

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

There are also two semilunar valves:

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

Anatomy Labeling Activity

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Physiology of the Heart

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

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

1. Circulation Through the Heart: The Heart as a Pump

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

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

Did you know?

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

Concept Check

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

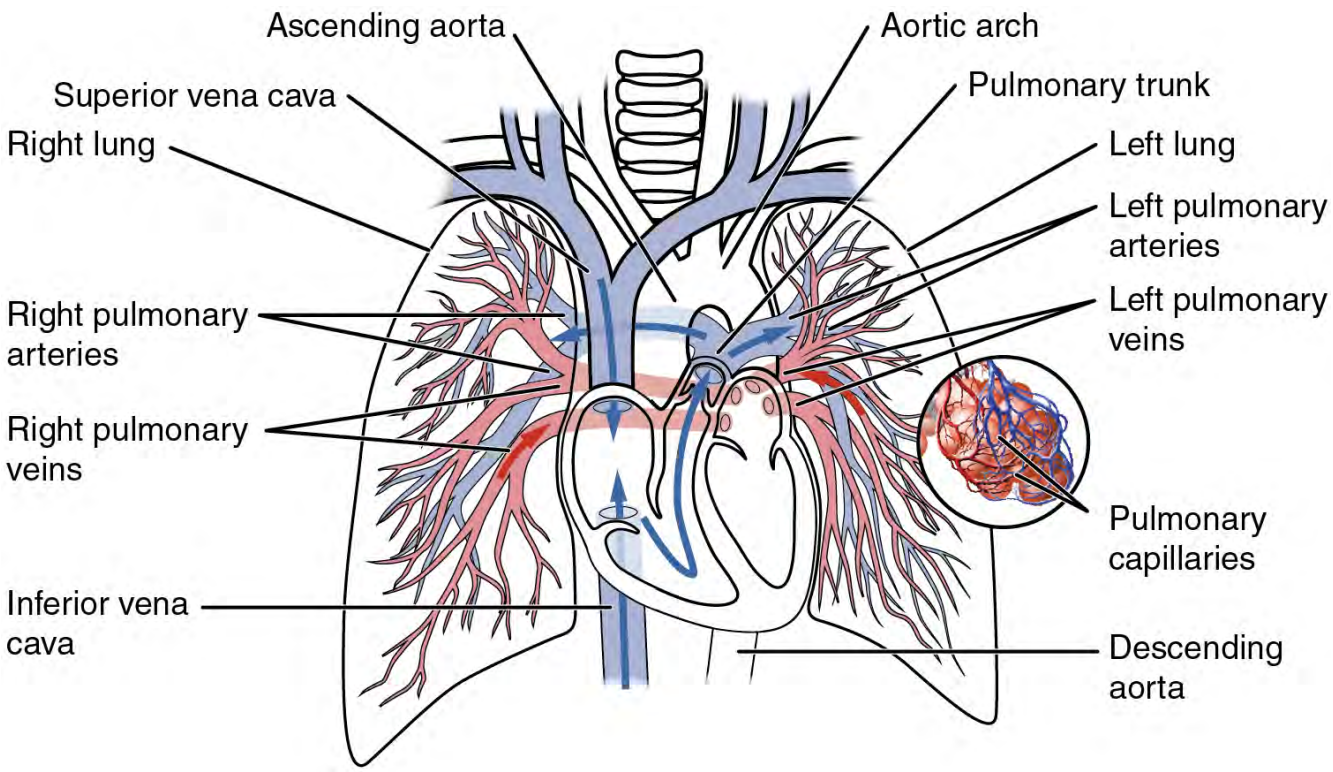

Figure 9.3. Pulmonary Circuit Blood exiting from the right ventricle flows into the pulmonary trunk, which bifurcates into the two pulmonary arteries. These vessels branch to supply blood to the pulmonary capillaries, where gas exchange occurs within the lung alveoli. Blood returns via the pulmonary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

Pulmonary Circuit

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

Concept Check

On Figure 9.4 below, use your finger to trace the pathway of blood flowing through the left side of the heart, naming each of the following structures as you encounter them: right and left pulmonary veins, left atrium, mitral valve, left ventricle, aortic valve, aorta.

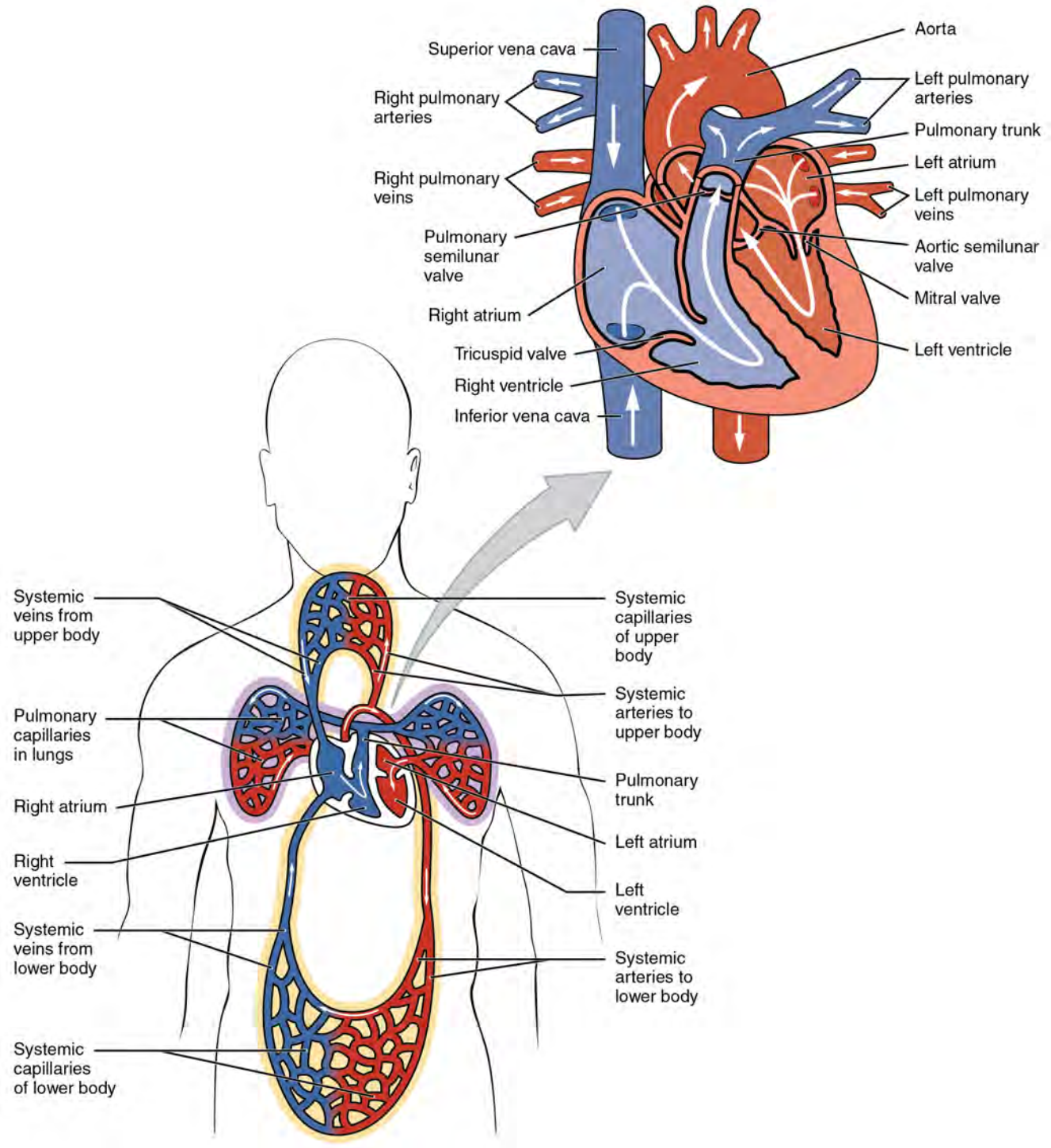

Figure 9.4. Dual System of the Human Blood Circulation. Blood flows from the right atrium to the right ventricle, where it is pumped into the pulmonary circuit. The blood in the pulmonary artery branches is low in oxygen but relatively high in carbon dioxide. Gas exchange occurs in the pulmonary capillaries (oxygen into the blood, carbon dioxide out), and blood high in oxygen and low in carbon dioxide is returned to the left atrium. From here, blood enters the left ventricle, which pumps it into the systemic circuit. Following the exchange in the systemic capillaries (oxygen and nutrients out of the capillaries and carbon dioxide and wastes in), blood returns to the right atrium and the cycle is repeated. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Cardiac Cycle

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

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

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

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

Concept Check

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

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

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

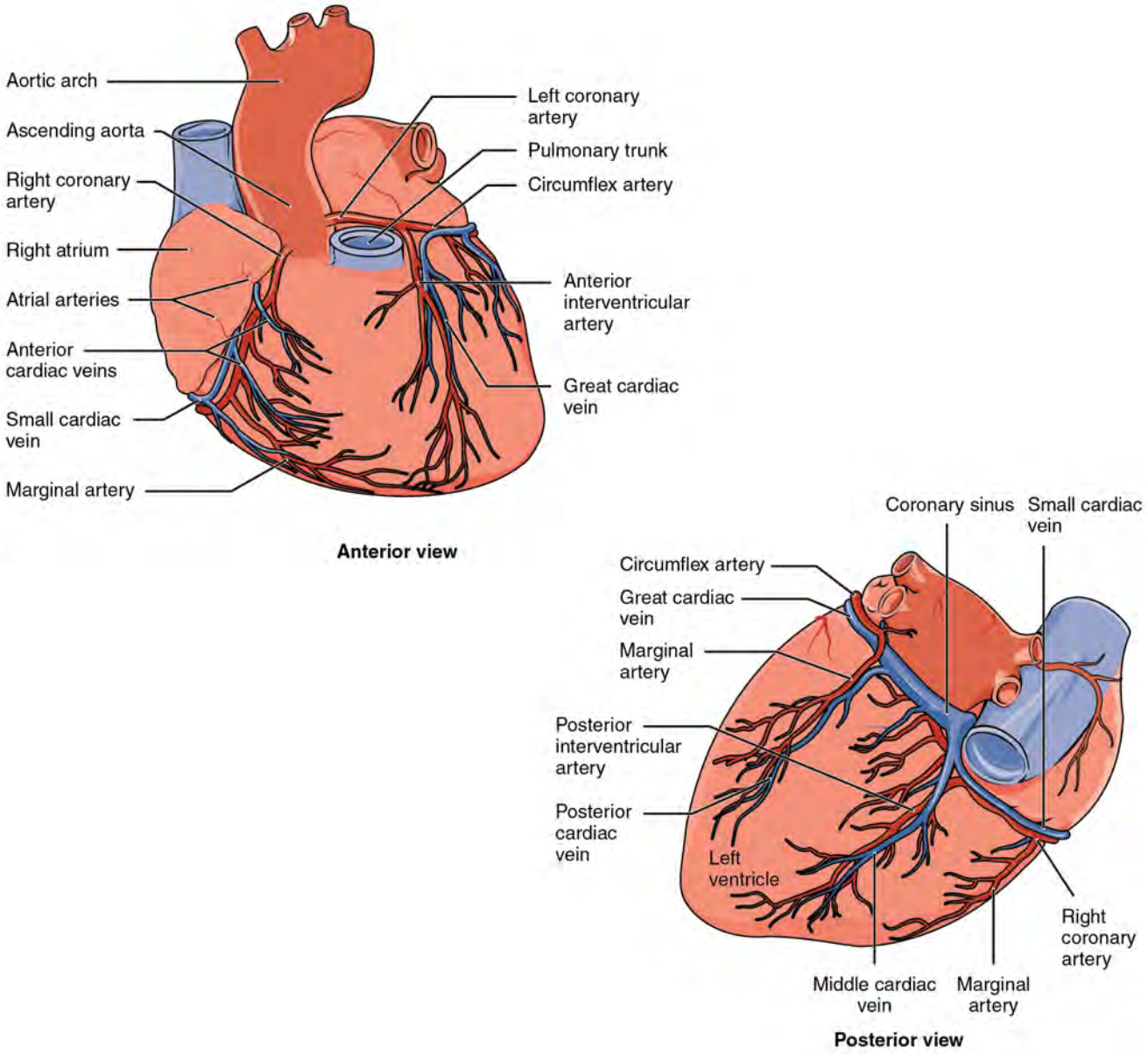

Figure 9.5 Coronary Circulation. The anterior view of the heart shows the prominent coronary surface vessels. The posterior view of the heart shows the prominent coronary surface vessels. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

3. The Heart's Electrical Conduction System

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

Watch this video:

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.uwf.edu/medicalterminology/?p=92#oembed-2

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

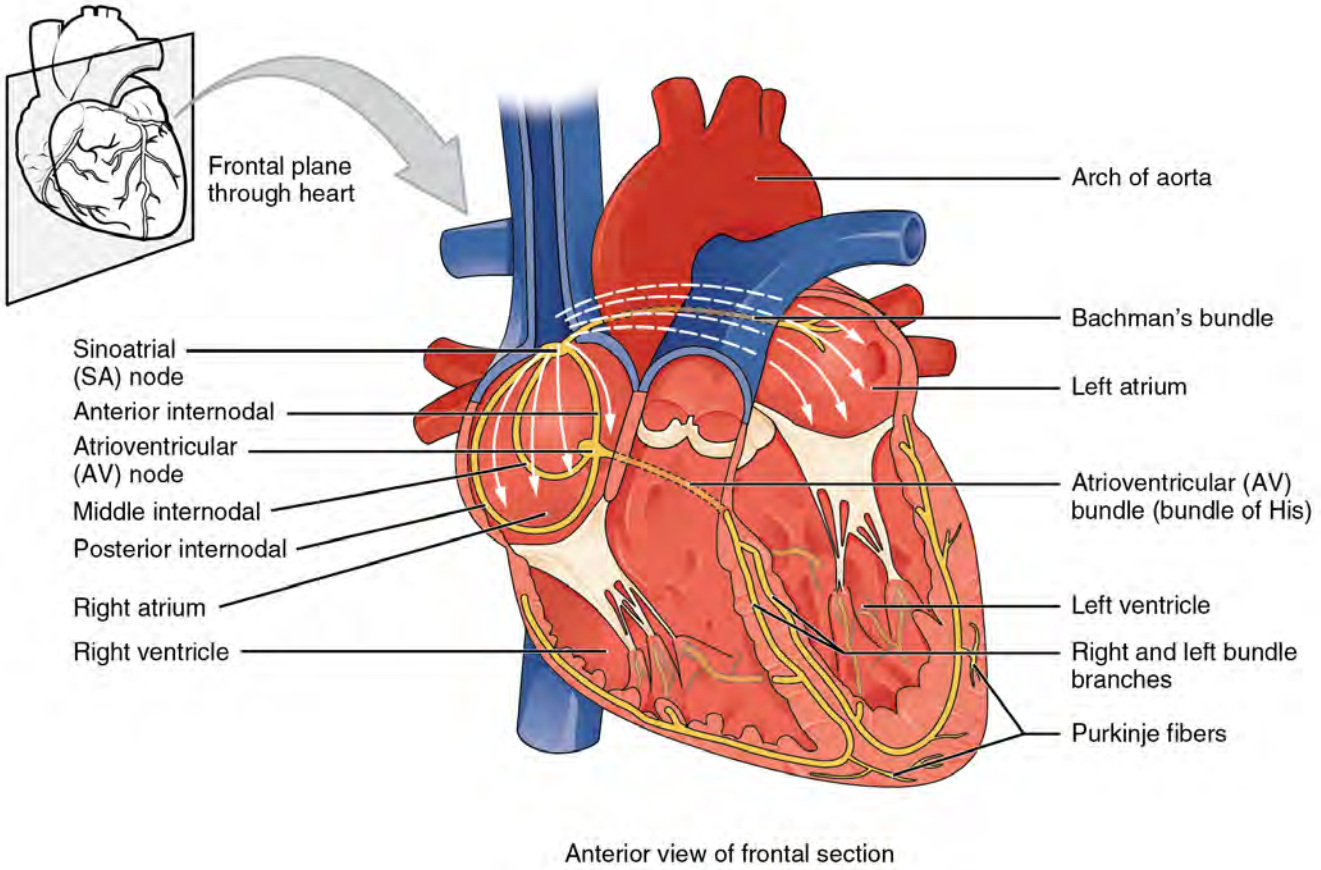

Figure 9.6. Conduction System of the Heart. Specialized conducting components of the heart include the sinoatrial node, the internodal pathways, the atrioventricular node, the atrioventricular bundle, the right and left bundle branches, and the Purkinje fibers. From Betts et al., 2013. Licensed under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

Concept Check

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

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

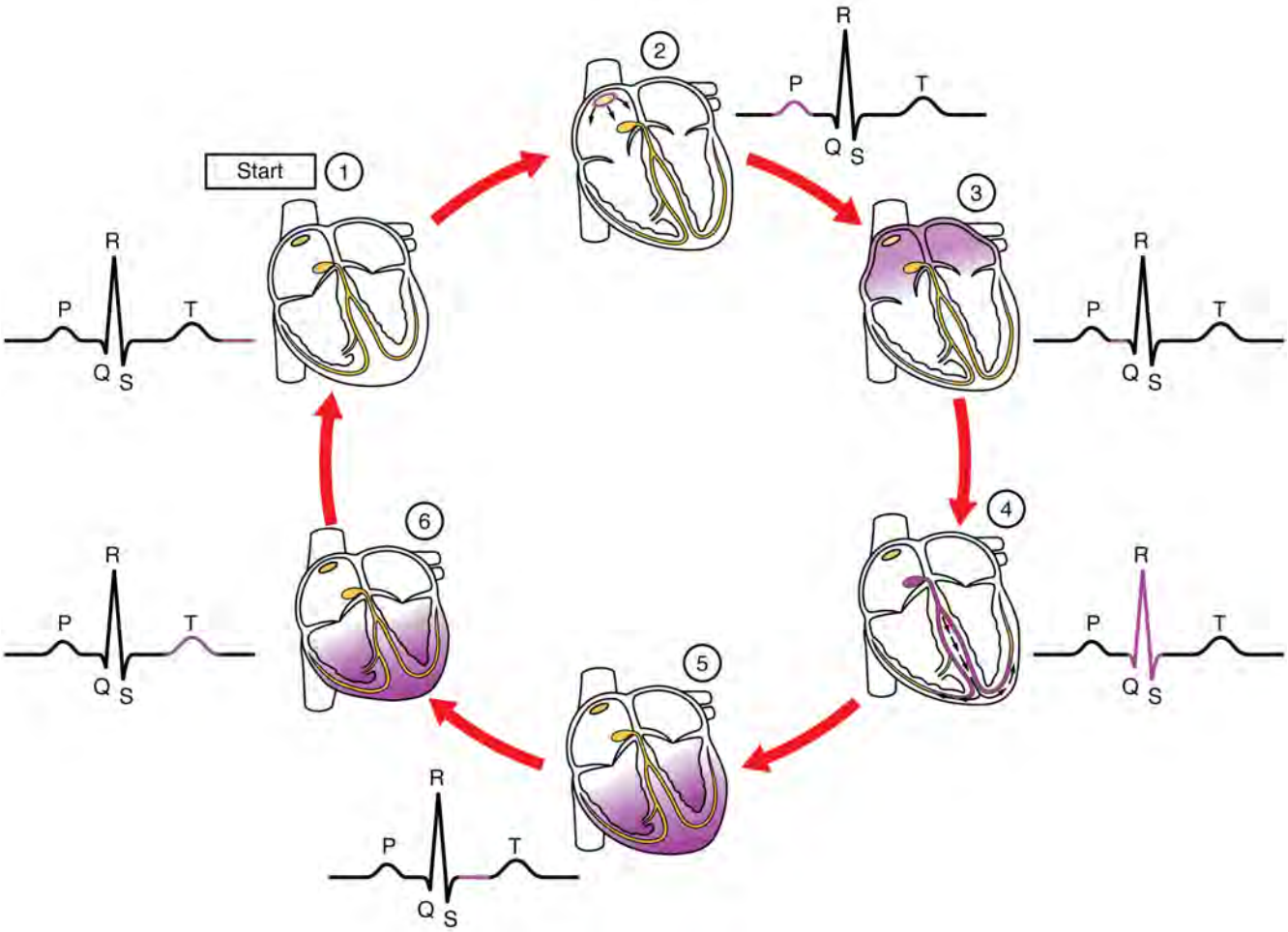

Figure 9.7. ECG Tracing Correlated to the Cardiac Cycle. This diagram correlates an ECG tracing with the electrical and mechanical events of a heart contraction. Each segment of an ECG tracing corresponds to one event in the cardiac cycle. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Practice Terms Related to the Cardiovascular System

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Common Abbreviations for the Cardiovascular System

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.uwf.edu/medicalterminology/?p=92#h5p-59

Diseases and Disorders of the Heart

Cardiomyopathy

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

Other types of cardiomyopathy include:

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

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

Heart Failure

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

Valvular Heart Disease

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

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

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

Visit the Center for Disease Control and Prevention's web page on valvular heart disease to learn more.

Aneurysms

An aneurysm is a defect in the wall of an artery in which the wall becomes thin and weak and starts to balloon out as blood pulses against the vessel wall. This can happen to any artery and even to the myocardial walls. Aneurysms sometimes occur in the portion of the aorta that is in the thorax (see Figure 9.8). If these aneurysms start to leak between layers of the vessel wall, the condition is known as aortic dissection. If an aortic or cardiac aneurysm bursts, there is sudden, massive internal bleeding (Centers for Disease Control and Prevention, n.d.-c).

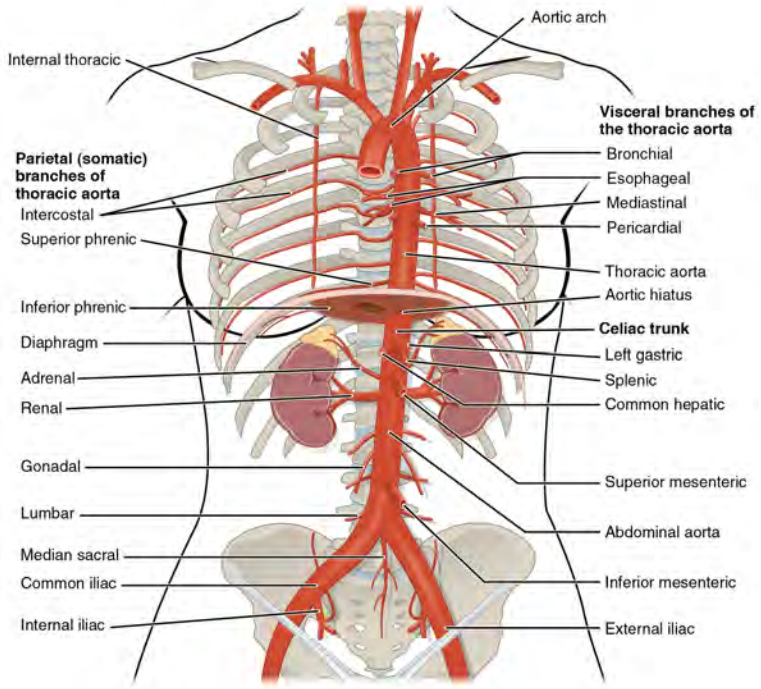


Figure 9.8. Arteries of the Thoracic and Abdominal Regions The thoracic aorta gives rise to the arteries of the visceral and parietal branches. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

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

Heart Defects

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

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

- **Patent ductus arteriosus** is a congenital condition in which the ductus arteriosus fails to close. If untreated, the condition can result in congestive heart failure.
- **Patent foramen ovale** is one type of atrial septal defect (ASD), due to a failure of the hole in the **interatrial septum**

to close at birth.

  - As much as 20 to 25% of the general population may have a patent foramen ovale. Most have the benign, asymptomatic version but in extreme cases, a surgical repair is required to close the opening permanently.

- **Tetralogy of Fallot** is a congenital condition that may also occur from exposure to unknown environmental factors; it occurs when there is an opening in the **interventricular septum** caused by blockage of the pulmonary trunk, normally at the pulmonary semilunar valve. This allows blood that is relatively low in oxygen from the right ventricle to flow into the left ventricle and mix with the blood that is relatively high in oxygen.
  - Signs and symptoms include a distinct heart murmur, low blood oxygen percent saturation, **dyspnea**, **polycythemia**, clubbing of the fingers and toes, and in children, difficulty in feeding or failure to grow and develop.
  - It is the most common cause of **cyanosis** following birth. Other heart defects may also accompany this condition, which is typically confirmed by **echocardiography** imaging.
- In the case of severe septal defects, including both tetralogy of fallot and patent foramen ovale, failure of the heart to develop properly can lead to a condition commonly known as a **blue baby.** Regardless of normal skin pigmentation, individuals with this condition have an insufficient supply of oxygenated blood, which leads to **cyanosis**, especially when active.

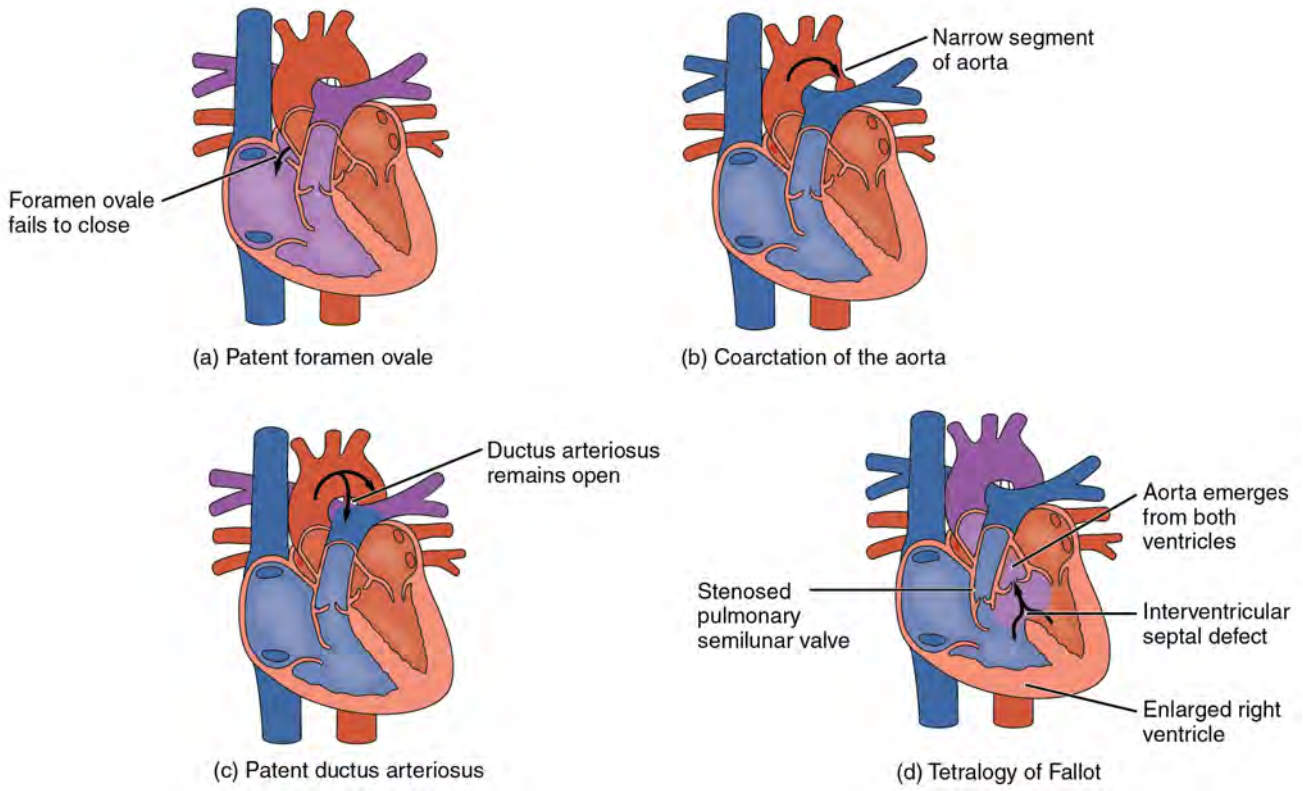


Figure 9.9. Congenital Heart Defects. (a) A patent foramen ovale defect is an abnormal opening in the interatrial septum, or more commonly, a failure of the foramen ovale to close. (b) Coarctation of the aorta is an abnormal narrowing of the aorta. (c) A patent ductus arteriosus is the failure of the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

Diseases Related to Coronary Circulation

Coronary Artery Disease (CAD)

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

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

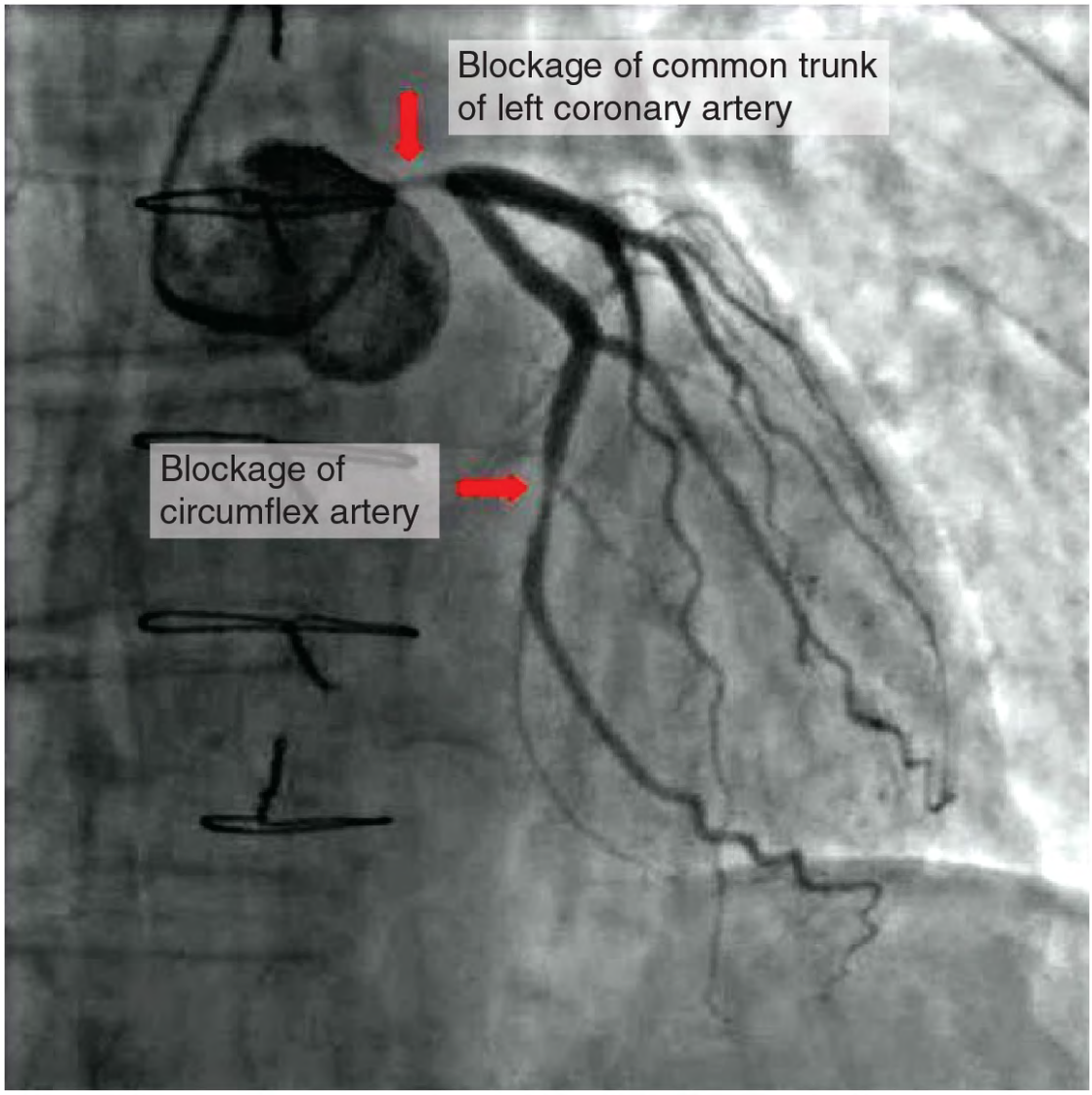


Figure 9.10. Angiogram of Atherosclerotic Coronary Arteries. In this coronary angiogram (X-ray), the dye makes visible two occluded coronary arteries. Such blockages can lead to decreased blood flow (ischemia) and insufficient oxygen (hypoxia) delivered to the cardiac tissues. If uncorrected, this can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

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

- **Angioplasty** is a procedure in which the **occlusion** is mechanically widened with a balloon. A specialized catheter with an expandable tip is inserted into a blood vessel in the arm or leg, and then directed to the site of the occlusion. At this point, the balloon is inflated to compress the plaque material and to open the vessel to increase blood flow. Once the balloon is deflated and retracted, a stent consisting of a specialized mesh is typically inserted at the site of occlusion to reinforce the weakened and damaged walls and prevent re-occlusion.
- **Coronary bypass surgery (Coronary artery bypass graft CABG)** is a surgical procedure which grafts a replacement vessel obtained from another part of the body to bypass the occluded area.

Myocardial Infarction

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

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

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

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

Other diagnostic tests include:

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

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

Did you know?

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

Diseases of the (Electrical) Conduction System

Arrhythmia

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

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

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

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

Did you know?

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

Abnormal Heart Rates

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

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

Heart Block

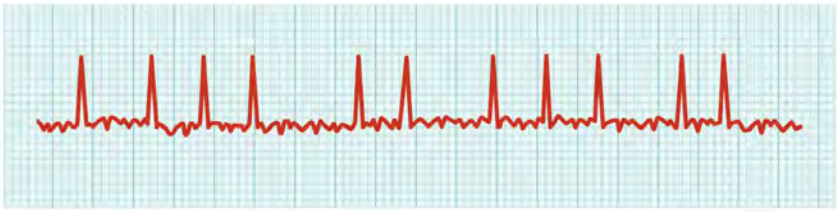
A **heart block** refers to an interruption in the normal conduction pathway. Heart blocks are generally named after the part of the conduction system that is causing the problem. For example, bundle branch blocks occur within either the left or right atrioventricular bundle branches.

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

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

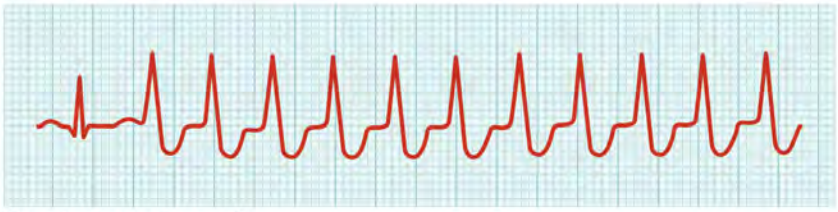
Note how half of the P waves are not followed by the QRS complex and T waves while the other half are.
Question: What would you expect to happen to heart rate (pulse)?

(a) Second-degree (partial) block



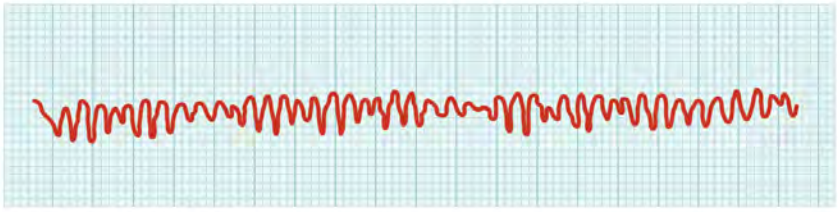
Note the abnormal electrical pattern prior to the QRS complexes. Also note how the frequency between the QRS complexes has increased.
Question: What would you expect to happen to heart rate (pulse)?

(b) Atrial fibrillation



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

(c) Ventricular tachycardia



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

(d) Ventricular fibrillation

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

(e) Third-degree block

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

Medical Terms in Context

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Medical Specialties Related to the Cardiovascular System

Cardiologists and Thoracic Surgeons

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

Cardiology Technologists

Cardiology technologists complete a college training program and perform diagnostic tests such as **electrocardiography** and stress testing, as well as **pacemaker** monitoring (Bureau of Labor Statistics, 2021). Please visit the Bureau of Labor Statistics' web page on cardiology technologists for more information.

Cardiovascular Perfusionists

Cardiovascular perfusionists complete a college training program and are responsible for operation of the heart-lung bypass machine during open heart surgery. They also monitor the patient's vitals and administer medications (New York State Education Department, 2020). For more information, please read this job description from the American Board of Cardiovascular Perfusion (PDF).

Cardiovascular System Vocabulary

Ablation

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

Aneurysm

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

Angina pectoris

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

Angiogram

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

Antihypertensives

A class of medications used to treat high blood pressure.

Arrhythmia

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

Asymptomatic

Having no signs or symptoms of disease.

Atherosclerosis

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

Auscultation

Listening to the heart using a stethoscope.

Atrioventricular (AV)

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

Atrioventricular (AV) valves

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

Bradycardia

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

Cardiac

Having to do with the heart.

Cardiac troponin

The regulatory protein for muscle contraction.

Cardiogenic

Originating from the heart.

Cardiologist

A physician who studies and treats diseases of the heart.

Cardiology

The study of the heart.

Cardiomegaly

Enlarged heart.

Cardiomyopathy

Disease of the heart muscle.

Compliance

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

Computerized tomography (CT)

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

Congenital

Present at birth.

Creatine kinase MB

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

Cyanosis

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

Diabetes mellitus

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

Diaphoresis

Sweating.

Diastole

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

Ductus arteriosus

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

Dyspnea

Difficulty breathing.

Echocardiogram

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

Echocardiography

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

Electrocardiogram (ECG/EKG)

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

Electrocardiograph

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

Electrocardiography

The science of recording the electrical activity of the heart.

Endocarditis

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

Foramen ovale

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

Great vessels

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

Heart murmur

An abnormal heart sound.

Heart rate

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

High-density lipoprotein (HDL)

Often referred to as "good" cholesterol.

Hypercholesterolemia

Higher than normal levels of cholesterol in the blood.

Hyperlipidemia

Excessive fat in the blood.

Hypertension

Abnormally high blood pressure.

Implantable cardioverter defibrillators (ICD)

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

Inferior vena cava

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

Interatrial septum

The wall separating the right and left atria.

Interventricular septum

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

Ischemia

Lack of blood flow to body tissues.

Low-density lipoprotein (LDL)

Often referred to as 'bad' cholesterol.

Magnetic Resonance Imaging (MRI)

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

Mitral valve

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

Myocardial infarction (MI)

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

Myocarditis

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

Occlusion

A blockage.

Pacemaker

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

Palpitations

A rapid or irregular heartbeat that a person can feel.

Pericardial fluid

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

Pericarditis

Inflammation of the (sac) surrounding the heart.

Pericardiocentesis

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

Plaque

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

Polycythemia

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

Pulmonary trunk

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

Roots of the great vessels

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

Serous membrane

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

Sinus rhythm

The normal electrical pattern followed by contraction of the heart.

Sphygmomanometer

A blood pressure cuff attached to a measuring device.

Stethoscope

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

Superior vena cava

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

Syncope

Fainting.

Systole

Period of time when the heart muscle is contracting.

Tachycardia

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

Valvuloplasty

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

Test Yourself

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

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Image Descriptions

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

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

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

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

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

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

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

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

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

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

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

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

10. Blood Vessels and Blood

Learning Objectives

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

Blood Vessels and Blood Word Parts

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

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Introduction to the Blood Vessels and Blood

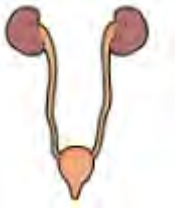
Our large, complex bodies need blood to deliver nutrients to and remove wastes from our trillions of cells. The heart, as discussed in the previous chapter, pumps blood throughout the body in a network of blood vessels. Together, these three components—blood, heart, and vessels—make up the cardiovascular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

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

Table 10.1 Interaction of the Circulatory System with Other Body Systems. A table depicting the various body systems and the role of the circulatory system in each. Adapted from Betts et al., 2013. Licensed under CC BY 4.0.

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

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

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

Watch this video:

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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.

Practice Medical Terms Related to the Blood Vessels and Blood

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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.

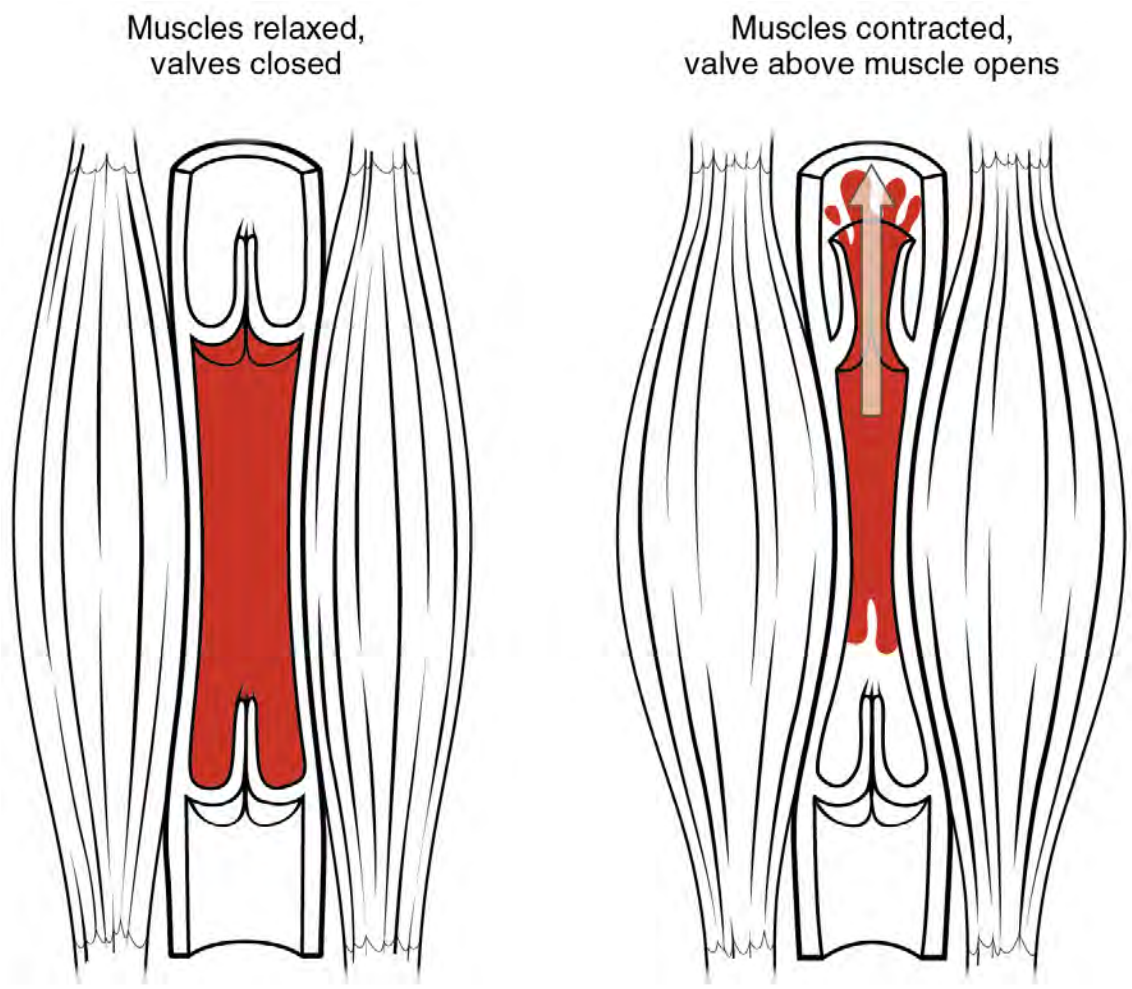


Figure 10.1 Skeletal Muscle Pump. The contraction of skeletal muscles surrounding a vein compresses the blood and increases the pressure in that area. This action forces blood closer to the heart where venous pressure is lower. Note the importance of the one-way valves to assure that blood flows only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

Concept Check

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

Both arteries and veins have the same three distinct tissue layers, called **tunics**, for the garments first worn by ancient Romans. From the most interior layer to the outer, these tunics are the **tunica intima,** the **tunica media**, and the **tunica externa** (see Figure 10.3). The smooth muscle in the middle layer, the tunica media, provides the vessel with the ability to **vasoconstrict** and **vasodilate** as needed to ensure sufficient blood flow.

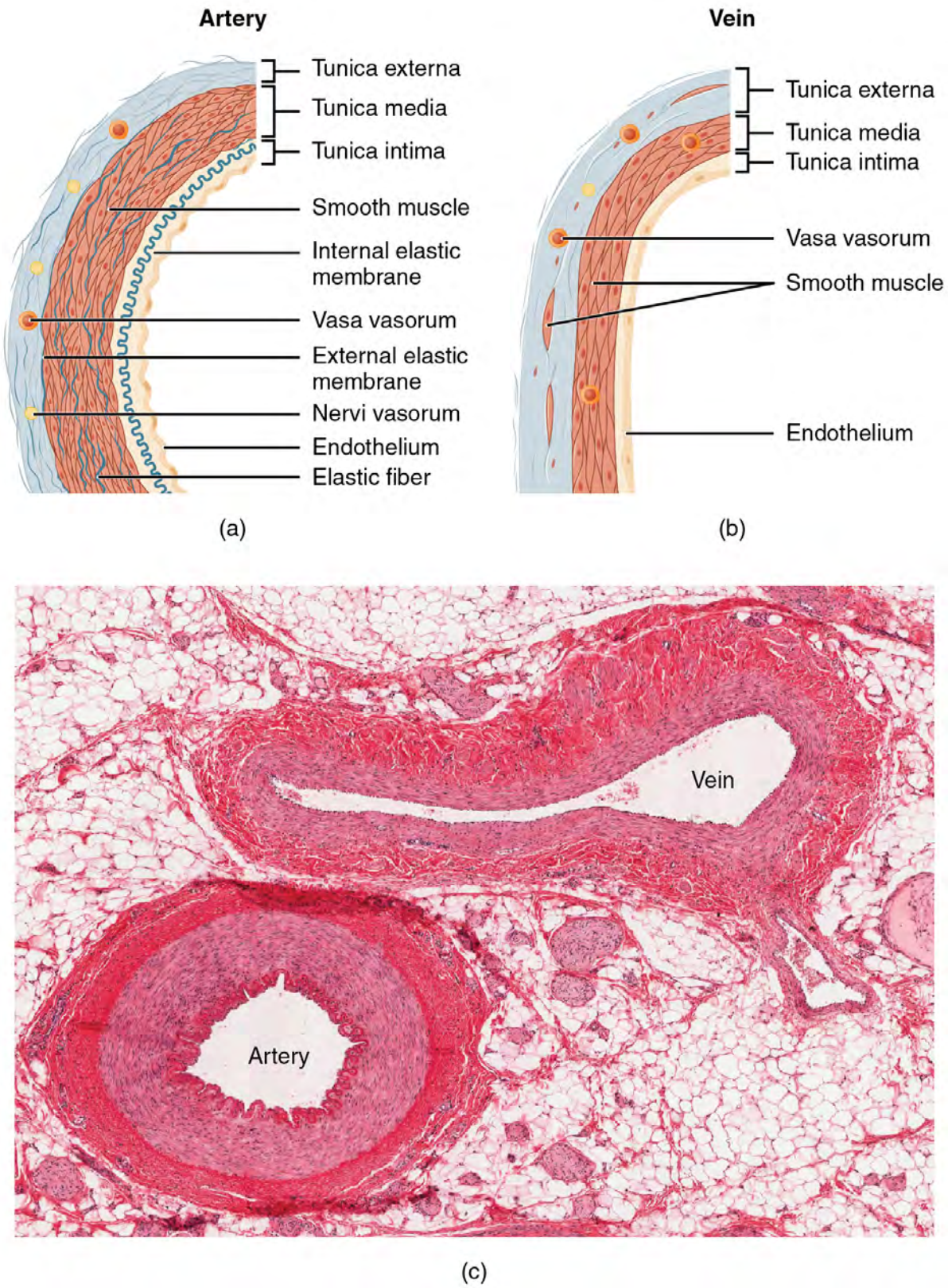


Figure 10.2 Structure of Blood Vessels. (a) Arteries and (b) veins share the same general features, but the walls of arteries are much thicker because of the higher pressure of the blood that flows through them. (c) A micrograph shows the relative differences in thickness. LM × 160. (Micrograph provided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

The table below compares the features of arteries and veins.

Table 10.2. Comparison of Arteries and Veins. From Betts et al., 2013. Licensed under CC BY 4.0.

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

The Major Arteries and Veins in the Human Body

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

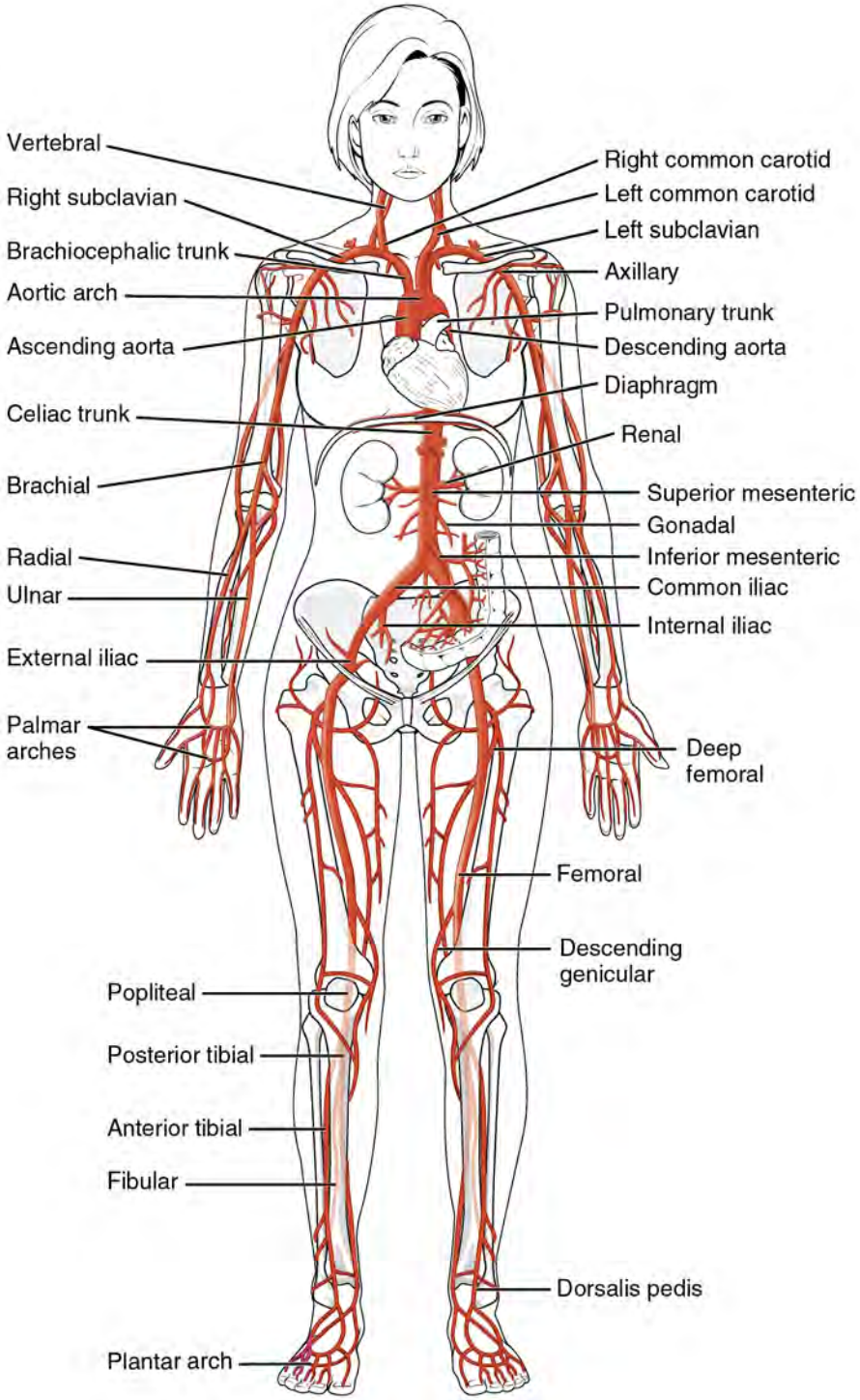


Figure 10.3 Systemic Arteries. The major systemic arteries shown here deliver oxygenated blood throughout the body. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

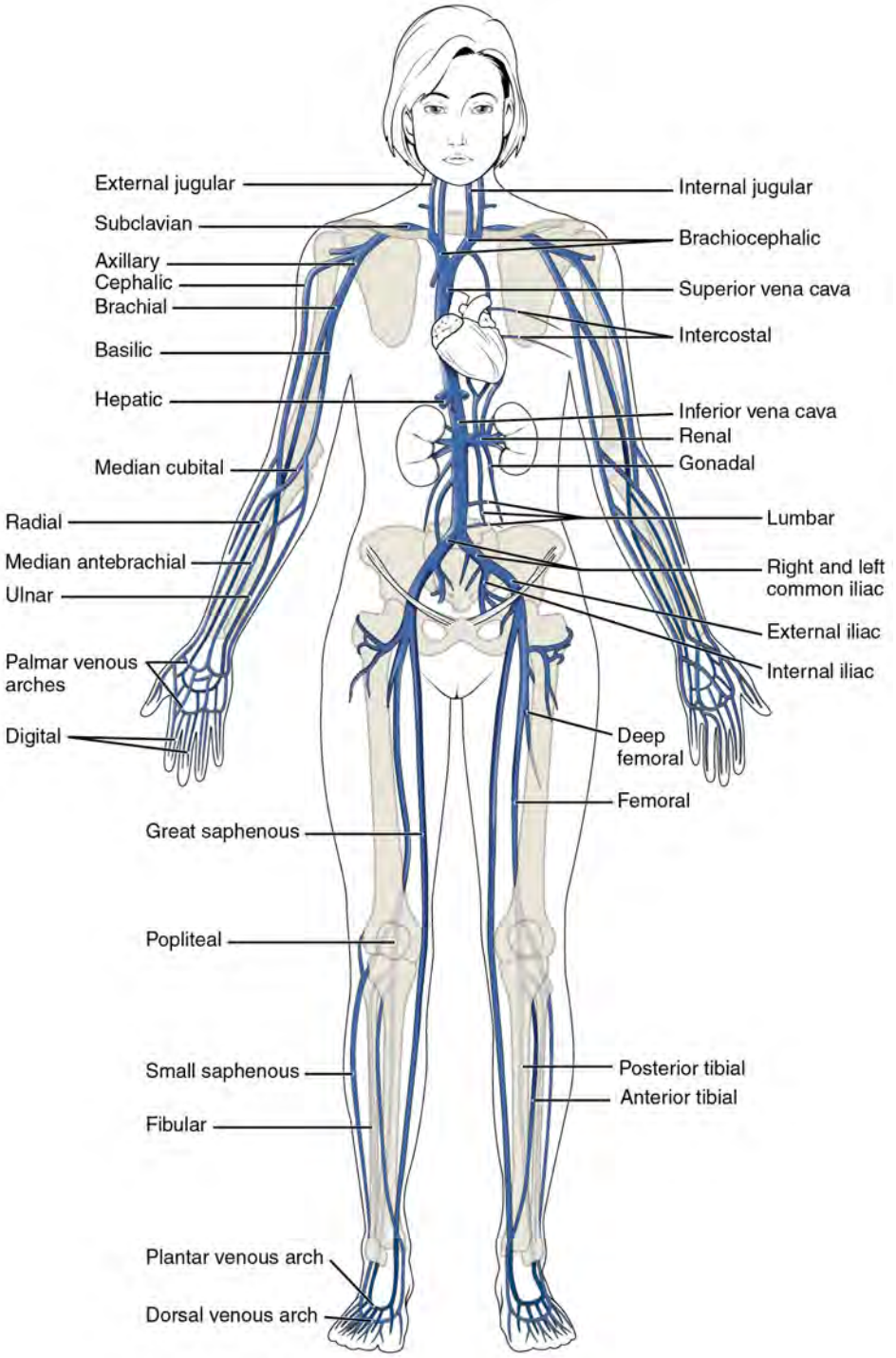


Figure 10.4 Major Systemic Veins of the Body. The major systemic veins of the body are shown here in an anterior view. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Concept Check

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

Physiology of the Blood Vessels

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

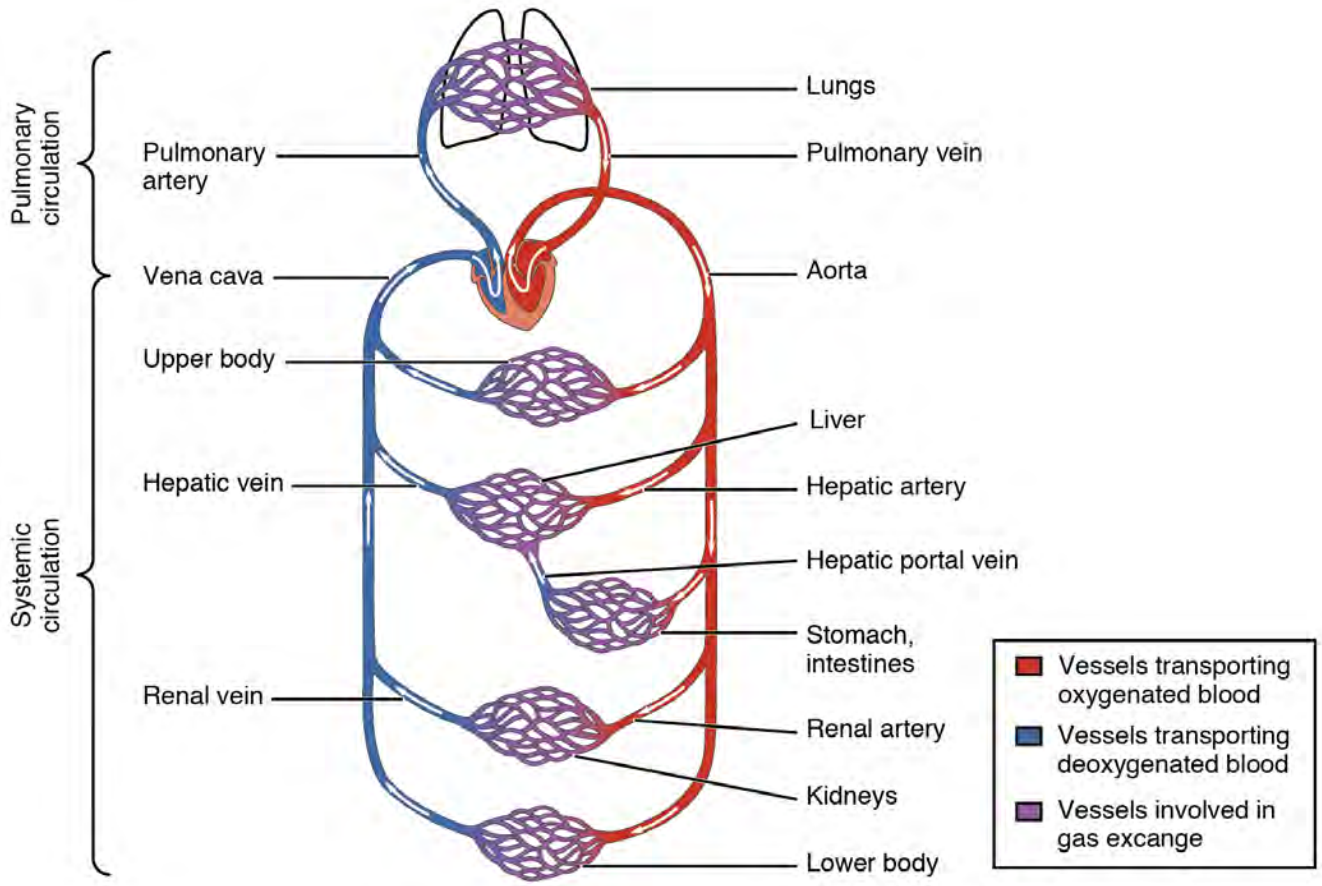


Figure 10.5 Cardiovascular Circulation. The pulmonary circuit moves blood from the right side of the heart to the lungs and back to the heart. The systemic circuit moves blood from the left side of the heart to the head and body and returns it to the right side of the heart to repeat the cycle. The arrows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

Blood Pressure

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

Five variables influence blood flow and blood pressure:

- **Cardiac output**
- **Vessel compliance**
- Volume of the blood

- **Viscosity** of the blood
- Blood vessel length and diameter

Did you know?

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

Pulse

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

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

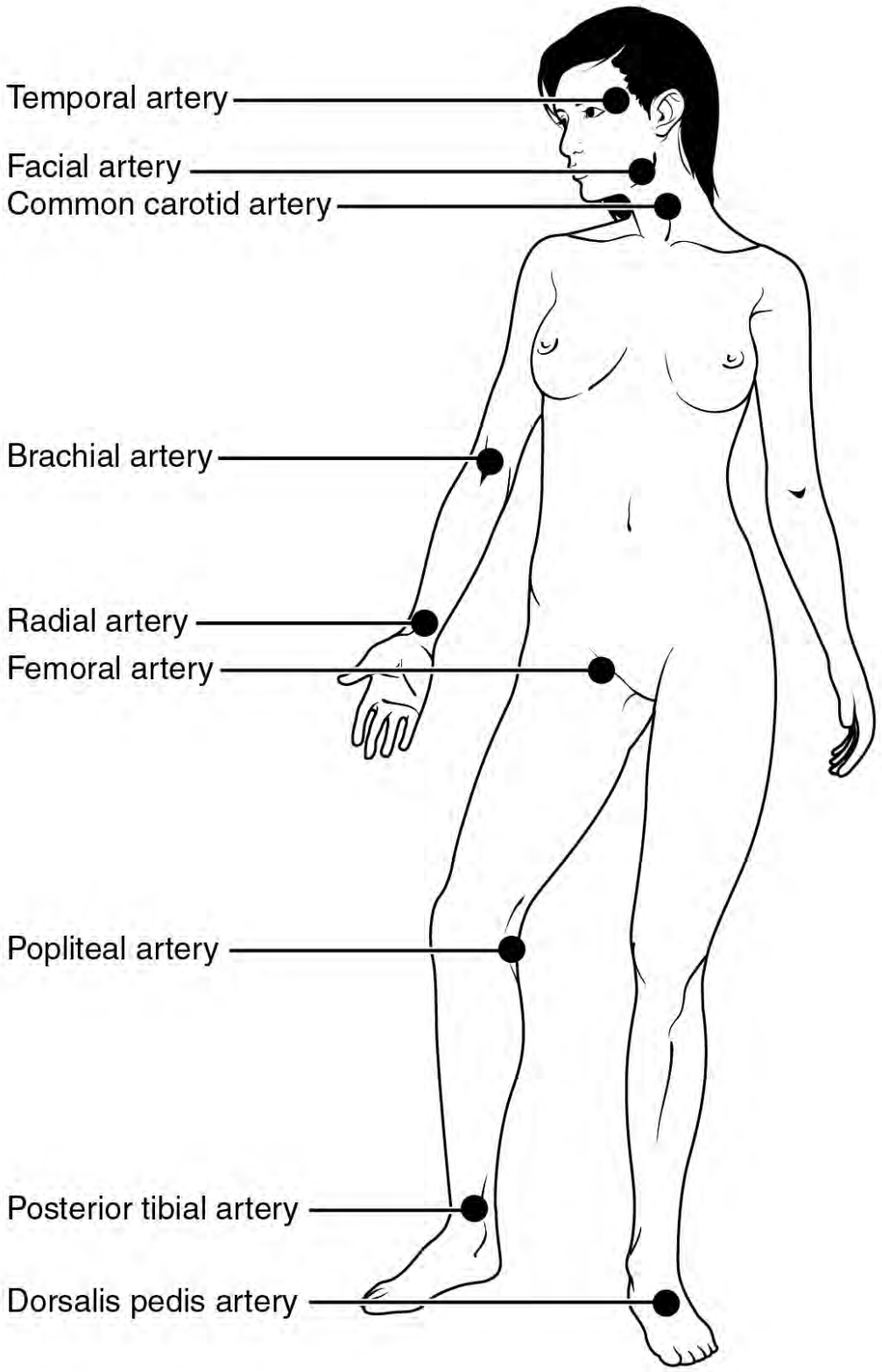


Figure 10.6 Pulse Sites. The pulse is most readily measured at the radial artery, but can be measured at any of the pulse points shown. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

Blood is a connective tissue made up of cellular elements and an extracellular matrix. The cellular elements are referred to as the **formed elements** and include **red blood cells (RBCs)**, **white blood cells (WBCs)**, and **platelets**. The extracellular matrix, called **plasma**, makes blood unique among connective tissues because it is fluid. This fluid, which is mostly water, perpetually suspends the formed elements and enables them to circulate throughout the body within the cardiovascular system. In the laboratory, blood samples are often **centrifuged** in order to separate the components of blood from one another (see the figure below). **Erythrocytes** are the heaviest elements in blood and settle at the very bottom of the tube. Above the erythrocyte layer we see the **buffy coat**, a pale, thin layer of **leukocytes** and **thrombocytes**, which together make up less than 1% of the sample of whole blood. Above the buffy coat is the blood plasma, normally a pale, straw-colored fluid, which constitutes the remainder of the sample.

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

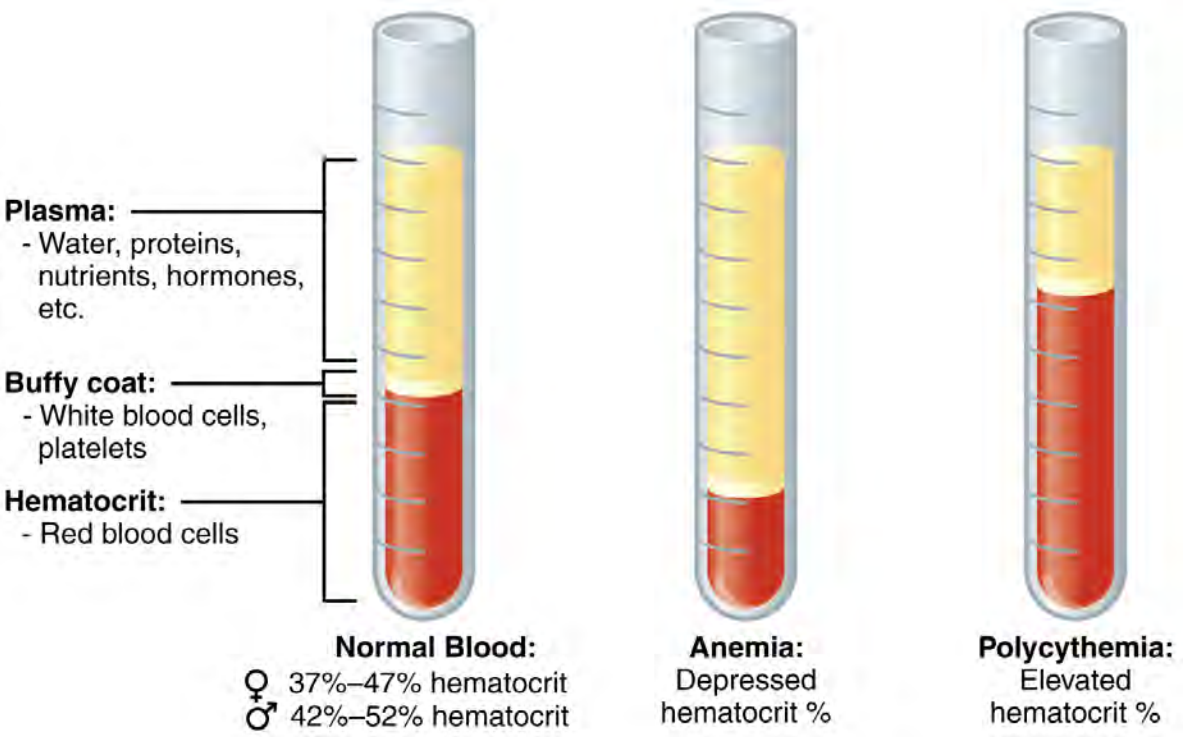


Figure 10.7 Composition of Blood. The cellular elements of blood include a vast number of erythrocytes and comparatively fewer leukocytes and platelets. Plasma is the fluid in which the formed elements are suspended. A sample of blood spun in a centrifuge reveals that plasma is the lightest component.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

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

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

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

Did you know?

Blood constitutes approximately 8% of adult body weight.

Concept Check

Use the table above to answer these questions:

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

Blood Plasma

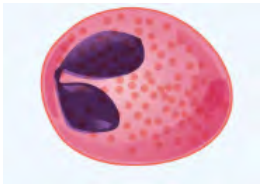
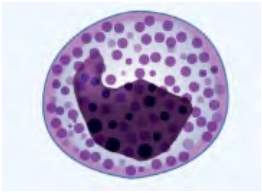
Like other fluids in the body, plasma is composed primarily of water. In fact, it is about 92% water. Dissolved or suspended within this water is a mixture of substances, most of which are proteins. The major components of plasma and their functions are summarized in the table above.

Formed Elements (Erythrocytes, Leukocytes, Thrombocytes)

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

Table 10.4 Summary of Formed Elements in Blood. Adapted from Betts et al., 2013. Licensed under CC BY 4.0.

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (μL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
Erythrocytes (red blood cells)  *Red Blood Cell*	n/a	5.2 million (4.4-5.0 million)	Flattened biconcave disk; no nucleus; pale red color	Transport oxygen and some carbon dioxide between tissues and lungs	Lifespan of approximately 120 days
Leukocytes (white blood cells)	n/a	7000 (5000 – 10,000)	Obvious dark-staining nucleus	All function in body defenses	Exit capillaries and move into tissues; lifespan of usually a few hours or days
Leukocytes (white blood cells) Types	**Granulocytes including neutrophils, eosinophils, and basophils**	**4360 (1800-9950)**	**Abundant granules in cytoplasm; nucleus normal lobed**	**Nonspecific (innate) resistance to disease**	**Classified according to membrane-bound granules in cytoplasm**
	Neutrophils  *Neutrophil Cell*	4150 (1800-7300)	Nuclear lobes increase with age; pale lilac granules	Phagocytic; particularly effective against bacteria. Release cytotoxic chemicals from granules	Most common leukocyte; lifespan of minutes to days

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (µL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
	Eosinophils  *Eosinophils Cell*	165 (0-700)	Nucleus generally two-lobed; bright red-orange granules	Phagocytic cells; particularly effective with antigen-antibody complexes. Release antihistamines. Increase in allergies and parasitic infections	Lifespan of minutes to days
	Basophils  *Basophil Cell*	44 (0-150)	Nucleus generally two-lobed but difficult to see due to presence of heavy, dense, dark purple granules	Promotes inflammation	Least common leukocyte; lifespan unknown
	Agranulocytes including lymphocytes and monocytes	2640 (1700-4950)	Lack abundant granules in cytoplasm; have a simple-shaped nucleus that may be indented	Body defenses	Group consists of two major cell types from different lineages

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (μL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
	Lymphocytes  *Lymphocytes Cell*	2185 (1500-4000)	Spherical cells with a single often large nucleus occupying much of the cell's volume; stains purple; see in large (natural killer cells) and small (B and T cells) variants	Primarily specific (adaptive) immunity; T cells directly attack other cells (cellular immunity). B cells release antibodies (humoral immunity); natural killer cells are similar to T cells but nonspecific	Initial cells originate in bone marrow, but secondary production occurs in lymphatic tissue; several distinct subtypes; memory cells form after exposure to a pathogen and rapidly increase responses to subsequent exposure; lifespan of many years
	Monocytes  *Monocytes Cell*	455 (200-950)	Largest leukocyte with an indented or horseshoe-shaped nucleus	Very effective phagocytic cells engulfing pathogens or worn-out cells; also serve as antigen-presenting cells (APCs) for other components of the immune system	Produced in red bone marrow; referred to as macrophages after leaving circulation

FORMED ELEMENT	MAJOR SUBTYPES	NUMBER PRESENT PER MICROLITER (µL) AND MEAN (RANGE)	APPEARANCE IN A STANDARD BLOOD SMEAR	SUMMARY OF FUNCTIONS	COMMENTS
Platelets  *Platelet Cells*	n/a	350,000 (150,000 – 500,000)	Cellular fragments surrounded by a plasma membrane and containing granules; purple stain	Hemostasis plus release growth factors for repair and healing of tissue	Formed from megakaryocytes that remain in the red bone marrow and shed platelets into circulation

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

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

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

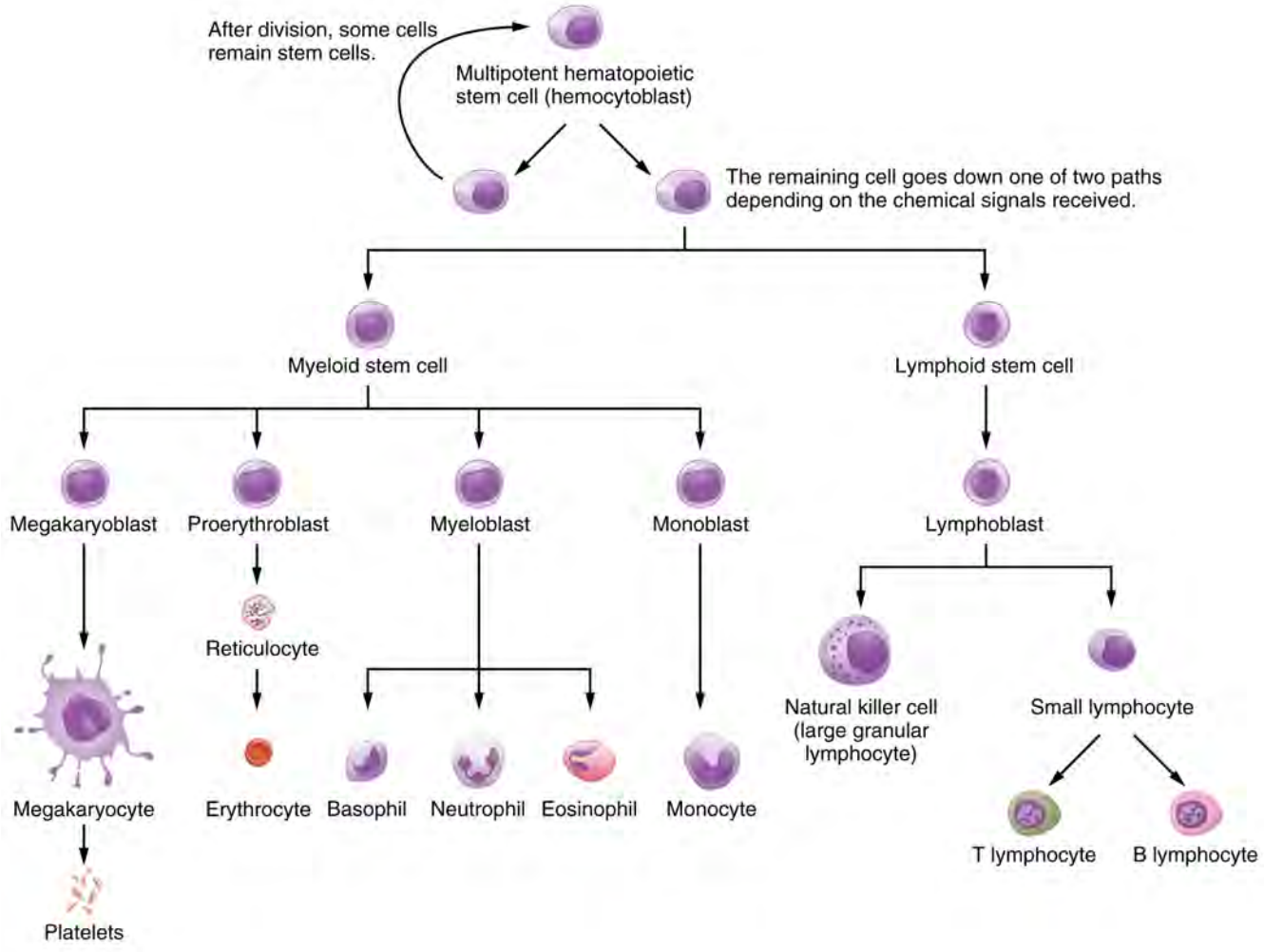


Figure 10.8 Hematopoietic System of Bone Marrow. Hemopoiesis is the proliferation and differentiation of the formed elements of blood. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Erythrocytes

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

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

Leukocytes

Leukocytes protect the body against invading microorganisms and body cells with mutated DNA, and they clean up debris; thus, they are a major component of the body's defenses against disease. Figure 10.10 shows the different types of leukocytes.

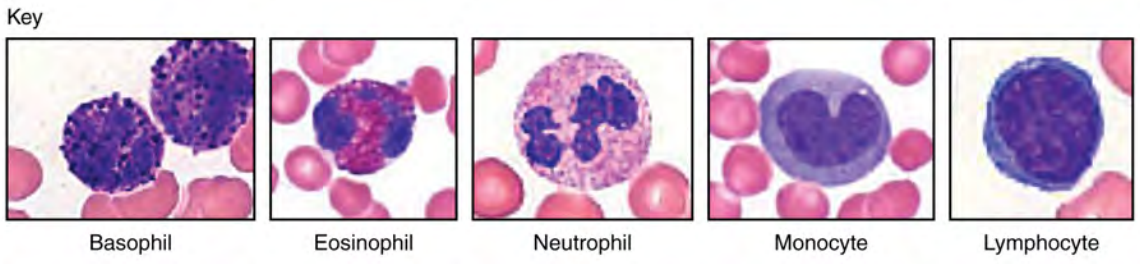


Figure 10.10 Leukocytes. (Micrographs provided by the Regents of University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Concept Check

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

Leukocytes routinely leave the bloodstream to perform their **defensive** functions in the body's tissues, where they are often given distinct names, such as **macrophage** or **microglia**, depending on their function. As shown in Figure 10.11 below, they leave the capillaries—the smallest blood vessels—or other small vessels through a process known as **emigration** or **diapedesis** in which they squeeze through adjacent cells in a blood vessel wall.

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

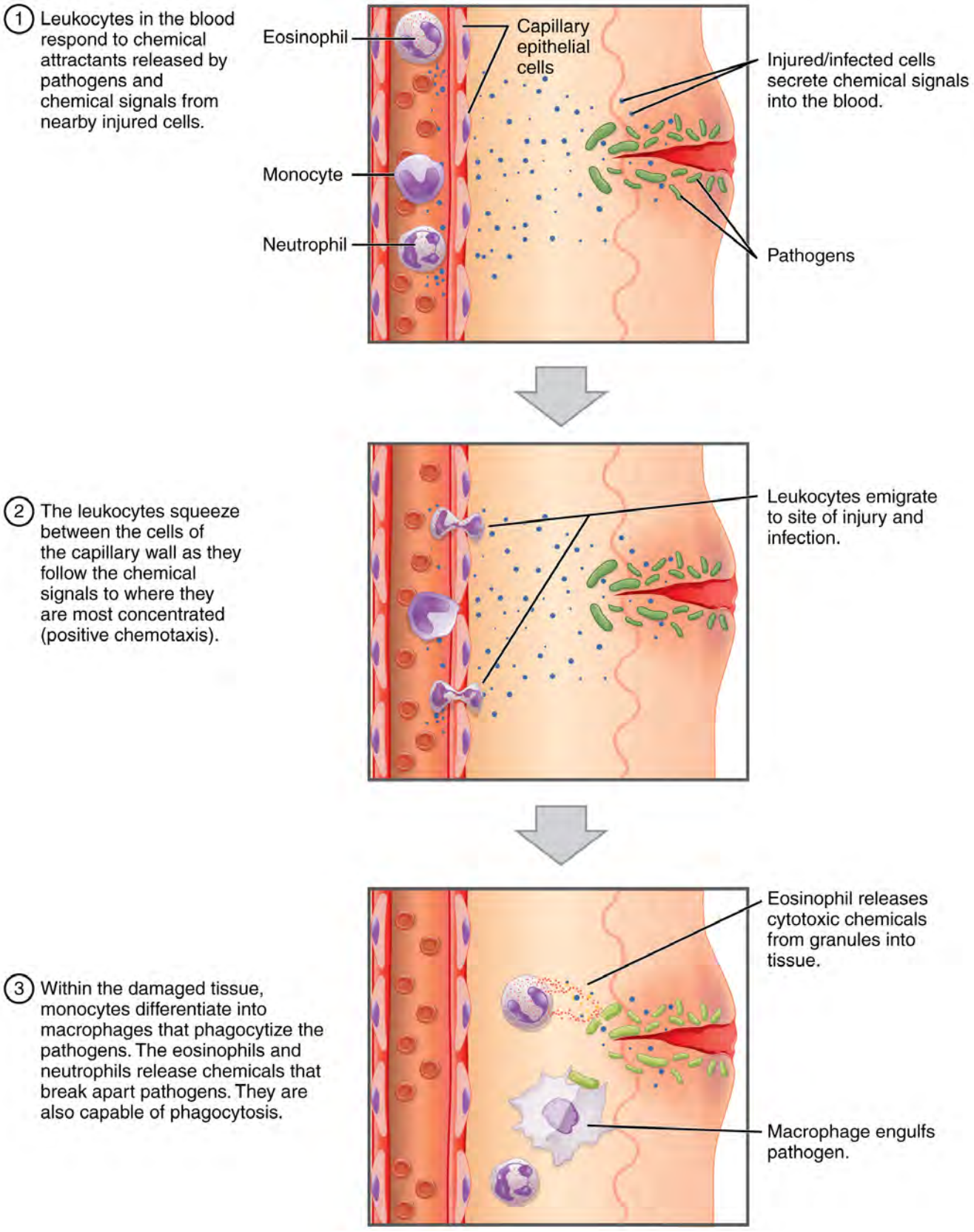


Figure 10.11 Emigration. Leukocytes exit the blood vessel and then move through the connective tissue of the dermis toward the site of a wound. Some leukocytes, such as the eosinophil and neutrophil, are characterized as granular leukocytes. They release chemicals from their granules that destroy pathogens;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

Licensed under CC BY 4.0. [Image description.]

Lymphocytes

Lymphocytes are a type of leukocyte. The three major groups of lymphocytes include natural killer cells, B cells, and T cells.

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

Platelets

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

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

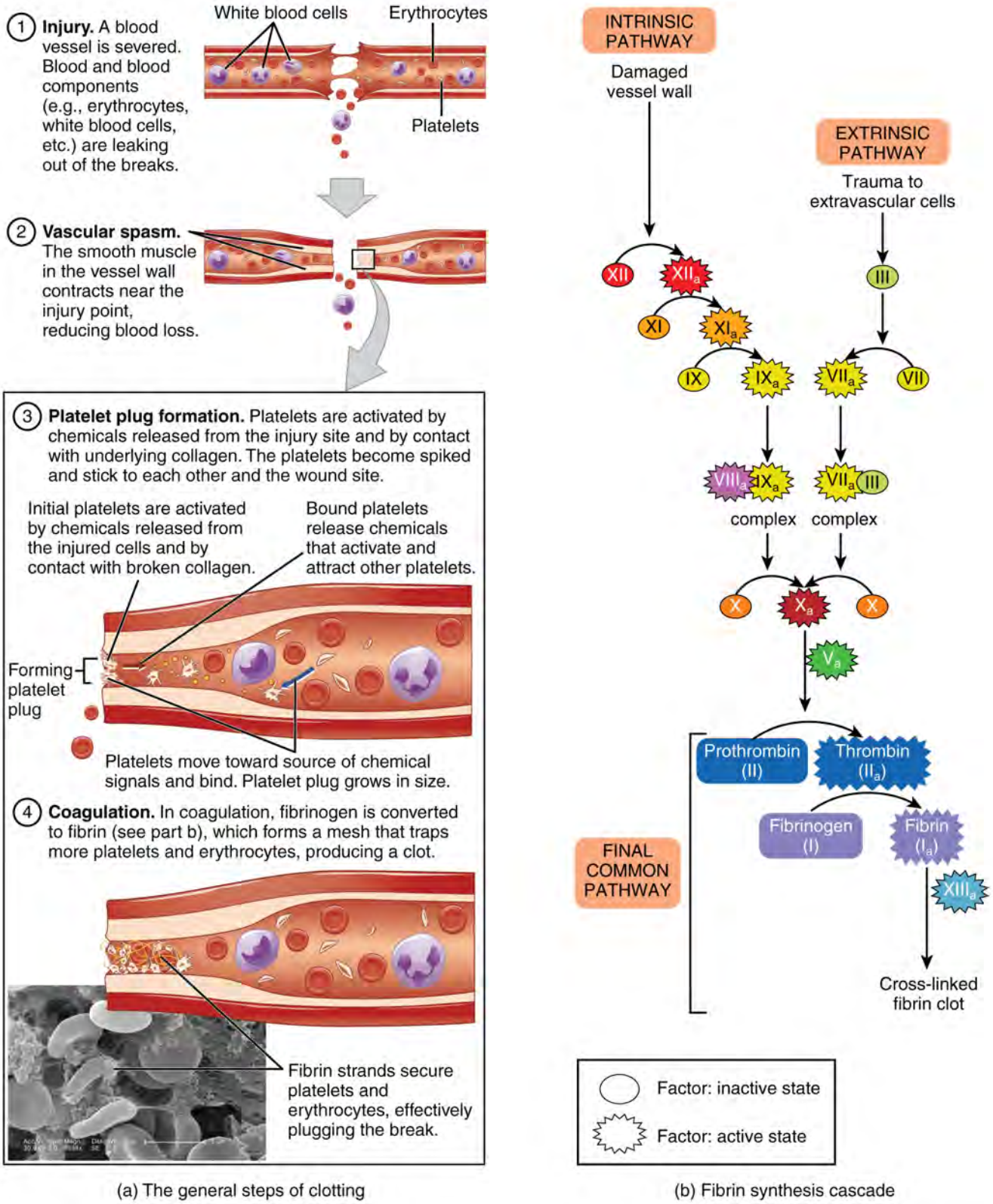


Figure 10.12 Hemostasis. (a) An injury to a blood vessel initiates the process of hemostasis. Blood clotting involves three steps. First, vascular spasm constricts the flow of blood. Next, a platelet plug forms to temporarily seal small openings in the vessel. Coagulation then enables the repair of the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

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

Concept Check

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

Physiology of Blood

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

Transportation

Nutrients from the foods you eat are absorbed in the digestive tract. Most of these travel in the bloodstream directly to the liver, where they are processed and released back into the bloodstream for delivery to body cells.

Oxygen from the air you breathe diffuses into the blood, which moves from the lungs to the heart, which then pumps it out to the rest of the body.

Endocrine glands scattered throughout the body release their products, called **hormones**, into the bloodstream, which carries them to distant target cells.

Blood also picks up **cellular wastes** and byproducts, and transports them to various organs for removal. For instance, blood moves carbon dioxide to the lungs for **exhalation** from the body, and various waste products are transported to the kidneys and liver for excretion from the body in the form of urine or bile.

Defense

Leukocytes protect the organism from disease-causing bacteria, cells with **mutated** DNA that could multiply to become cancerous, or body cells infected with viruses.

When damage to the vessels results in bleeding, blood platelets and certain proteins dissolved in the plasma, interact to block the ruptured areas of the blood vessels involved. This protects the body from further blood loss.

Homeostasis

If you were exercising on a warm day, your rising core body temperature would trigger several homeostatic mechanisms, including increased transport of blood from your core to your body periphery, which is typically cooler. As blood passes through the vessels of the skin, heat would be dissipated to the environment, and the blood returning to your body core would be cooler. In contrast, on a cold day, blood is diverted away from the skin to maintain a warmer body core. In extreme cases, this may result in frostbite.

Blood helps to regulate the water content of body cells. Blood also helps to maintain the chemical balance of the body. Proteins and other compounds in blood act as buffers, which thereby help to regulate the **pH** of body tissues. The pH of blood ranges from 7.35 to 7.45.

Concept Check

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

- Hemostasis
- Homeostasis
- Hematopoiesis

Blood Types

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

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

failure.

ABO Blood Group

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

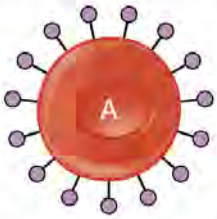
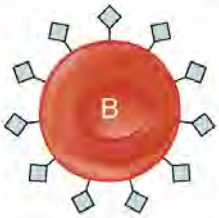
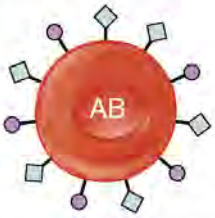
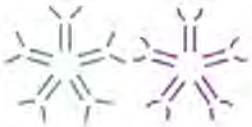
	Blood Type			
	A	B	AB	O
Red Blood Cell Type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in Red blood Cell	 A antigen	 B antigen	 A and B antigens	None
Blood Types Compatible in an Emergency	A, O	B, O	A, B, AB, O (AB^+ is the universal recipient)	O (O is the universal donor)

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

- Blood Type A
  - People whose erythrocytes have **A antigens** on their erythrocyte membrane surface.
  - People who have type A blood, without any prior exposure to incompatible blood, have preformed **anti-B antibodies** circulating in their blood. These antibodies will cause a serious immune reaction if they encounter blood that has B antigens.

- Blood Type B
  - People whose erythrocytes have **B antigens.**
  - People with type B blood have preformed **anti-A antibodies.**
- Blood Type AB
  - People can also have **both A and B antigens** on their erythrocytes, in which case they are blood type AB.
  - Individuals with type AB blood, **do not have preformed antibodies** to either A or B antigens.
- Blood Type O
  - People with **neither A nor B antigens** are designated blood type O.
  - People with type O blood have **both anti-A and anti-B antibodies** circulating in their blood plasma.

Rh Blood Group

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

Hemolytic Disease of the Newborn (HDN)

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

- In a **first pregnancy** problems are rare**,** since the baby's Rh^+ cells rarely cross the **placenta**. However, during or immediately after birth, the Rh^- mother can be exposed to the baby's Rh^+ cells (Figure 10.14). Research has shown that this occurs in about 13 to 14% of such pregnancies. After exposure, the mother's immune system begins to generate anti-Rh antibodies.
- In a **second pregnancy** if a mother should conceive a Rh^+ baby, the Rh antibodies she has produced can cross the placenta into the fetal bloodstream and destroy the fetal RBCs. This condition, known as **hemolytic disease of the newborn (HDN)** or erythroblastosis fetalis. This may cause anemia in mild cases, but the agglutination and hemolysis can be so severe that without treatment the fetus may die in the womb or shortly after birth.
  - A drug known as RhoGAM, short for Rh immune globulin, can temporarily prevent the development of Rh antibodies in the Rh^- mother, thereby averting this potentially serious disease for the fetus. RhoGAM antibodies destroy any fetal Rh^+ erythrocytes that may cross the placental barrier. RhoGAM is normally administered to Rh^- mothers during weeks 26 to 28 of pregnancy and within 72 hours following birth.

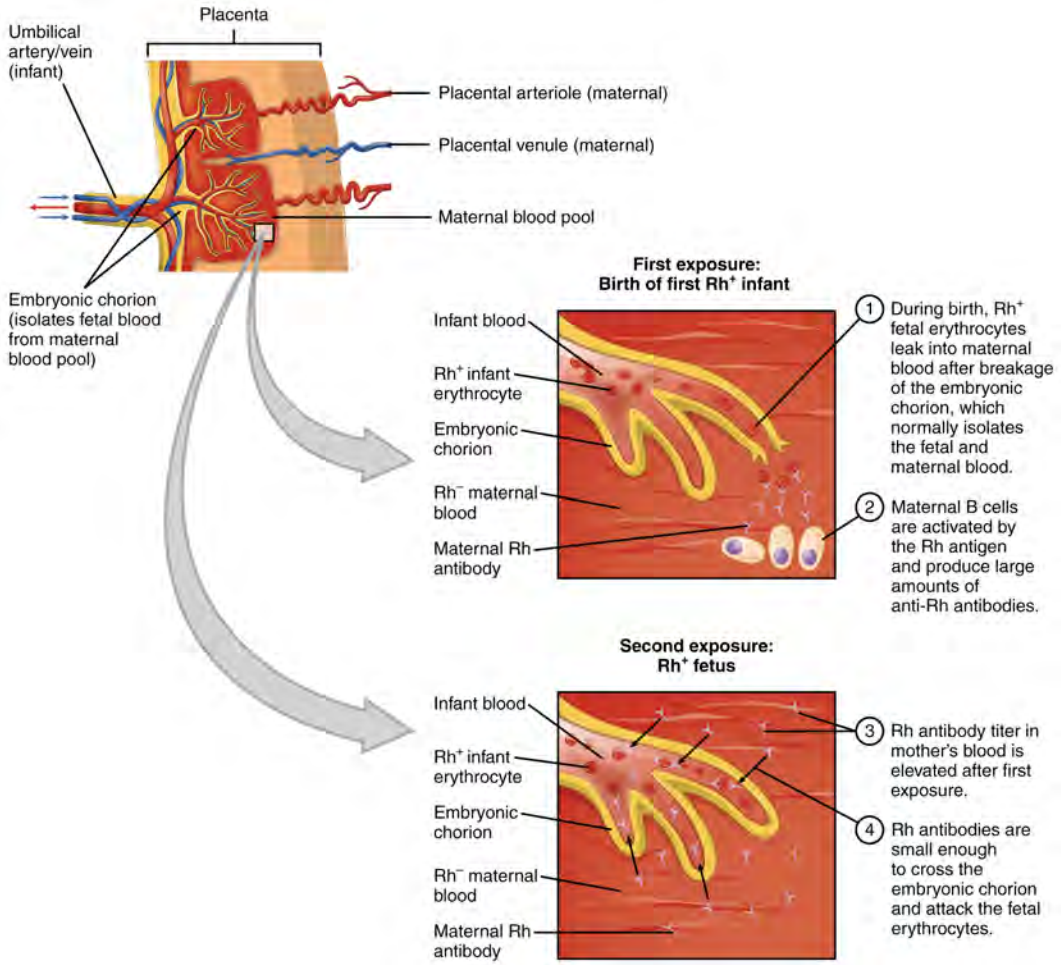


Figure 10.14 Erythroblastosis Fetalis. The first exposure of an Rh− mother to Rh+ erythrocytes during pregnancy induces sensitization. Anti-Rh antibodies begin to circulate in the mother's bloodstream. A second exposure occurs with a subsequent pregnancy with an Rh+ fetus in the uterus. Maternal anti-Rh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

Blood Transfusions

Figure 10.15 is an example of a commercially produced "bedside" card which enables quick typing of both a recipient's and donor's blood before transfusion. The card contains three reaction sites or wells. One is coated with an anti-A antibody, one with an anti-B antibody, and one with an anti-D antibody (tests for the presence of Rh factor D). Mixing a drop of blood and saline into each well enables the blood to interact with a preparation of type-specific antibodies, also called anti-seras. Agglutination of RBCs in a given site indicates a positive identification of the blood antigens, in this case A and Rh antigens for blood type A+. To avoid serious and potentially fatal immune reactions, the donor's and recipient's blood types must match.

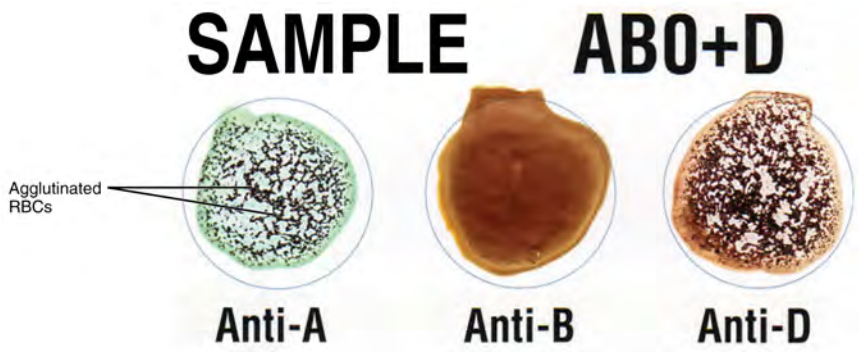


Figure 10.15. Cross Matching Blood Types. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

Practice Terms Related to the Blood Vessels and Blood

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

Diseases and Disorders of Blood Vessels and Blood

Arteriosclerosis

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

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

Atherosclerosis is a type of arteriosclerosis in which **plaques** form when circulating triglycerides, cholesterol and other substances seep between the damaged endothelial lining cells and become trapped within the artery wall, resulting in narrowed arteries and impaired blood flow (see Figure 10.16).

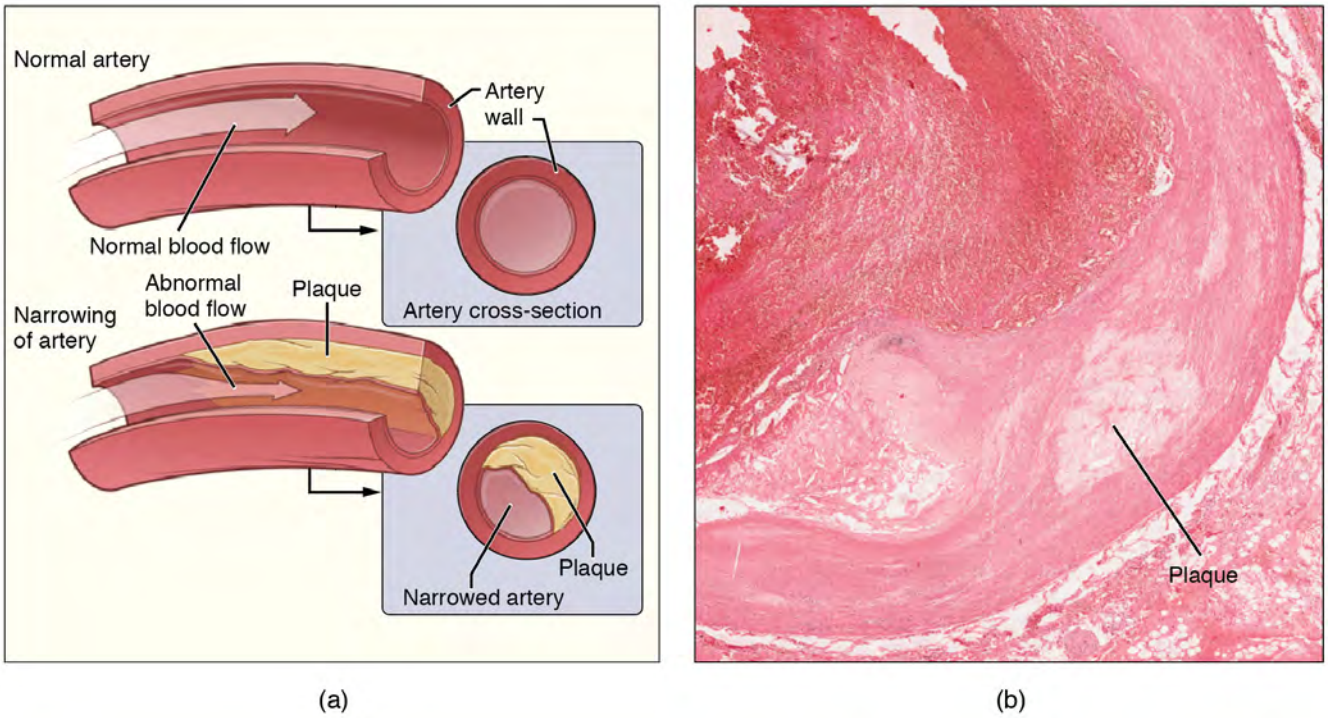


Figure 10.16 Atherosclerosis. (a) Atherosclerosis can result from plaques formed by the buildup of fatty, calcified deposits in an artery. (b) Plaques can also take other forms, as shown in this micrograph of a coronary artery that has a buildup of connective tissue within the artery wall. LM × 40. (Micrograph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

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

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

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

Edema and Varicose Veins

Despite the presence of valves and the contributions of other anatomical and physiological adaptations that assist in moving blood through veins, over the course of a day, some blood will inevitably pool, especially in the lower limbs, due to the pull of gravity. Any blood that accumulates in a vein will increase the pressure within it, which can then

be reflected back into the smaller veins, venules, and eventually even the capillaries. This increased pressure in the capillaries will push fluids out of the capillaries and into the interstitial fluid, causing a condition called **edema**.

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

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

Edema may be accompanied by varicose veins, especially in the superficial veins of the legs (see Figure 10.17). This disorder arises when defective valves allow blood to accumulate within the veins, causing them to distend, twist, and become visible on the surface of the skin. Varicose veins may occur in both sexes, but are more common in women and are often related to pregnancy. More than simple cosmetic blemishes, varicose veins are often painful and sometimes itchy or throbbing. Without treatment, they tend to grow worse over time. The use of a support hose, as well as elevating the feet and legs whenever possible, may be helpful in alleviating this condition.

Hypertension

Hypertension is defined as chronic and persistent blood pressure measurements of 140/90 mm Hg or above. Pressures

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

Hemorrhage

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

Circulatory Shock

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

There are several recognized forms of shock:

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

Erythrocyte Disorders

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

Anemia

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

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

Blood Loss Anemias:

Causes:

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

Anemias Caused by Faulty or Decreased RBC Production:

- **Sickle cell anemia**
    - A genetic disorder involving the production of an abnormal type of hemoglobin that delivers less oxygen to tissues and causes erythrocytes to assume a sickle (or crescent) shape (Figure 10.18).
- **Iron deficiency anemia**
    - The most common type of anemia and results when the amount of available iron is insufficient to allow the production of sufficient heme.
- **Vitamin deficiency anemia** (Generally insufficient vitamin B12 and folate).
- **Megaloblastic anemia** involves a deficiency of vitamin B12 and/or folate, often due to inadequate dietary intake.
- **Pernicious anemia** is caused by poor absorption of vitamin B12 and is often seen in patients with **Crohn's disease**, surgical removal of the intestines or stomach (common in some weight loss surgeries), intestinal parasites, and **AIDS**.
- **Aplastic anemia** is the condition in which myeloid stem cells are defective or replaced by cancer cells, resulting in insufficient quantities of RBCs being produced. This condition may be inherited, or it may be triggered by radiation, medication, chemotherapy, or infection.
- **Thalassemia** is an inherited condition typically occurring in individuals from the Middle East, the Mediterranean, African, and Southeast Asia, in which maturation of the RBCs does not proceed normally. The most severe form is called Cooley's anemia.

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

Did you know?

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

Polycythemia

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

Platelet Disorders/Clotting Disorders

Thrombocytosis

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

Thrombophilia

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

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

Thrombocytopenia

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

Hemophilia

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

Leukocyte Disorders

Leukopenia

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

Leukocytosis

Leukocytosis is excessive leukocyte proliferation. Although leukocyte counts are high, the cells themselves are often nonfunctional, leaving the individual at increased risk for disease.

Leukemia

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

Lymphoma

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

Other Conditions Related to Abnormal Leukocyte Counts

Table 10.5. Conditions Related to Abnormal White Blood Cell Counts. From Betts et al., 2013. Licensed under CC BY 4.0.

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

Common Blood Vessels and Blood Abbreviations

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.uwf.edu/medicalterminology/?p=111#h5p-65

Medical Terms in Context

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.uwf.edu/medicalterminology/?p=111#h5p-66

Medical Specialties and Procedures Related to the Blood Vessels and Blood

Vascular Surgeons

Vascular surgery is a specialty in which the physician treats diseases of the blood and lymphatic vessels. This includes repair and replacement of diseased or damaged vessels, removal of plaque from vessels, minimally invasive procedures including the insertion of venous catheters, and traditional surgery. For more information, please visit the Society for Vascular Surgery web page.

Hematologists

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

Diagnostic Vascular Technologists

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

Phlebotomist

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

Medical Laboratory Technologists/Technicians

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

Bone Marrow Biopsy/Bone Marrow Transplant

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

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

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

Blood Vessels and Blood Vocabulary

Acquired immunodeficiency syndrome (AIDS)

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

Anaphylaxis

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

Anemia

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

Aneurysm

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

Angiography

A procedure to x-ray blood vessels.

Angioplasty

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

Angioscope

Instrument used for visual examination of blood vessels.

Angioscopy

Endoscopic examination of blood vessels.

Anti-B antibodies

Proteins that will mount an immune response against B antigens.

Antibodies

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

Antigens

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

Aortic stenosis

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

Artery

A blood vessel that transports blood away from the heart.

Arteriole

A very small artery that leads to a capillary.

Arteriogram

An x-ray of arteries.

Arteriosclerosis

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

Atherectomy

Excision of fatty plaque.

Atherosclerosis

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

Brachial artery

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

Capillaries

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

Cardiac output

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

Cardiac tamponade

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

Cardiogenic

Originating from the heart.

Carotid artery

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

Centrifugation

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

Chemoreceptors

Cells that sense changes in chemical levels.

Chemotaxis

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

Compliance

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

Coronary artery bypass graft (CABG)

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

Coronary heart disease

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

Crohn's disease

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

Diapedesis

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

Diastolic pressure

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

Edema

Swelling due to excessive liquid in the tissues.

Embolus

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

Endarterectomy

Excision of plaque from within the artery.

Endothelium

Epithelium that lines vessels in the lymphatic and cardiovascular systems.

Epiphyses

The wider section at the end of long bones.

Erythrocyte

A red blood cell.

Erythropoietin (EPO)

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

Extramedullary hematopoiesis

Hematopoiesis outside the medullary cavity of adult bones.

Heart rate

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

Hematocrit

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

Hematologist

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

Hematology

The study of blood and blood-forming issues.

Hematoma

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

Hemolysis

The breakdown of red blood cells.

Hemopoiesis

The process by which the body produces blood.

Hemopoietic growth factors

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

Hemorrhage

Excessive bleeding.

Hemostasis

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

Homeostasis

The state of steady internal conditions maintained by living things.

Hypertension

Abnormally high blood pressure.

Hypothermia

Abnormally low body temperature.

Hypothyroidism

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

Hypovolemic

An abnormally low volume of blood circulating through the body.

Hypoxemia

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

Hypoxia

Lack of oxygen supply to the tissues.

Immunodeficiency

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

Intravenous

Into or within the vein.

Ischemia

Lack of blood flow to body tissues.

Leukocyte

White blood cell(s).

Leukocytopenia

An abnormal decrease in the number of leukocytes.

Lupus

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

Lymphadenitis

Inflammation of lymph nodes.

Lymphadenopathy

Disease or swelling of the lymph nodes.

Lymphoma

A form of cancer in which masses of malignant T and/or B lymphocytes collect in lymph nodes, the spleen, the liver, and other tissues. These leukocytes do not function properly, and the patient is vulnerable to infection.

Macrophage

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

Medulla oblongata

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

Myeloma

Cancer that arises in plasma cells.

Myelopoiesis

Formation of bone marrow.

Pancytopenia

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

Perfusion

Penetration of blood.

Peripheral arterial disease

Obstruction of vessels in peripheral regions of the body.

pH

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

Phagocytized

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

Phlebitis

Inflammation of a vein.

Phlebotomist

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

Phlebotomy

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

Placenta

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

Plaque

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

Plasma cells

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

Plasmapheresis

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

Pneumothorax

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

Polycythemia vera

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

Pulmonary embolism

A blood clot within the lung.

Rheumatoid arthritis

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

Sepsis

Organismal-level inflammatory response to a massive infection.

Sickle cell disease

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

Splenectomy

Excision of the spleen.

Splenomegaly

Enlarged spleen.

Sphygmomanometer

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

Systolic pressure

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

Thalassemia

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

Thrombocyte

Platelets.

Thrombocytopenia

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

Thrombocytosis

A condition in which there are too many platelets.

Thrombophlebitis

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

Thrombosis

The formation of unwanted blood clots.

Thrombus

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

Thrombolysis

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

Thymectomy

Excision of the thymus gland.

Thymoma

Tumor of the thymus gland.

Tissue rejection

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

Vasoconstriction

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

Vasodilation

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

Veins

Blood vessels that carry blood back to the heart.

Venules

Small blood vessels that carry blood to a vein.

Viscosity

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

Test Yourself

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.uwf.edu/medicalterminology/?p=111#h5p-67

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Image Descriptions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

12. Respiratory System

Learning Objectives

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

Respiratory System Word Parts

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

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Introduction to the Respiratory System

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

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

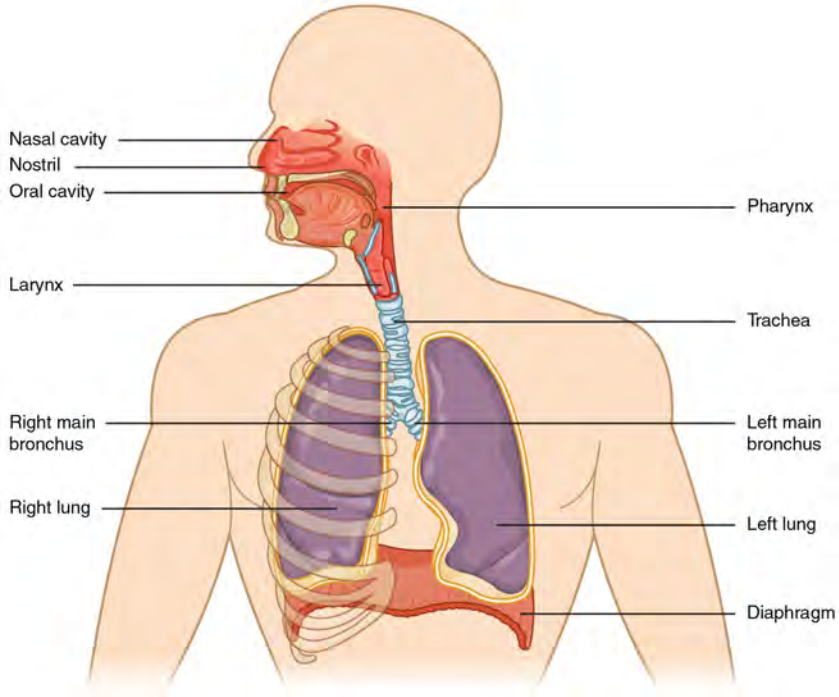

Figure 12.1 Major Respiratory Structures. The major respiratory structures span the nasal cavity to the diaphragm. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Did you know?

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

Watch this video:

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

Practice Medical Terms Related to the Respiratory System

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Anatomy (Structures) of the Respiratory System

The Nose and its Adjacent Structures

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

- **external nose**
- **internal nose**

The **nares** open into the nasal cavity, which is separated into left and right sections by the nasal septum (Figure 12.2). The **nasal septum** is formed anteriorly by a portion of the **septal cartilage** and posteriorly by the perpendicular plate of the ethmoid bone and the thin vomer bones.

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

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

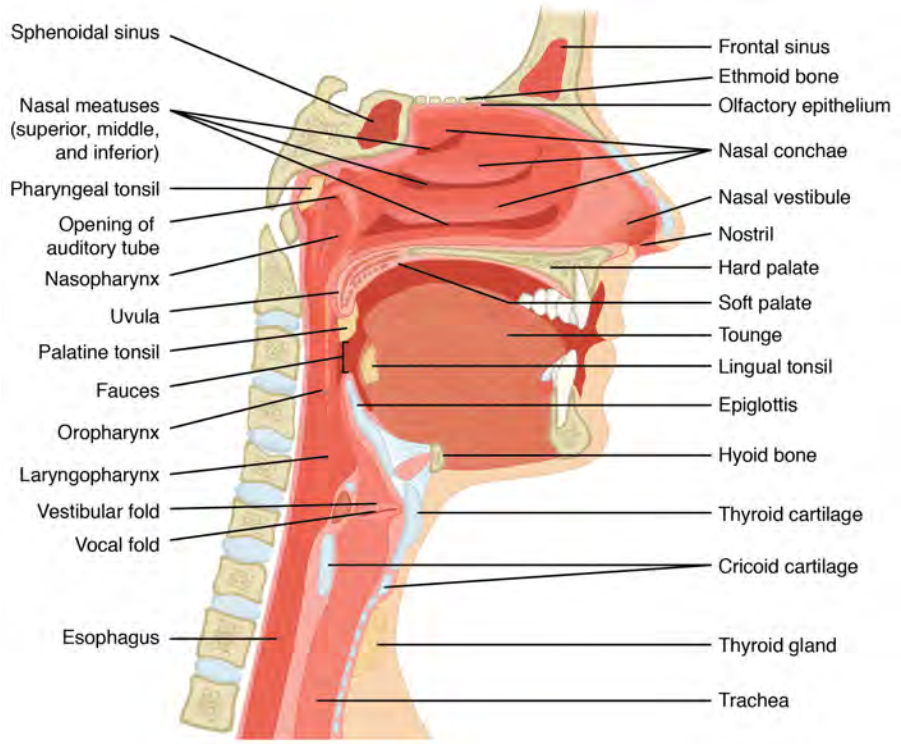

Figure 12.2 Upper Airway. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

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

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

The conchae, meatuses, and paranasal sinuses are lined by respiratory epithelium composed of pseudostratified ciliated columnar epithelium (Figure 12.3). The epithelium contains specialized epithelial cells that produce mucus to trap debris. The cilia of the respiratory epithelium help to remove mucus and debris with a constant beating motion, sweeping materials towards the throat to be swallowed.

This moist epithelium functions to warm and humidify incoming air. Capillaries located just beneath the nasal epithelium warm the air by convection. Serous and mucus-producing cells also secrete **defensins**, or immune cells that patrol the connective tissue providing additional protection.

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

Did you know?

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

Pharynx

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

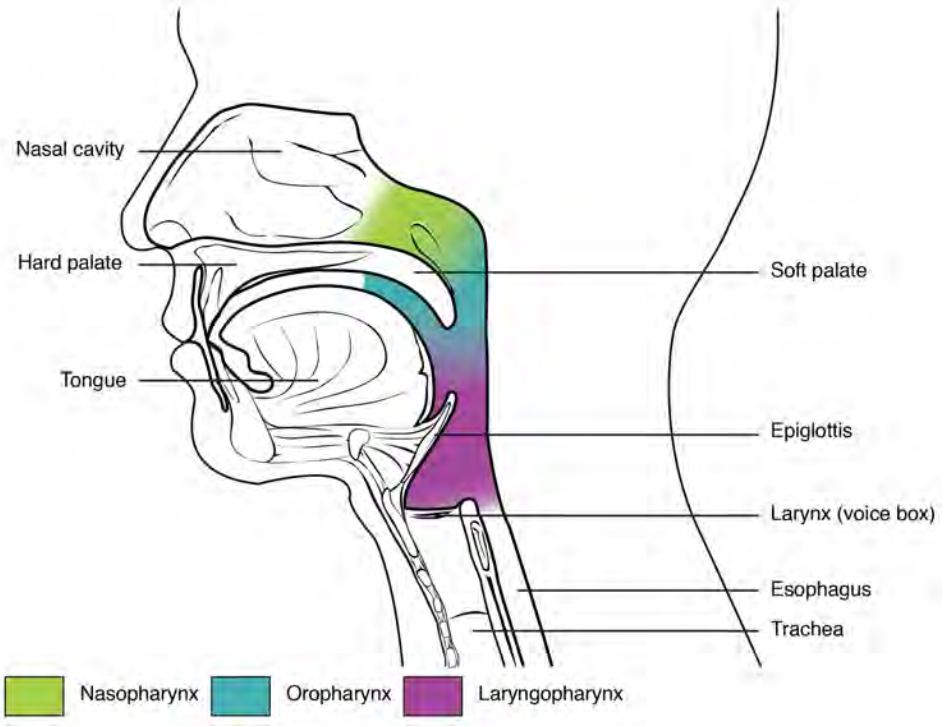

Figure 12.4 Divisions of the Pharynx. The pharynx is divided into three regions: the nasopharynx, the oropharynx, and the laryngopharynx. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

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

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

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

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

Larynx

The structure of the **larynx** is formed by several pieces of cartilage. Three large cartilage pieces form the major structure of the larynx.

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

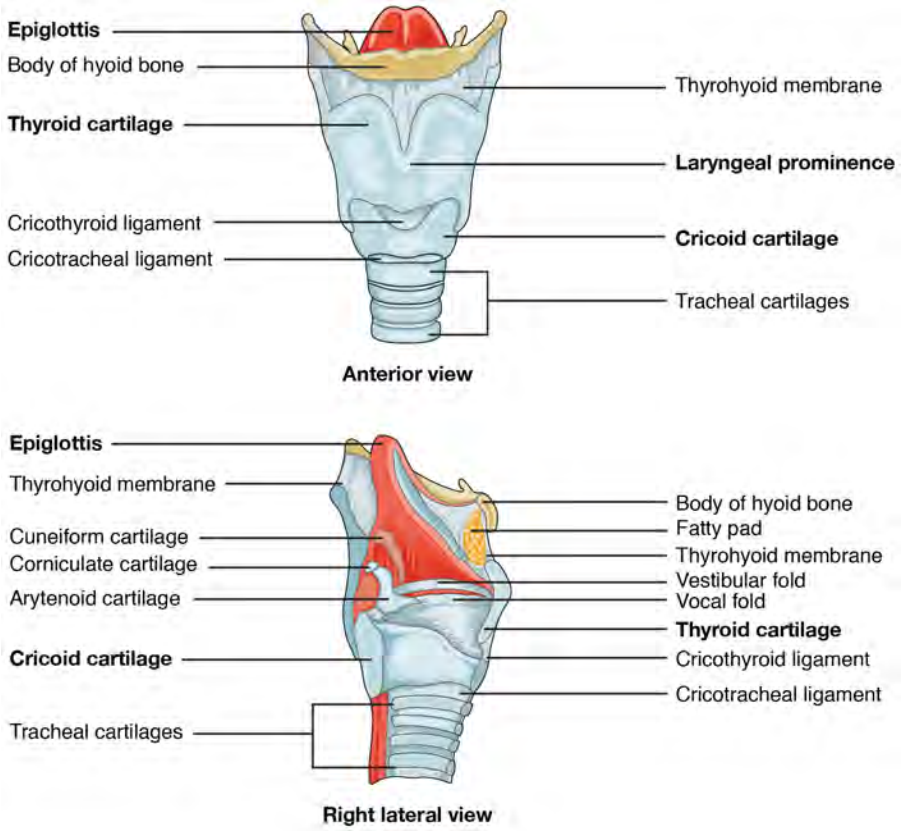

Figure 12.5 Larynx. The larynx extends from the laryngopharynx and the hyoid bone to the trachea. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

The act of swallowing causes the pharynx and larynx to lift upward, allowing the pharynx to expand and the epiglottis

of the larynx to swing downward, closing the opening to the trachea. These movements produce a larger area for food to pass through, while preventing food and beverages from entering the trachea.

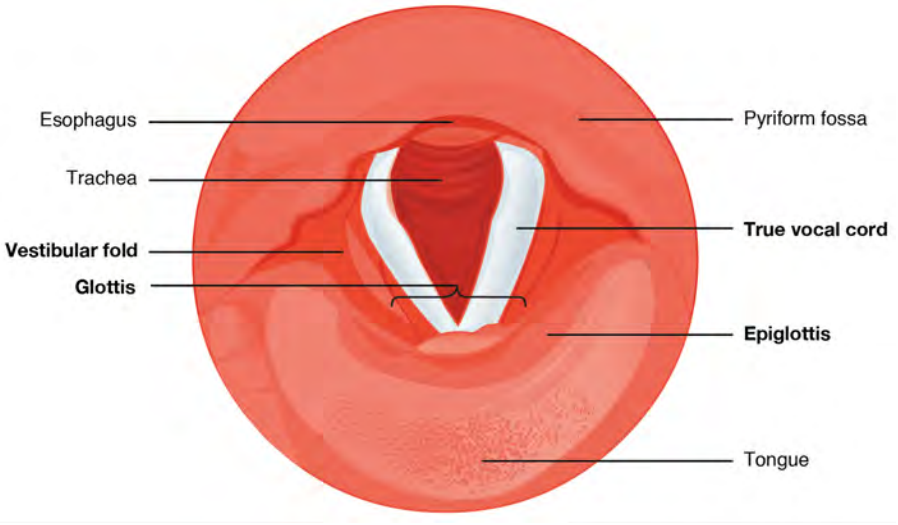

Figure 12.6 Vocal Cords. The true vocal cords and vestibular folds of the larynx are viewed inferiorly from the laryngopharynx. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

Did you know?

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

Trachea

The **trachea** is formed by 16 to 20 stacked, C-shaped pieces of hyaline cartilage that are connected by dense connective tissue. The trachealis muscle and elastic connective tissue together form the **fibroelastic membrane**. The fibroelastic membrane allows the trachea to stretch and expand slightly during inhalation and exhalation, whereas the rings of cartilage provide structural support and prevent the trachea from collapsing. The trachealis muscle can be contracted to force air through the trachea during exhalation. The trachea is lined with pseudostratified ciliated columnar epithelium, which is continuous with the larynx. The esophagus borders the trachea posteriorly.

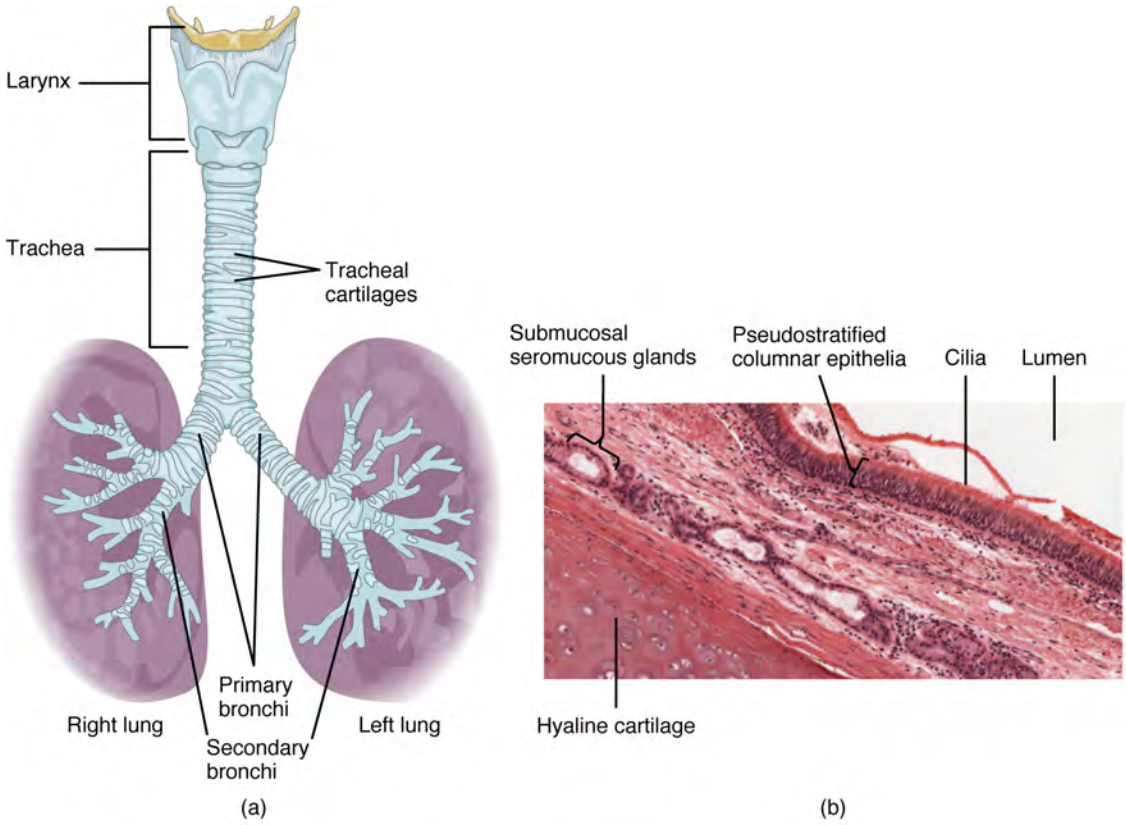

Figure 12.7 Trachea. (a) The tracheal tube is formed by stacked, C-shaped pieces of hyaline cartilage. (b) The layer visible in this cross-section of tracheal wall tissue between the hyaline cartilage and the lumen of the trachea is the mucosa, which is composed of pseudostratified ciliated columnar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

Bronchial Tree

The trachea branches into the right and left primary bronchi at the **carina**. These bronchi are also lined by pseudostratified ciliated columnar epithelium containing mucus-producing goblet cells (Figure 12.7b). The carina is a raised structure that contains specialized nervous tissue that induces violent coughing if a foreign body, such as food, is present. Rings of cartilage, similar to those of the trachea, support the structure of the bronchi and prevent their collapse. The primary bronchi enter the lungs at the **hilum**. The bronchi continue to branch into a bronchial tree. A bronchial tree (or respiratory tree) is the collective term used for these multiple-branched bronchi. The main function of the bronchi, like other conducting zone structures, is to provide a passageway for air to move into and out of each lung. The mucous membrane traps debris and pathogens.

A bronchiole branches from the tertiary bronchi. Bronchioles, which are about 1 mm in diameter, further branch until they become the tiny terminal bronchioles, which lead to the structures of gas exchange. There are more than 1,000 terminal bronchioles in each lung. The muscular walls of the bronchioles do not contain cartilage like those of the bronchi. This muscular wall can change the size of the tubing to increase or decrease airflow through the tube.

Respiratory Zone

In contrast to the **conducting zone**, the **respiratory zone** includes structures that are directly involved in gas exchange. The respiratory zone begins where the terminal bronchioles join a respiratory bronchiole, the smallest type of bronchiole (see Figure 12.8), which then leads to an alveolar duct, opening into a cluster of alveoli.

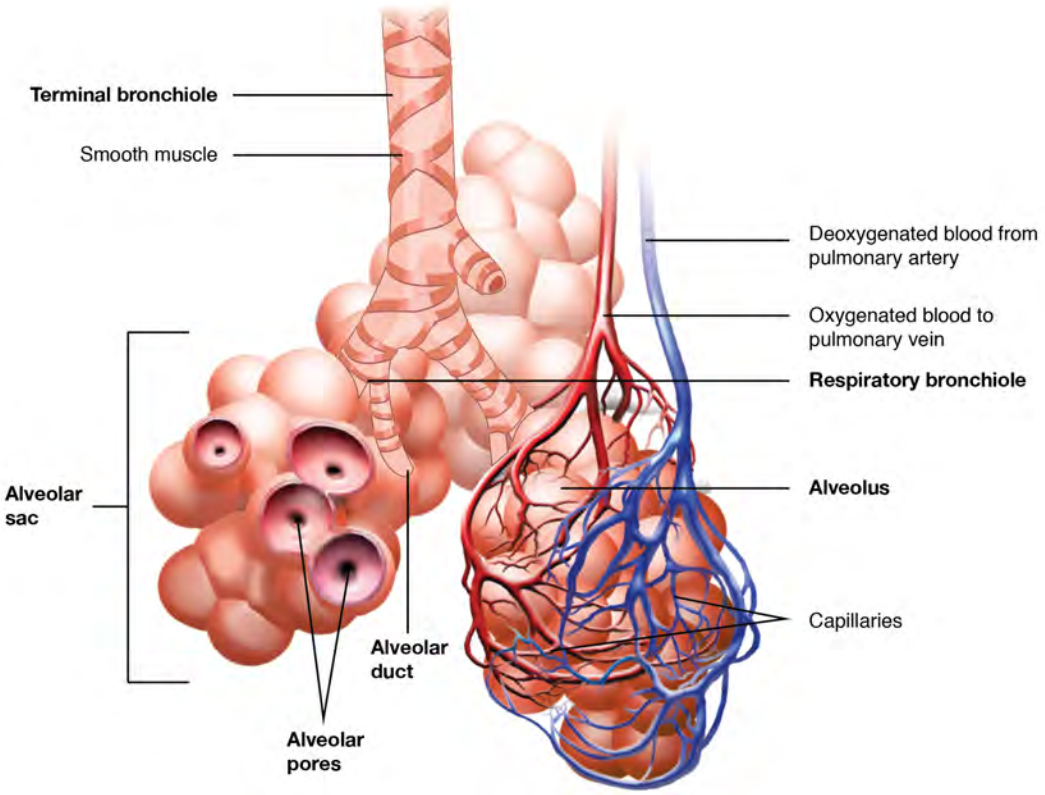

Figure 12.8 Respiratory Zone. Bronchioles lead to alveolar sacs in the respiratory zone, where gas exchange occurs. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

Alveoli

An **alveolar duct** opens into a cluster of alveoli. An alveolus is one of the many small, grape-like sacs that are attached to the alveolar ducts. An alveolar sac is a cluster of many individual alveoli that are responsible for gas exchange. An alveolus is approximately 200 μm in diameter with elastic walls that allow the alveolus to stretch during air intake, which greatly increases the surface area available for gas exchange. Alveoli are connected to their neighbors by alveolar pores, which help maintain equal air pressure throughout the alveoli and lung (see Figure 12.9).

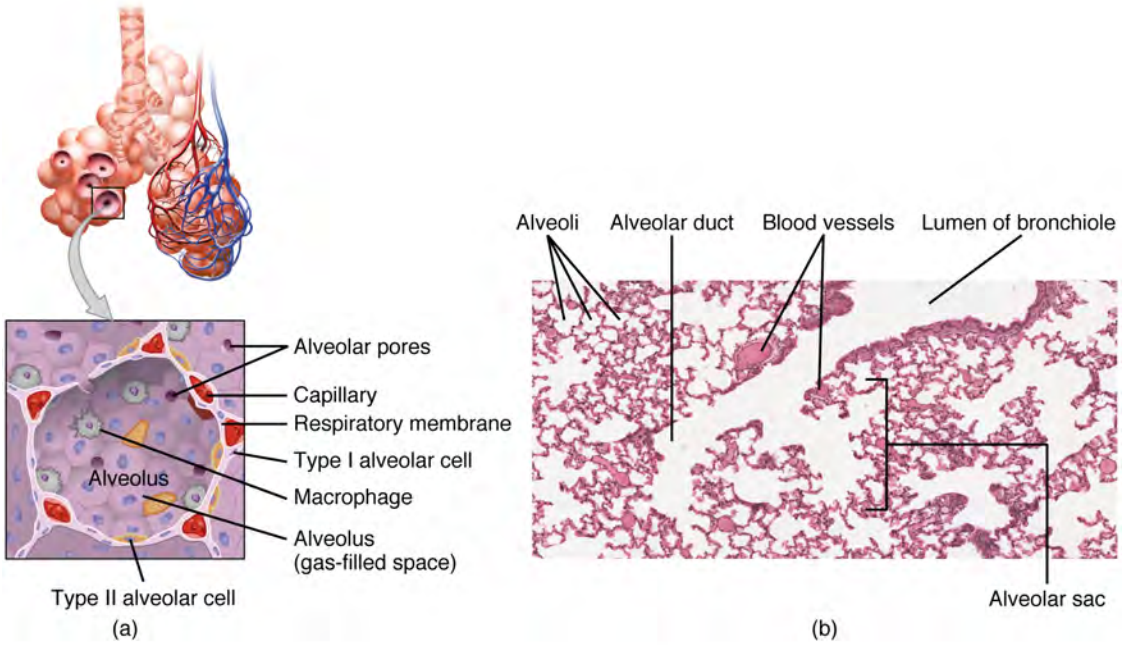

Figure 12.9 Structures of the Respiratory Zone. (a) The alveolus is responsible for gas exchange. (b) A micrograph shows the alveolar structures within lung tissue. LM × 178. (Micrograph provided by the Regents of University of Michigan Medical School © 2012). From Betts et al., 2013. Licensed under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

Concept Check

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

Gross Anatomy of the Lungs

The lungs are pyramid-shaped, paired organs that are connected to the trachea by the right and left bronchi; on the inferior surface, the lungs are bordered by the **diaphragm**. The lungs are enclosed by the pleurae, which are attached to the mediastinum. The right lung is shorter and wider than the left lung, and the left lung occupies a smaller volume than the right. The **cardiac notch** allows space for the heart (see Figure 12.10). The apex of the lung is the superior region, whereas the base is the opposite region near the diaphragm. The costal surface of the lung borders the ribs. The mediastinal surface faces the midline.

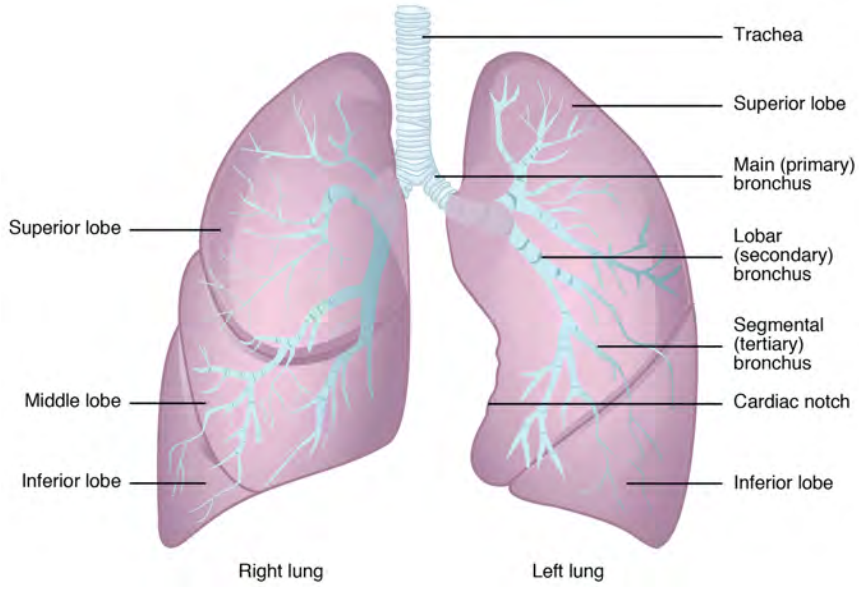

Figure 12.10 Gross Anatomy of the Lungs. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

Can you correctly label the respiratory system structures?

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Physiology (Function) of the Respiratory System

Blood Supply

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

- This blood supply contains deoxygenated blood and travels to the lungs where **erythrocytes** pick up oxygen to be transported to tissues throughout the body.

- The **pulmonary artery** carries deoxygenated, arterial blood to the alveoli.
- The pulmonary artery branches multiple times as it follows the bronchi, and each branch becomes progressively smaller in diameter.
- One arteriole and an accompanying venule supply and drain one pulmonary lobule. As they near the alveoli, the pulmonary arteries become the pulmonary capillary network.
- The pulmonary capillary network consists of tiny vessels with very thin walls that lack smooth muscle fibers.
- The capillaries branch and follow the bronchioles and structure of the alveoli. It is at this point that the capillary wall meets the alveolar wall, creating the respiratory membrane.
- Once the blood is oxygenated, it drains from the alveoli by way of multiple pulmonary veins, which exit the lungs through the **hilum**.

Nervous Innervation

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

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

Reflexes such as coughing, and the ability of the lungs to regulate oxygen and carbon dioxide levels, also result from **autonomic** nervous system control. Sensory nerve fibers arise from the vagus nerve, and from the second to fifth thoracic ganglia. The pulmonary plexus is a region on the lung root formed by the entrance of the nerves at the hilum. The nerves then follow the bronchi in the lungs and branch to innervate muscle fibers, glands, and blood vessels.

Pleura of the Lungs

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

The pleurae consist of two layers:

1. The **visceral pleura** is the layer that is superficial to the lungs and extends into and lines the lung fissures (see Figure 12.11).
2. The **parietal pleura** is the outer layer that connects to the thoracic wall, the mediastinum, and the diaphragm.

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

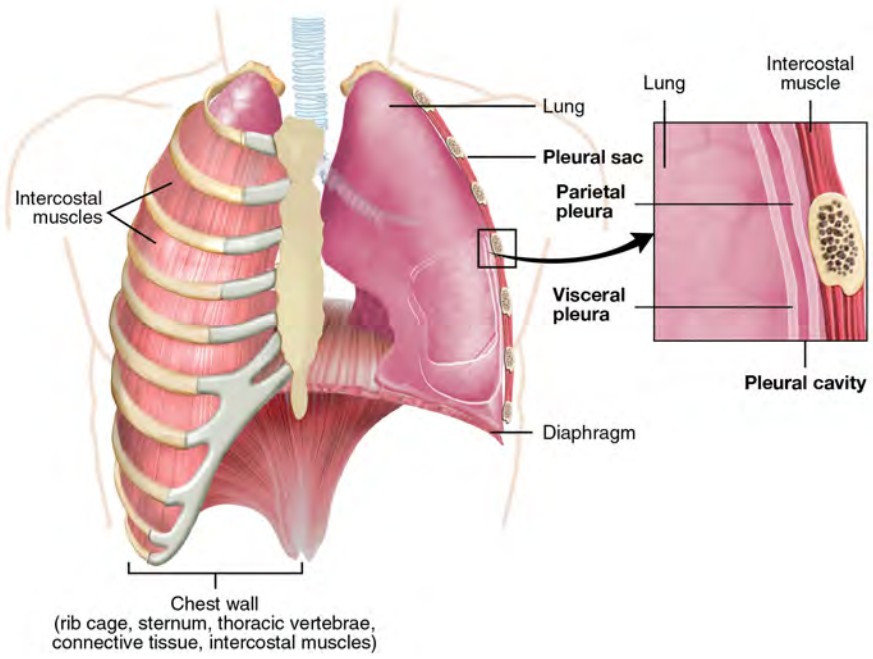

Figure 12.11 Parietal and Visceral Pleurae of the Lungs. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

The pleurae perform two major functions:

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

Pulmonary Ventilation

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

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

Pulmonary ventilation comprises two major steps: inspiration and expiration. **Inspiration** is the process of having air enter the lungs and expiration is the process of expelling air from the lungs (Figure 12.12). A respiratory cycle is one sequence of inspiration and expiration.

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

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

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

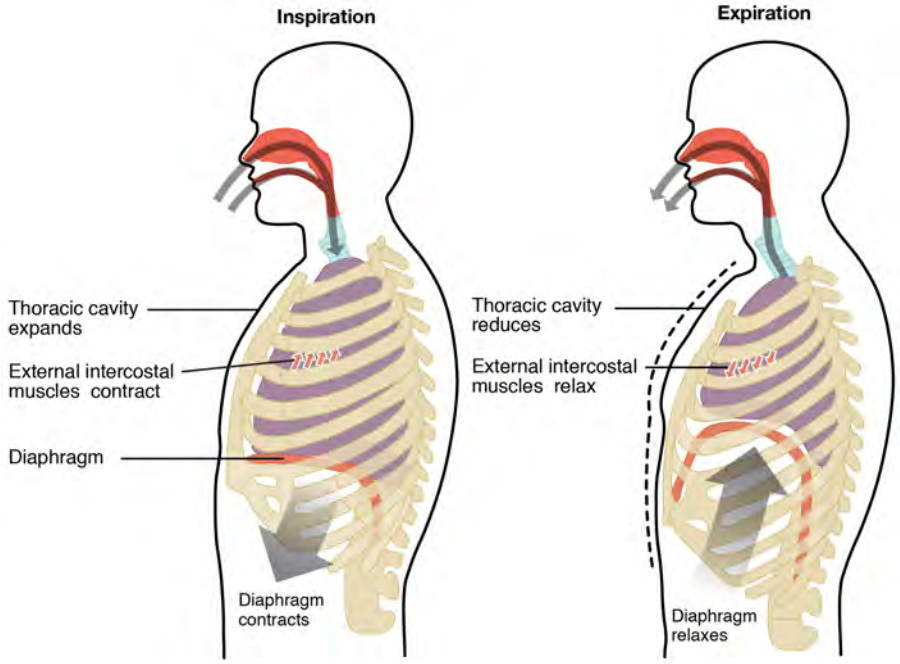

Figure 12.12 Inspiration and Expiration. Inspiration and expiration occur due to the expansion and contraction of the thoracic cavity, respectively. From Betts et al., 2013. Licensed under CC BY 4.0. [Image description.]

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

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

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

- **Quiet breathing**, also known as **eupnea**, is a mode of breathing that occurs at rest and does not require the cognitive thought of the individual. During quiet breathing, the diaphragm and external intercostals must contract.
- **Diaphragmatic breathing**, also known as deep breathing, requires the diaphragm to contract. As the diaphragm relaxes, air passively leaves the lungs.
- **Costal breathing**, also known as a shallow breath, requires contraction of the intercostal muscles. As the intercostal muscles relax, air passively leaves the lungs.

- **Forced breathing**, also known as **hyperpnea**, is a mode of breathing that can occur during exercise or actions that require the active manipulation of breathing, such as singing.
    - During forced breathing, inspiration and expiration both occur due to muscle contractions. In addition to the contraction of the diaphragm and intercostal muscles, other accessory muscles must also contract.
        - During **forced inspiration**, muscles of the neck contract and lift the thoracic wall, increasing lung volume.
        - During **forced expiration**, accessory muscles of the abdomen contract, forcing abdominal organs upward against the diaphragm. This helps to push the diaphragm further into the thorax, pushing more air out. In addition, accessory muscles help to compress the rib cage, which also reduces the volume of the thoracic cavity.

Concept Check

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

Respiratory Rate and Control of Ventilation

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

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

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

Did you know?

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

Watch this video:

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Practice Terms Related to the Respiratory System

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Common Abbreviations for the Respiratory System

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.uwf.edu/medicalterminology/?p=69#h5p-19

Diseases and Disorders of the Respiratory System

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

The Effects of Second-Hand Tobacco Smoke

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

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

Chronic Obstructive Pulmonary Disease (COPD)

COPD is a term used to represent a number of respiratory diseases, including chronic bronchitis and emphysema. COPD is a **chronic** condition with most symptoms appearing in middle-aged or older adults. Signs and symptoms include shortness of breath, cough, and sputum production. There is no cure for COPD. Shortness of breath may be controlled with **bronchodilators**. The best plan is to avoid triggers and getting sick. Clients with COPD are advised to avoid people who are sick, get vaccinated against influenza and pneumococcal pneumonia, and reduce their exposure to pollution and cigarette smoke. While there are several risk factors, as many as 75% of cases are associated with cigarette smoking (National Heart, Lung, and Blood Institute, n.d.). To learn more about COPD, visit the National Heart, Lung, and Blood Institute's web page.

Asthma

Asthma is a chronic disease characterized by inflammation, **edema** of the airway, and bronchospasms which can inhibit air from entering the lungs. Bronchospasms can lead to an "asthma attack." An attack may be triggered by environmental factors such as dust, pollen, pet hair, or dander, changes in the weather, mold, tobacco smoke, and respiratory infections, or by exercise and stress.

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

Lung Cancer

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

There are two types of lung cancer, **small cell lung cancer (SCLC)** and non-small cell lung cancer (NSCLC). Both cancers occur when **malignant** cells form in the tissues of the lung. If **metastasis** occurs, lung cancer cells spread to other parts of the body. Treatment will depend on the type of lung cancer and the stage at diagnosis. Treatments may include surgery, chemotherapy, targeted therapy, immunotherapy, and radiation therapy (National Cancer Institute, 2021a, 2021b).

Sleep Apnea

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

Medical Terms in Context

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Medical Specialties and Procedures Related to the Respiratory System

Respiratory Therapists (RTs)

Respiratory therapists (RTs) are healthcare professionals that monitor, assess, and treat people who are having problems breathing. RTs must have at least a two-year degree. RTs measure lung capacity, test oxygen and carbon dioxide levels, perform chest physiotherapy to remove mucus from patients' lungs, and operate ventilator equipment (Bureau of Labor Statistics, 2021). For more information, visit the American Association for Respiratory Care web page.

Thoracic Surgeon

A thoracic surgeon refers to a surgeon who has specialized in either thoracic (chest) surgery or cardiothoracic (heart and chest) surgery (National Cancer Institute, n.d.). To learn about the career path, read this PDF from The Society of Thoracic Surgeons.

Spirometry Testing

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

- **Respiratory volume** describes the amount of air in a given space within the lungs, or which can be moved by the lung, and is dependent on a variety of factors.
- **Tidal volume** refers to the amount of air that enters the lungs during quiet breathing, whereas inspiratory reserve

volume is the amount of air that enters the lungs when a person inhales past the tidal volume.

- **Expiratory reserve volume** is the extra amount of air that can leave with forceful expiration, following tidal expiration.
- **Residual volume** is the amount of air that is left in the lungs after expelling the expiratory reserve volume.
- **Respiratory capacity** is the combination of two or more volumes.
- **Anatomical dead space** refers to the air within the respiratory structures that never participates in gas exchange, because it does not reach functional alveoli.
- **Respiratory rate** is the number of breaths taken per minute, which may change during certain diseases or conditions.

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

Watch this video:

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

Respiratory System Vocabulary

Adenoidectomy

Excision of the adenoids.

Alveolar duct

Small tube that leads from the terminal bronchiole to the respiratory bronchiole and is the point of attachment for alveoli.

Alveolitis

Inflammation of the alveoli.

Aphonia

Condition of the absence of one's voice.

Apnea

A temporary absence of respiration.

Asphyxia

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

Aspirate

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

Atelectasis

Failure of the lung to expand (inflate) completely.

Autonomic

Involuntary or unconscious.

Benign

Non-cancerous.

Bronchiectasis

Dilation of the bronchi.

Bronchitis

Inflammation of the bronchus.

Bronchodilators

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

Bronchogenic carcinoma

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

Bronchopneumonia

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

Bronchoscope

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

Bronchoscopy

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

Bronchospasm

Spasmodic contraction of the smooth muscle of the bronchi.

Carcinogen

Any substance that causes cancer.

Cardiac notch

An indentation on the surface of the left lung.

Carina

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

Chronic

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

Computerized tomography (CT)

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

Conducting zone

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

Cyanotic

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

Defensins

The lysozyme enzyme and proteins which have antibacterial properties.

Diaphragm

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

Dysphonia

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

Dyspnea

Difficulty breathing.

Epiglottitis

Inflammation of the epiglottis.

Endoscope

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

Endoscopy

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

Epiglottis

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

Epistaxis

Nosebleed.

Erythrocytes

Red blood cells.

Eupnea

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

Expiration

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

External nose

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

Fauces

The opening of the oral cavity into the pharynx.

Fibroelastic membrane

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

Glottis

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

Hard palate

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

Hemothorax

Hemorrhage within the pleural cavity.

Hematologist

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

Hematology

The study of blood and blood-forming issues.

Hilum of the lung

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

Hypercapnia

Abnormally elevated blood levels of CO_2 (carbon dioxide).

Hyperpnea

Forced breathing or breathing that is excessive.

Hypocapnia

Abnormally low blood levels of CO_2 (carbon dioxide).

Hypoxemia

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

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

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

Pleural effusion

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

Pleurisy

Inflammation of the pleura.

Pneumoconiosis

A condition caused by the inhalation of dust.

Pneumonectomy

Excision of the lung.

Pneumonia

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

Pneumothorax

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

Polysomnography (PSG)

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

Posterior

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

Pulmonary artery

Artery that arises from the pulmonary trunk.

Pulmonary edema

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

Pulmonary embolism

A blood clot within the lung.

Radiologist

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

Radiography

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

Radiology

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

Respiratory zone

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

Rhinitis

Inflammation of the mucous membranes of the nose.

Rhinoplasty

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

Rhinorrhea

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

Septal cartilage

The flexible hyaline cartilage connected to the nasal bone.

Sinusitis

Inflammation of the sinuses.

Soft palate

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

Sonogram

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

Spirometry

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

Sputum

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

Stethoscope

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

Sympathetic nervous system (SNS)

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

Tachypnea

Rapid breathing.

Thoracalgia

Pain in the chest.

Thoracentesis

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

Thoracic

Pertaining to the chest.

Thoracoscope

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

Thoracoscopy

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

Thoracotomy

An operation to open the chest.

Tonsillectomy

Excision of the tonsils.

Tonsillitis

Inflammation of the tonsils.

Tracheitis

Inflammation of the trachea.

Tracheostomy

Surgery to create an opening into the trachea.

Tracheotomy

Surgical incision of the trachea.

Trachea

The windpipe.

Upper respiratory infection

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

Uvula

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

Ventilator

A machine used to help a patient breathe.

Test Yourself

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.uwf.edu/medicalterminology/?p=69#h5p-23

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Image Descriptions

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

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

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

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

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

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

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

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

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

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

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

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