1. What is the lymphatic system and what are its functions?
2. Detail the path followed by fluid entering lymphatic capillaries. What forces cause the fluid to follow that path?
1. Compare and contrast lymph nodes, thymus, and spleen.
2. Compare and contrast specific and nonspecific defenses. Give at least two specific examples of each (2 specific, 2 non-specific).
1. Describe how T-cells function in immune response.
2. Describe how antibodies function in immune response.
3. How and why does an allergic reaction occur?
4. Describe the path of food from mouth to anus detailing the digestive processes occurring at each stage.
5. What is the alimentary canal? What moves through it and how is that movement accomplished? (be specific)
6. How are carbohydrates digested? Proteins? Fats? Where are each (carbs, proteins, and fats) absorbed?
7. What are the functions of the liver?
8. What is bile and how does it function?
10. Define respiration and list each major step.
11. What are nasal conchae and what purpose do they serve?
12. Detail the path of a typical oxygen atom from the moment it is breathed in to the moment it is breathed out. What form is that oxygen in when it is breathed in? What form is it in when it is breathed out?
13. How is the process of breathing physically accomplished?
15. What is hyperventilation and how does it affect the length of time one can hold their breath? Why does it have this affect?
1. Describe the process of gas exchange in the lungs.
Chapter 14

Lymphatic System and Immunity
Structure and Function

A. The lymphatic system is comprised of
   1. a network of vessels that transport body fluids
   2. the cells and chemicals in those vessels
   3. the organs and glands that produce them

B. Lymphatic vessels collect and carry away excess fluid from interstitial spaces

C. Special vessels called lacteals transport fats to the circulatory system.

D. The organs of the lymphatic system help defend against disease.
Lymphatic Pathways

A. Lymphatic pathways

1. start as lymphatic capillaries
   a) tiny, closed-ended tubes
   b) extend into interstitial spaces
   c) receive tissue fluid through thin walls
   d) once inside tissue fluid is called lymph

2. merge to form larger lymphatic vessels
   a) walls of are thinner than those of veins
   b) constructed with the same three layers
   c) semilunar valves to prevent backflow
   d) Larger vessels pass through lymph nodes
   e) merge to form lymphatic trunks

3. empty into the circulatory system.
1. The lymphatic trunks
   a) drain lymph from the body
   b) named for the regions they drain

2. These trunks join one of two collecting ducts
   a) The thoracic duct drains into the left subclavian vein
   b) right lymphatic duct drains into the right subclavian vein
Lymph Movement

A. The hydrostatic pressure of tissue fluid drives the entry of lymph into lymphatic capillaries.

B. Forces that move lymph through lymphatic vessels
   1. skeletal
   2. muscle contraction
   3. breathing movements
   4. contraction of smooth muscle in the walls of lymphatic trunks
**Lymph Nodes**

A. Lymph nodes are located along lymphatic pathways and contain **lymphocytes** and **macrophages** to clean the lymph

B. Structure of **Lymph nodes**
   1. bean-shaped
   2. blood vessels, nerves, and efferent lymphatic vessels attached to the indented **hilum**
   3. afferent lymphatic vessels entering on the convex surface.
C. Locations of Lymph Nodes
   1. The lymph nodes generally occur in chains along the parts of the larger lymphatic vessels.

D. Functions of Lymph Nodes
   1. The macrophages and lymphocytes within lymph nodes filter lymph and remove bacteria and cellular debris before lymph is returned to the blood.
   2. Lymph nodes are also centers of lymphocyte production; these cells function in immune surveillance.
Thymus and Spleen

A. The functions of the thymus and spleen are similar to those of lymph nodes.

B. Thymus

1. The thymus is a soft, bi-lobed organ located behind the sternum; it shrinks in size during the lifetime (large in children, microscopic in the elderly).

2. The thymus is surrounded by a connective tissue capsule that extends inside it and divides it into lobules.
3. *Lobules* contain lymphocytes, some of which mature into T lymphocytes (T cells) that leave the thymus to provide immunity.

4. The thymus secretes the hormone *thymosin*, which influences the maturation of T lymphocytes once they leave the thymus.
C. Spleen

1. The spleen lies in the upper left abdominal cavity and is the body’s largest lymphatic organ.

2. The spleen resembles a large lymph node except that it contains blood instead of lymph.

3. Inside the spleen lies
   a. white pulp
      (containing many lymphocytes)
   b. red pulp
      (RBCs, macrophages, and lymphocytes).

4. The spleen filters the blood and removes damaged blood cells and bacteria.
Body Defenses Against Infection

A. Diseases-causing agents, also called pathogens, can produce infections within the body.

B. The body has two lines of defense against pathogens: nonspecific defenses that guard against any pathogen, and specific defenses (immunity) that mount a response against a very specific target.

1. Specific defenses are carried out by lymphocytes that recognize a specific invader.

2. Nonspecific and specific defenses work together to protect the body against infection.
★ Nonspecific Defenses

A. **Species Resistance**

1. A species is resistant to diseases that affects another species

2. Unique chemical environment or temperature that fails to provide the conditions required by the pathogens of another species
B. Mechanical Barriers

1. The unbroken skin and mucous membranes of the body create mechanical barriers that prevent the entry of certain pathogens.

2. Mechanical barriers represent the body’s first line of defense.
C. Chemical Barriers

1. **Chemical barriers**, such as the highly acidic and caustic environment provided by gastric juice, or lysozyme in tears, kill many pathogens.

2. **Interferons**, hormone-like peptides that serve as antiviral substances, are produced by cells when they are infected with viruses and induce nearby cells to produce antiviral enzymes that protect them from infection.
D. Fever

1. **Fever** offers powerful protection against infection by interfering with the proper conditions that promote bacterial growth.

   a. During fever, the amount of iron in the blood is reduced, and thus fewer nutrients are available to support the growth of pathogens.

   b. Phagocytic cells attack with greater vigor when the temperature rises.
E. Inflammation

1. **Inflammation**, a tissue response to a pathogen, is characterized by redness, swelling, heat, and pain.

2. Major actions that occur during an inflammatory response include:
   a. dilation of blood vessels
   b. increase of blood volume in affected areas
   c. invasion of white blood cells into the affected area
   d. appearance of fibroblasts and their production of a sac around the area.
F. Phagocytosis

1. The most active phagocytes are *neutrophils* and *monocytes*; these leave the bloodstream at areas of injury by diapedesis.

   a. Neutrophils engulf smaller particles; monocytes attack larger ones.
2. Monocytes give rise to *macrophages*, which become fixed in various tissues.

3. Monocytes, macrophages, and neutrophils constitute the *mononuclear phagocytic system*.

4. Phagocytosis also removes foreign particles from the lymph.
Specific Defenses (Immunity)

A. The body’s *third line of defense*, **immunity** refers to the response mounted by the body against specific, recognized foreign molecules.
B. Antigens

1. Before birth, the body makes an inventory of “self” proteins and other large molecules.

2. **Antigens** are generally larger molecules that elicit an immune response.

   a. Sometimes small molecules called **haptens** combine with larger molecules and become antigenic.
C. Lymphocyte Origins

1. During fetal development, red bone marrow releases lymphocytes into circulation,
   a. 70-80% of which become **T lymphocytes** (T cells)
   b. the remainder of which become **B lymphocytes** (B cells).
2. Undifferentiated lymphocytes that reach the thymus become T cells; B cells are thought to mature in the bone marrow.

3. Both B and T cells reside in lymphatic organs.
1. Stem cells in red bone marrow give rise to lymphocyte precursors.

2. Some lymphocyte precursors are processed in the thymus to become T cells.

3. Some lymphocyte precursors are processed within the bone marrow to become B cells.

4. Both T cells and B cells are transported through the blood to lymphatic organs, such as the lymph nodes, lymphatic ducts, and spleen.
D. Lymphocyte Functions

1. T cells attack foreign, antigen-bearing cells, such as bacteria, by direct cell-to-cell contact, providing **cell-mediated immunity**.

2. T cells also secrete *cytokines* (lymphokines) that enhance cellular response to antigens.
3. T cells may also secrete toxins that kill target cells, or produce growth-inhibiting factors or interferon to interfere with viruses and tumor cells.

4. B cells attack pathogens by differentiating into plasma cells that secrete antibodies (immunoglobulins).

5. Body fluids attack and destroy specific antigens or antigen-bearing particles through antibody-mediated immunity also called humoral immune response.
E. T Cells and the Cellular Immune Response

1. T cell activation requires the presence of an antigen-presenting cell, such as a B cell or macrophage, that has already encountered the antigen.
2. In order for a helper T cell to become activated, it must first encounter a macrophage displaying the antigen on its major histocompatibility complex (MHC) proteins; if the antigen fits the helper T cell’s antigen receptor, it becomes activated and stimulates B cells to produce antibodies.
3. *Cytotoxic T cells* continually monitor the body's cells, recognizing and eliminating tumor cells and virus-infected cells by release of proteins, cutting holes and by other means.

   a. Cytotoxic T cells become activated when an antigen binds to its receptors.

4. *Memory T cells* provide a no-delay response to any future exposure to the same antigen.
1. B cell combines with antigen

2. Macrophage displays digested antigen on its surface

3. Helper T cell contacts displayed antigen

4. Activated helper T cell interacts with B cell (which has combined with an identical antigen) and releases cytokines, which activate the B cell
F. B Cells and the Humoral Immune Response

1. A B cell may become activated and produce a clone of cells when its antigen receptor encounters its matching antigen, but most B cells need helper T cells for activation.

2. When a helper T cell encounters a B cell that has itself encountered an antigen, the helper T cell releases cytokines that activate the B cell so that it can divide and form a clone.

4. Like T cells, some of the B cells become *memory cells* to respond to future encounters with the antigen.
Antigen

Antigen receptor

Activated B cell

Receptor-antigen combination

Cytokines from helper T cell

Proliferation

Clone of B cells

Proliferation and Differentiation

Released antibodies

Plasma cell (antibody-secreting cell)

Memory cell (dormant cell)

Endoplasmic reticulum

Plasma cell (antibody-secreting cell)

Memory cell (dormant cell)
G. Types of Antibodies

1. There are five major types of antibodies (immunoglobulins) that constitute the \textit{gamma globulin} fraction of the plasma.
H. Antibody Actions

1. Antibodies can react to antigens in three ways:
   a. direct attack
   b. activation of complement
   c. stimulation of changes in areas that help prevent the spread of the pathogens.

2. Direct attack methods include
   a. agglutination
   b. precipitation
   c. neutralization of antigens
3. The activation of complement can produce opsonization, chemotaxis, inflammation, or lysis in target cells or antigens.

- Opsonization—enhancing phagocytosis of antigens
- Chemotaxis—attracting macrophages and neutrophils
- Lysis—rupturing membranes of foreign cells
- Clumping of antigen-bearing agents
- Altering the molecular structure of viruses
J. Practical Classification of Immunity

1. *Naturally acquired active immunity* occurs after exposure to the antigen itself.

2. *Artificially acquired active immunity* occurs through the use of *vaccines*, without the person becoming ill from the disease.

3. *Artificially acquired passive immunity* involves the injection of gamma globulin containing antibodies and is short-lived.

4. *Naturally acquired passive immunity* occurs as antibodies are passed from mother to fetus and is short-lived.
K. Allergic Reactions

1. Allergic reactions to allergens are excessive immune responses that may lead to tissue damage.

2. A delayed-reaction allergy results from repeated exposure to substances that cause inflammatory reactions in the skin.
3. An **immediate-reaction allergy** is an inherited ability to overproduce IgE.

4. During allergic reactions, mast cells release histamine and leukotrienes, producing a variety of effects.

5. Allergy mediators sometimes flood the body, resulting in anaphylactic shock, a severe form of immediate-reaction allergy.
Chapter 15
Digestion and Nutrition
Introduction

A. **Digestion** refers to the *mechanical* and *chemical* breakdown of foods so that nutrients can be absorbed by cells.

B. The digestive system carries out the process of digestion.

C. The **digestive system** consists of the alimentary canal, leading from mouth to anus, and several accessory organs whose secretions aid the processes of digestion.
ACCESSORY ORGANS

Salivary glands
Secrete saliva, which contains enzymes that initiate breakdown of carbohydrates

Liver
Produces bile, which emulsifies fat

Gallbladder
Stores bile and introduces it into small intestine

Pancreas
Produces and secretes pancreatic juice, containing digestive enzymes and bicarbonate ions, into small intestine

ALIMENTARY CANAL

Mouth
Mechanical breakdown of food; begins chemical digestion of carbohydrates

Pharynx
Connects mouth with esophagus.

Esophagus
Peristalsis pushes food to stomach

Stomach
Secretes acid and enzymes. Mixes food with secretions to begin enzymatic digestion of proteins

Small intestine
Mixes food with bile and pancreatic juice. Final enzymatic breakdown of food molecules; main site of nutrient absorption

Large intestine
Absorbs water and electrolytes to form feces

Rectum
Regulates elimination of feces

Anus
D. Structure of the Wall

1. The wall of the alimentary canal consists of the same four layers throughout its length, with only slight variations according to the functions of specific sections of the canal.

   a. The inner layer is the **mucosa**, which is lined with epithelium attached to connective tissue; it protects tissues of the canal and carries on secretion and absorption.
b. The next layer is the submucosa, which is made up of loose connective tissue housing blood and lymph vessels and nerves; it nourishes the surrounding layers of the canal.
c. The **muscular layer** consists of inner *circular fibers* and outer *longitudinal fibers* that propel food through the canal.

d. The outer layer, or **serosa**, is composed of *visceral peritoneum* that protects underlying tissues and secretes serous fluid to keep the canal from sticking to other tissues in the abdominal cavity.
C. Movements of the Tube

1. The motor functions of the alimentary canal are of two types—mixing movements and propelling movements.

2. *Mixing movements* occur when smooth muscles contract rhythmically in small sections of the tube.
3. *Propelling movements* include a wavelike motion called peristalsis, which is caused by contraction behind a mass of food as relaxation allows the mass to enter the next segment of the tube.
Mouth

A. The mouth is the first portion of the alimentary canal; it functions to receive food and begins mechanical digestion by mastication.
Salivary Glands

A. The salivary glands secrete saliva, which moistens and dissolves food particles, binds them together, allows tasting, helps to cleanse the mouth and teeth, and begins carbohydrate digestion.
B. Salivary Secretions

1. Salivary glands contain *serous* cells that produce a watery fluid with *amylase*, and *mucous* cells that produce lubricating and binding mucus.

2. Salivary glands receive parasympathetic stimulation that triggers the production of a large volume of saliva at the sight or smell of food.
C. Swallowing Mechanism

1. Swallowing reflexes can be divided into three stages.
   
a. Food is mixed with saliva and voluntarily forced into the pharynx with the tongue.
b. Sensory receptors in the pharynx sense food, which triggers swallowing reflexes.

c. In the third stage of swallowing, peristalsis transports the food in the esophagus to the stomach.
D. Esophagus

1. The esophagus is a straight, collapsible passageway leading to the stomach.

2. Mucous glands are scattered throughout the submucosa of the esophagus and produce mucus to moisten and lubricate the inner lining of the tube.

3. The lower esophageal sphincter helps to prevent regurgitation of the stomach contents into the esophagus.
Stomach

A. The stomach is a J-shaped muscular organ that receives and mixes food with digestive juices, and propels food to the small intestine.
B. Gastric Secretions

1. **Gastric glands** within the mucosa of the stomach open as gastric pits.

2. Gastric glands generally contain three types of secretory cells.
   a. *Mucous cells* produce mucus that protects the stomach lining.
   b. *Chief cells* secrete **pepsin** (to digest protein)
   c. *Parietal cells* secrete hydrochloric acid.
C. Gastric Absorption

1. The stomach absorbs only small quantities of water and certain salts, alcohol, and some lipid-soluble drugs.
D. Mixing and Emptying Actions

1. Following a meal, mixing actions of the stomach turn the food into chyme and pass it toward the pyloric region using peristaltic waves.

2. As chyme fills the duodenum, accessory organs—the pancreas, liver, and gallbladder—add their secretions.
Pancreas

A. The pancreas has an exocrine function of producing pancreatic juice that aids digestion.
B. Structure of the Pancreas

1. The **pancreas** is closely associated with the small intestine.

2. The cells that produce pancreatic juice, called **pancreatic acinar cells**, make up the bulk of the pancreas.

3. The pancreatic and bile ducts join and empty into the small intestine, which is surrounded by the **hepatopancreatic sphincter**.
C. Pancreatic Juice

1. Pancreatic juice contains enzymes that digest carbohydrates, fats, proteins, and nucleic acids.

2. Pancreatic enzymes include pancreatic amylase, pancreatic lipase, trypsin, chymotrypsin, carboxypeptidase, and two nucleases.

3. Protein-digesting enzymes are released in an inactive form and are activated upon reaching the small intestine.
1. Acidic chyme enters duodenum

2. Intestinal mucosa releases secretin into bloodstream

3. Secretin stimulates pancreas to secrete bicarbonate ions

4. Pancreatic juice rich in bicarbonate ions passes down pancreatic ducts to the duodenum

5. Bicarbonate ions neutralize acidic chyme
Liver

A. The reddish-brown liver, located in the upper right quadrant of the abdominal cavity, is the body’s largest internal organ.

B. Liver Structure

1. The liver is divided into right and left lobes, and is enclosed by a fibrous capsule.

2. Kupffer cells carry on phagocytosis in the liver.

3. Secretions from hepatic cells are collected in bile canals that converge to become hepatic ducts and finally form the common hepatic duct.
C. Liver Functions

1. The liver carries on many diverse functions for the body.

2. The liver is responsible for many metabolic activities, such as the metabolism of carbohydrates, lipids, and proteins.

3. The liver also stores glycogen, vitamins A, D, and B\textsubscript{12}, iron, and blood.
4. The liver filters the blood, removing damaged red blood cells and foreign substances, and removes toxins.

5. The liver's role in digestion is to secrete bile.
D. Composition of Bile

1. **Bile** is a yellowish-green liquid that hepatic cells secrete; it includes water, *bile salts*, *bile pigments*, *cholesterol*, and *electrolytes*.

2. Bile pigments are breakdown products from red blood cells.

3. Only the bile salts have a digestive function.
E. Gallbladder

1. The **gallbladder** is a pear-shaped sac lying on the interior surface of the liver.

2. It is connected to the **cystic duct**, which joins the hepatic duct; these two ducts merge to form the **common bile duct** leading to the duodenum.

3. A sphincter muscle controls the release of bile from the common bile duct.
F. Functions of Bile Salts

1. Bile salts *emulsify* fats into smaller droplets and aid in the absorption of fatty acids, cholesterol, and certain vitamins.
Small Intestine

A. The lengthy small intestine receives secretions from the pancreas and liver, completes digestion of the nutrients in chyme, absorbs the products of digestion, and transports the remaining residues to the large intestine.
B. Structure of the Small Intestinal Wall

1. The inner wall of the small intestine is lined with finger-like intestinal villi, which greatly increase the surface area available for absorption and aid in mixing actions.

2. Each villus contains a core of connective tissue housing blood capillaries and a lymphatic capillary called a lacteal.

3. Between the bases of adjacent villi are tubular intestinal glands.
C. Secretions of the Small Intestine

1. Cells that secrete mucus in the small intestine include goblet cells, which are abundant throughout the mucosa, and *mucus-secreting glands* located in the submucosa of the duodenum.

2. Intestinal glands at the bases of the villi secrete large amounts of watery fluid that carry digestive products into the villi.
D. Regulation of Small Intestinal Secretions

1. Mechanical and chemical stimulation from chyme causes goblet cells to secrete mucus.

2. Distention of the intestinal wall stimulates parasympathetic reflexes that stimulate secretions from the small intestine.
E. Absorption in the Small Intestine

1. The small intestine is the major site of absorption within the alimentary canal.

2. Monosaccharides are absorbed by the villi through active transport or facilitated diffusion and enter blood capillaries.
3. Amino acids are absorbed into the villi by active transport and are carried away in the blood.

4. Fatty acids are absorbed and transported differently than the other nutrients.
   a. Fatty acid molecules dissolve into the cell membranes of the villi.
b. The endoplasmic reticula of the cells reconstruct the lipids.
c. These lipids collect in clusters that become encased in protein (chylomicrons).
d. Chylomicrons are carried away in lymphatic lacteals until they eventually join the bloodstream.

5. The intestinal villi also absorb water (by osmosis) and electrolytes (by active transport).
1. Fatty acids resulting from fat digestion enter epithelial cell.
2. Fatty acids are used to synthesize fats in endoplasmic reticulum.
3. Fats collect in clusters encased in protein to form chylomicrons.
4. Chylomicrons leave epithelial cell and enter lacteal.
5. Lymph in lacteal transports chylomicrons away from intestine.
B. Parts of the Large Intestine

1. The large intestine consists of the cecum (pouch at the beginning of the large intestine), colon (ascending, transverse, descending, and sigmoid regions), the rectum, and the anal canal.

2. The anal canal opens to the outside as the anus; it is guarded by an involuntary internal anal sphincter and a voluntary external anal sphincter muscle.
C. Structure of the Large Intestinal Wall

1. The large intestinal wall has the same four layers found in other areas of the alimentary canal, but lacks many of the features of the small intestinal mucosa such as villi.

2. Fibers of longitudinal muscle are arranged in teniae coli that extend the entire length of the colon, creating a series of pouches (haustra).
D. Functions of the Large Intestine

1. The large intestine does not digest or absorb nutrients, but it does secrete mucus.

2. The large intestine absorbs electrolytes and water.

3. The large intestine contains important bacteria which synthesize vitamins and use cellulose.
E. Movements of the Large Intestine

1. The movements of the large intestine are similar to those of the small intestine.

2. Peristaltic waves happen only two or three times during the day.

3. Defecation is stimulated by a *defecation reflex* that forces feces into the rectum where they can be expelled.
Carbohydrate Utilization

1. The monosaccharides that are absorbed in the small intestine are fructose, galactose, and glucose; the liver converts the first two into glucose.

2. Excess glucose is stored as glycogen in the liver or is converted into fat and stored in adipose tissue.
Lipid Utilization

1. Digestion breaks down triglycerides into fatty acids and glycerol.

2. The liver and adipose tissue control triglyceride metabolism which has many steps.

3. The liver can convert fatty acids from one form to another, but it cannot synthesize the essential fatty acids that must be obtained from the diet.
4. The liver controls circulating lipids and cholesterol.

5. Excessive lipids are stored in adipose tissue.
Vitamins

A. Vitamins are organic compounds required in small amounts for normal metabolic processes, and are not produced by cells in adequate amounts.

1. Vitamins are fat-soluble (vitamins A, D, E, and K) or water-soluble (B vitamins and vitamin C).
B. Fat-Soluble Vitamins

1. Fats-soluble vitamins dissolve in fats and are influenced by some of the factors that influence lipid absorption.

2. Fat-soluble vitamins are stored in moderate quantities in the body and are usually not destroyed by cooking or processing foods.
3. Table 15.8 lists the characteristics, functions, sources, and recommended daily allowances (RDA) for adults for the fat-soluble vitamins.

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Characteristics</th>
<th>Functions</th>
<th>Sources and RDA(^*) for Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>Occurs in several forms; synthesized from carotenes; stored in liver; stable in heat, acids, and bases; unstable in light</td>
<td>Necessary for synthesis of visual pigments, mucoproteins, and mucopolysaccharides; for normal development of bones and teeth; and for maintenance of epithelial cells</td>
<td>Liver, fish, whole milk, butter, eggs, leafy green vegetables, yellow and orange vegetables and fruits; RDA = 4,000–5,000 IU(^7)</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>A group of steroids; resistant to heat, oxidation, acids, and bases; stored in liver, skin, brain, spleen, and bones</td>
<td>Promotes absorption of calcium and phosphorus; promotes development of teeth and bones</td>
<td>Produced in skin exposed to ultraviolet light; in milk, egg yolk, fish liver oils, fortified foods; RDA = 400 IU</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>A group of compounds; resistant to heat and visible light; unstable in presence of oxygen and ultraviolet light; stored in muscles and adipose tissue</td>
<td>An antioxidant; prevents oxidation of vitamin A and polyunsaturated fatty acids; may help maintain stability of cell membranes</td>
<td>Oils from cereal seeds, salad oils, margarine, shortenings, fruits, nuts, and vegetables; RDA = 30 IU</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>Occurs in several forms; resistant to heat, but destroyed by acids, bases, and light; stored in liver</td>
<td>Required for synthesis of prothrombin, which functions in blood clotting</td>
<td>Leafy green vegetables, egg yolk, pork liver, soy oil, tomatoes, cauliflower; RDA = 55–70 µg</td>
</tr>
</tbody>
</table>

\(^*\)RDA = recommended daily allowance.  
\(^7\)IU = international unit.
C. Water-Soluble Vitamins

1. Water-soluble vitamins, including the **B vitamins** and vitamin C, are necessary for normal cellular metabolism in the oxidation of carbohydrates, lipids, and proteins.
2. **Vitamin C** (ascorbic acid) is needed for the production of collagen, the metabolism of certain amino acids, and the conversion of folacin into folic acid.

3. Table 15.9 lists the characteristics, functions, sources and RDAs for adults of the water-soluble vitamins.
<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Characteristics</th>
<th>Functions</th>
<th>Sources and RDA* for Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamine (vitamin B₁)</td>
<td>Destroyed by heat and oxygen, especially in alkaline environment</td>
<td>Part of coenzyme required to oxidize carbohydrates; coenzyme required for ribose synthesis</td>
<td>Lean meats, liver, eggs, whole-grain cereals, leafy green vegetables, legumes; RDA = 1.5 mg</td>
</tr>
<tr>
<td>Riboflavin (vitamin B₂)</td>
<td>Stable to heat, acids, and oxidation; destroyed by bases and ultraviolet light</td>
<td>Part of enzymes and coenzymes required to oxidize glucose and fatty acids and for cellular growth</td>
<td>Meats, dairy products, leafy green vegetables, whole-grain cereals; RDA = 1.7 mg</td>
</tr>
<tr>
<td>Niacin (nicotinic acid) (vitamin B₃)</td>
<td>Stable to heat, acids, and bases; converted to niacinamide by cells; synthesized from tryptophan</td>
<td>Part of coenzymes required to oxidize glucose and to synthesize proteins, fats, and nucleic acids</td>
<td>Liver, lean meats, peanuts, legumes; RDA = 20 mg</td>
</tr>
<tr>
<td>Pantothenic acid (vitamin B₅)</td>
<td>Destroyed by heat, acids, and bases</td>
<td>Part of coenzyme A required to oxidize carbohydrates and fats</td>
<td>Meats, whole-grain cereals, legumes, milk, fruits, vegetables; RDA = 10 mg</td>
</tr>
<tr>
<td>Vitamin B₆</td>
<td>Group of three compounds; stable to heat and acids; destroyed by oxidation, bases, and ultraviolet light</td>
<td>Coenzyme required to synthesize proteins and certain amino acids, to convert tryptophan to niacin, to produce antibodies, and to synthesize nucleic acids</td>
<td>Liver, meats, bananas, avocados, beans, peanuts, whole-grain cereals, egg yolk; RDA = 2 mg</td>
</tr>
<tr>
<td>Cyanocobalamin (vitamin B₁₂)</td>
<td>Complex, cobalt-containing compound; stable to heat; inactivated by light, strong acids, and strong bases; absorption regulated by intrinsic factor from gastric glands; stored in liver</td>
<td>Part of coenzyme required to synthesize nucleic acids and to metabolize carbohydrates; plays role in myelin synthesis; needed for normal red blood cell production</td>
<td>Liver, meats, milk, cheese, eggs; RDA = 3–6 μg</td>
</tr>
<tr>
<td>Folacin (folic acid)</td>
<td>Occurs in several forms; destroyed by oxidation in acid environment or by heat in alkaline environment; stored in liver, where it is converted into folinic acid</td>
<td>Coenzyme required for metabolism of certain amino acids and for DNA synthesis; promotes red blood cell production</td>
<td>Liver, leafy green vegetables, whole-grain cereals, legumes; RDA = 0.4 mg</td>
</tr>
<tr>
<td>Biotin</td>
<td>Stable to heat, acids, and light; destroyed by oxidation and bases</td>
<td>Coenzyme required to metabolize amino acids and fatty acids, and to synthesize nucleic acids</td>
<td>Liver, egg yolk, nuts, legumes, mushrooms; RDA = 0.3 mg</td>
</tr>
<tr>
<td>Ascorbic acid (vitamin C)</td>
<td>Chemically similar to monosaccharides; stable in acids but destroyed by oxidation, heat, light, and bases</td>
<td>Required to produce collagen, to convert folacin to folinic acid, and to metabolize certain amino acids; promotes absorption of iron and synthesis of hormones from cholesterol</td>
<td>Citrus fruits, tomatoes, potatoes, leafy green vegetables; RDA = 60 mg</td>
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*RDA = recommended daily allowance.
Chapter 16
Respiratory System
Introduction

A. The respiratory system consists of tubes that filter incoming air and transport it into the microscopic alveoli where gases are exchanged.
B. The entire process of exchanging gases between the atmosphere and body cells is called \textit{respiration} and consists of the following:

1. \textit{ventilation}
2. gas exchange between blood and lungs
3. gas transport in the bloodstream
4. gas exchange between the blood and body cells
5. \textit{cellular respiration}.
Organs of the Respiratory System

A. The organs of the respiratory tract can be divided into two groups:

1. the *upper respiratory tract*
   (nose, nasal cavity, sinuses, and pharynx)

2. the *lower respiratory tract*
   (larynx, trachea, bronchial tree, and lungs).
B. Nasal Cavity

1. The **nasal cavity** is a space posterior to the nose that is divided medially by the **nasal septum**.

2. **Nasal conchae** divide the cavity into passageways that are lined with mucous membrane, and help increase the surface area available to warm and filter incoming air.

3. Particles trapped in the mucus are carried to the pharynx by ciliary action, swallowed, and carried to the stomach where gastric juice destroys any microorganisms in the mucus.
E. Pharynx

1. The **pharynx** is a common passageway for air and food.

2. The pharynx aids in producing sounds for speech.
G. Trachea

1. The trachea extends downward anterior to the esophagus and into the thoracic cavity, where it splits into right and left bronchi.

2. The inner wall of the trachea is lined with ciliated mucous membrane with many goblet cells that serve to trap incoming particles.

3. The tracheal wall is supported by 20 incomplete cartilaginous rings.
H. Bronchial Tree

1. The bronchial tree consists of branched tubes leading from the trachea to the alveoli.

2. The bronchial tree begins with the two primary bronchi, each leading to a lung.
3. The branches of the bronchial tree from the trachea are right and left primary bronchi; these further subdivide until bronchioles give rise to alveolar ducts which terminate in alveoli.

4. It is through the thin epithelial cells of the alveoli that gas exchange between the blood and air occurs.
II. Lungs

1. The right and left soft, spongy, cone-shaped lungs are separated medially by the mediastinum and are enclosed by the diaphragm and thoracic cage.

2. The bronchus and large blood vessels enter each lung.
Breathing Mechanism

A. *Ventilation* (breathing), the movement of air in and out of the lungs, is composed of *inspiration* and *expiration*.

B. Inspiration

1. *Atmospheric pressure* is the force that moves air into the lungs.

2. When pressure on the inside of the lungs decreases, higher pressure air flows in from the outside.
3. Air pressure inside the lungs is decreased by increasing the size of the thoracic cavity; due to surface tension between the two layers of pleura, the lungs follow with the chest wall expand.

4. Muscles involved in expanding the thoracic cavity include the diaphragm and the external intercostal muscles.
5. As the lungs expand in size, **surfactant** keeps the alveoli from sticking to each other so they do not collapse when internal air pressure is low.
C. Expiration

1. The forces of expiration are due to the elastic recoil of lung and muscle tissues and from the surface tension within the alveoli.

2. Forced expiration is aided by thoracic and abdominal wall muscles that compress the abdomen against the diaphragm.
D. Respiratory Air Volumes and Capacities

1. The measurement of different air volumes is called *spirometry*, and it describes four distinct respiratory volumes.

2. One inspiration followed by expiration is called a *respiratory cycle*; the amount of air that enters or leaves the lungs during one respiratory cycle is the *tidal volume*.
3. During forced inspiration, an additional volume, the **inspiratory reserve volume**, can be inhaled into the lungs. IRV + TV gives us the **inspiratory capacity**.

4. During a maximal forced expiration, an **expiratory reserve volume** can be exhaled, but there remains a **residual volume** in the lungs. Adding the two together gives us the **functional reserve capacity**.
5. **Vital capacity** is the tidal volume plus inspiratory reserve and expiratory reserve volumes combined.

6. Vital capacity plus residual volume is the **total lung capacity**.

7. *Anatomic dead space* is air remaining in the bronchial tree.
Control of Breathing

A. Normal breathing is a rhythmic, involuntary act even though the muscles are under voluntary control.
C. Factors Affecting Breathing

1. Chemicals, lung tissue stretching, and emotional state affect breathing.

2. *Chemosensitive areas* (central chemoreceptors) are associated with the respiratory center and are sensitive to changes in the blood concentration of carbon dioxide and hydrogen ions.
a. If either carbon dioxide or hydrogen ion concentrations rise, the central chemoreceptors signal the respiratory center, and breathing rate increases.
3. *Peripheral chemoreceptors* in the *carotid sinuses* and *aortic arch* sense changes in blood oxygen concentration, transmit impulses to the respiratory center, and breathing rate and tidal volume increase.
4. An *inflation reflex*, triggered by stretch receptors in the visceral pleura, bronchioles, and alveoli, helps to prevent overinflation of the lungs during forceful breathing.

5. **Hyperventilation** lowers the amount of carbon dioxide in the blood.
Alveolar Gas Exchanges

A. The alveoli are the only sites of gas exchange between the atmosphere and the blood.

B. Alveoli

1. The alveoli are tiny sacs clustered at the distal ends of the alveolar ducts.
C. Respiratory Membrane

1. The respiratory membrane consists of the epithelial cells of the alveolus, the endothelial cells of the capillary, and the two fused basement membranes of these layers.

2. Gas exchange occurs across this respiratory membrane.
D. Diffusion across the Respiratory Membrane

1. Gases diffuse from areas of higher pressure to areas of lower pressure.

2. In a mixture of gases, each gas accounts for a portion of the total pressure; the amount of pressure each gas exerts is equal to its partial pressure.
3. When the partial pressure of oxygen is higher in the alveolar air than it is in the capillary blood, oxygen will diffuse into the blood.

4. When the partial pressure of carbon dioxide is greater in the blood than in the alveolar air, carbon dioxide will diffuse out of the blood and into the alveolus.
5. A number of factors favor increased diffusion; more surface area, shorter distance, greater solubility of gases, and a steeper partial pressure gradient.
Gas Transport

A. Gases are transported in association with molecules in the blood or dissolved in the plasma.

B. Oxygen Transport

1. Over 98% of oxygen is carried in the blood bound to hemoglobin of red blood cells, producing oxyhemoglobin.

2. Oxyhemoglobin is unstable in areas where the concentration of oxygen is low, and gives up its oxygen molecules in those areas.
3. More oxygen is released as the blood concentration of carbon dioxide increases, as the blood becomes more acidic, and as blood temperature increases.

4. A deficiency of oxygen reaching the tissues is called hypoxia and has a variety of causes.
A. Alveolar wall

Blood flow (from body tissues)

Oxygen molecules

Hemoglobin molecules

Diffusion of oxygen

Alveolus

B. Capillary

Blood $P_{O_2} = 95$ mm Hg

Hemoglobin molecules

Diffusion of oxygen

Tissue cells

Blood $P_{O_2} = 40$ mm Hg

Tissue $P_{O_2} = 40$ mm Hg
C. Carbon Dioxide Transport

1. Carbon dioxide may be transported dissolved in blood plasma, as carbaminohemoglobin, or as bicarbonate ions.

2. Most carbon dioxide is transported in the form of bicarbonate.
3. When carbon dioxide reacts with water in the plasma, carbonic acid is formed slowly, but instead much of the carbon dioxide enters red blood cells, where the enzyme carbonic anhydrase speeds this reaction.
4. The resulting carbonic acid dissociates immediately, releasing bicarbonate and hydrogen ions.

5. Carbaminohemoglobin also releases its carbon dioxide which diffuses out of the blood into the alveolar air.