7.1 Organization of the Human Body

Learning Objectives

- List the levels of organization in the human body.
- Identify the four types of tissues that make up the body.
- Identify the six main organ systems.
- Describe how organs and organ systems work together to maintain homeostasis.

Introduction

How do cells work together to allow an organism to live?

Cells, like these nerve cells (pictured above), do not work in isolation. To send orders from your brain to your legs, for example, signals pass through many nerve cells. These cells work together to perform a similar function. Just as muscle cells work together, bone cells and many other cells do as well. A group of similar cells that work together is known as a tissue. Tissues work together to form organs, and organs work together to form organ systems, all of which allow an entire organism to live.

Guided Learning

Organization of your Body: Cells, Tissues, Organs, and Organ Systems

Cells are grouped together to carry out specific functions. A group of cells that work together form a tissue. Your body has four main types of tissues, as do the bodies of other animals. These tissues make up all structures and contents of your body. An example of each tissue type is pictured below (Figure below).

1 Photo by CK-12 / CC-BY-SA 3.0.
Your body has four main types of tissue: nervous tissue, epithelial tissue, connective tissue, and muscle tissue. They are found throughout your body.

1. **Epithelial tissue** is made up of layers of tightly packed cells that line the surfaces of the body. Examples of epithelial tissue include the skin, the lining of the mouth and nose, and the lining of the digestive system.
2. **Connective tissue** is made up of many different types of cells that are all involved in supporting and binding other tissues of the body. Examples include tendon, cartilage, and bone. Blood is also classified as a specialized connective tissue.
3. **Muscle tissue** is made up of bands of cells that contract and allow movement.
4. **Nervous tissue** is made up of nerve cells that sense stimuli and transmit signals. Nervous tissue is found in nerves, the spinal cord, and the brain.

**Groups of Tissues Form Organs**

A single tissue alone cannot do all the jobs that are needed to keep you alive and healthy. Two or more tissues working together can do a lot more. An **organ** is a structure made of two or more tissues that work together. The heart (Figure below) is made up of the four types of tissues.

---

2 *Body Tissues* by IGOR KISSELEV / CK-12 / CC-BY-SA 3.0.
The four different tissue types work together in the heart as they do in the other organs.

Groups of Organs Form Organ Systems

Your heart pumps blood around your body. But how does your heart get blood to and from every cell in your body? Your heart is connected to blood vessels such as veins and arteries. Organs that work together form an organ system. Together, your heart, blood, and blood vessels form your cardiovascular system.

What other organ systems can you think of?

Organ Systems Work Together

Your body’s twelve organ systems are shown below (Table below). Your organ systems do not work alone in your body. They must all be able to work together.

For example, one of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

<table>
<thead>
<tr>
<th>Organ System</th>
<th>Major Tissues and Organs</th>
<th>Function</th>
</tr>
</thead>
</table>

3 Four Tissues Heart by PATRICK J. LYNCH / CK-12 / CC-BY-SA 3.0.
<table>
<thead>
<tr>
<th>System</th>
<th>Structures</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular</td>
<td>Heart; blood vessels; blood</td>
<td>Transports oxygen, hormones, and nutrients to the body cells. Moves wastes and carbon dioxide away from cells.</td>
</tr>
<tr>
<td>Lymphatic</td>
<td>Lymph nodes; lymph vessels</td>
<td>Defend against infection and disease, moves lymph between tissues and the blood stream.</td>
</tr>
<tr>
<td>Digestive</td>
<td>Esophagus; stomach; small intestine; large intestine</td>
<td>Digests foods and absorbs nutrients, minerals, vitamins, and water.</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Pituitary gland, hypothalamus; adrenal glands; ovaries; testes</td>
<td>Produces hormones that communicate between cells.</td>
</tr>
<tr>
<td>Integumentary</td>
<td>Skin, hair, nails</td>
<td>Provides protection from injury and water loss, physical defense against infection by microorganisms, and temperature control.</td>
</tr>
<tr>
<td>Muscular</td>
<td>Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons</td>
<td>Involved in movement and heat production.</td>
</tr>
<tr>
<td>Nervous</td>
<td>Brain, spinal cord; nerves</td>
<td>Collects, transfers, and processes information.</td>
</tr>
<tr>
<td>Reproductive</td>
<td>Female: uterus; vagina; fallopian tubes; ovaries Male: penis; testes; seminal vesicles</td>
<td>Produces gametes (sex cells) and sex hormones.</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Trachea, larynx, pharynx, lungs</td>
<td>Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs).</td>
</tr>
<tr>
<td>Skeletal</td>
<td>Bones, cartilage; ligaments</td>
<td>Supports and protects soft tissues of body; produces blood cells; stores minerals.</td>
</tr>
<tr>
<td>Urinary</td>
<td>Kidneys; urinary bladder</td>
<td>Removes extra water, salts, and waste products from blood and body; controls pH; controls water and salt balance.</td>
</tr>
<tr>
<td>Immune</td>
<td>Bone marrow; spleen; white blood cells</td>
<td>Defends against diseases.</td>
</tr>
</tbody>
</table>

**Summary**

- The levels of organization in the human body include: cells, tissues, organs, and organ systems.
- There are four tissue types in the body: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.
Vocabulary

**cardiovascular system**
Organ system made up of the heart, blood, and blood vessels.

**cells**
Basic unit of structure and function of a living organism; the basic unit of life.

**connective tissue**
Group of cells that are all involved in supporting and binding other tissues of the body; i.e. tendon, cartilage, bone, and blood.

**epithelial tissue**
Layers of tightly packed cells that line the surfaces of the body.

**muscle tissue**
Bands of cells that contract and allow movement.

**nervous tissue**
Group of nerve cells that sense stimuli and transmit signals; found in brain, spinal cord, and nerves.

**organ**
Structure made of two or more tissues that work together.

**organ system**
Organs that work together to serve a common purpose.

**tissue**
Group of similar cells working together.

7.2 The Skeletal System

**Learning Objectives**
- Identify the main tissues and organs of the skeletal system.
- List four functions of the skeletal system.
- Describe three movable joints.
- Identify two nutrients that are important for a healthy skeletal system.
- Describe two skeletal system injuries.

**Introduction**
How important is your skeleton? Can you imagine your body without it? You would be a wobbly pile of muscle and internal organs, and you would not be able to move.
Guided Learning

Your skeleton is important for many different things. Bones are the main organs of the skeletal system. They are made up of living tissue. Humans are vertebrates, which are animals that have a backbone. The sturdy set of bones and cartilage that is found inside vertebrates is called a skeleton.

The adult human skeleton has 206 bones, some of which are named in Figure below. Strangely, even though they are smaller, the skeletons of babies and children have many more bones and more cartilage than adults have. As a child grows, these “extra” bones grow into each other, and cartilage slowly hardens to become bone tissue.

Living bones are full of life. They contain many different types of tissues. Cartilage is found at the end of bones and is made of tough protein fibers called collagen. Cartilage creates smooth surfaces for the movement of bones that are next to each other, like the bones of the knee.

Ligaments are made of tough protein fibers and connect bones to each other. Your bones, cartilage, and ligaments make up your skeletal system.

The skeletal system is made up of bones, cartilage, and ligaments. The skeletal system has many important functions in your body.
Functions of Bones

Your skeletal system gives shape and form to your body, but it is also important in maintaining homeostasis. The main functions of the skeletal system include:

- **Support:** The skeleton supports the body against the pull of gravity, meaning you don't fall over when you stand up. The large bones of the lower limbs support the rest of the body when standing.
- **Protection:** The skeleton supports and protects the soft organs of the body. For example, the skull surrounds the brain to protect it from injury. The bones of the rib cage help protect the heart and lungs.
- **Movement:** Bones work together with muscles to move the body.
- **Making blood cells:** Blood cells are mostly made inside certain types of bones.
- **Storage:** Bones store calcium. They contain more calcium than any other organ. Calcium is released by the bones when blood levels of calcium drop too low. The mineral phosphorus is also stored in bones.

Structure of Bones

Bones are organs. Recall that organs are made up of two or more types of tissues. Bones come in many different shapes and sizes, but they are all made of the same materials.

The two main types of bone tissue are compact bone and spongy bone.

- Compact bone makes up the dense outer layer of bones.
- Spongy bone is found at the center of the bone, and is lighter and less dense than compact bone.

Bones look tough, shiny, and white because they are covered by a layer called the periosteum. Many bones also contain a soft connective tissue called **bone marrow**. There are two types of bone marrow, red marrow and yellow marrow.

- Red marrow makes red blood cells, platelets, and most of the white blood cells for the body (discussed in the Diseases and the Body's Defenses chapter).
- Yellow marrow makes white blood cells.

The bones of newborn babies contain only red marrow. As children get older, some of their red marrow is replaced by yellow marrow. In adults, red marrow is found mostly in the bones of the skull, the ribs, and pelvic bones.

Bones come in four main shapes. They can be long, short, flat, or irregular. Identifying a bone as long, short, flat, or irregular is based on the shape of the bone, not the size of the bone. For example, both small and large bones can be classified as long bones. The small bones in your fingers and the largest bone in your body, the femur, are all long bones. The structure of a long bone is shown in **Figure** below.
Bones are made up of different types of tissues.

Joints and How They Move

A joint is a point at which two or more bones meet. There are three types of joints in the body:

1. Fixed joints do not allow any bone movement. Many of the joints in your skull are fixed (Figure below).
2. Partly movable joints allow only a little movement. Your backbone has partly movable joints between the vertebrae (Figure below).

Joints are a type of lever, which is a rigid object that is used to increase the amount of force put onto another object. Can openers and scissors are examples of levers. Joints reduce the amount of energy that is spent moving the body around. Just imagine how difficult it would be to walk about if you did not have knees!

5 Tissues in Bone by CHRISTOPHER AUYELNG / CK-12 / CC-BY-SA 3.0.
The skull has fixed joints. Fixed joints do not allow any movement of the bones, which protects the brain from injury.

The joints between your vertebrae are partially movable.

---

6 Fixed Joints Skill by ALEX GRICHENKO / CK-12 / CC-BY-SA 3.0.
7 Partly Movable Joints Vertebrae by LAURA GUERIN / CK-12 / CC-BY-SA 3.0.
Review

- Bones, cartilage, and ligaments make up the skeletal system.
- The skeleton supports the body against the pull of gravity.
- The skeleton provides a framework that supports and protects the soft organs of the body.
- Bones work together with muscles to move the body.
- Blood cells are mostly made inside the bone marrow.
- There are three types of joints in the body: fixed, partly movable, and movable.

Vocabulary

**bone marrow**
Tissue found on the inside of bones; produces blood cells.

**cartilage**
Tissue found in the joints between bones; also helps form the rib cage, ear, nose, and bronchial tubes.

**ligament**
Tissue that connects bones to other bones.

**movable joint**
A join which allows movement.

**skeletal system**
The internal framework of the body which consists of 270 bones at birth and 206 by adulthood.

**skeleton**
The sturdy set of bones and cartilage that is found inside vertebrates.

7.3 The Muscular System

**Learning Objectives**

- Identify the three muscle types in the body.
- Describe how skeletal muscles and bones work together to move the body.

**Introduction**

The **muscular system** is the body system that allows us to move. You depend on many muscles to keep you alive. Your heart, which is mostly muscle, pumps blood around your body. Muscles are always moving in your body. Muscles use **ATP**, a form of energy to move.
Guided Learning

Types of Muscles

Each muscle in the body is made up of cells called muscle fibers. Muscle fibers are long, thin cells that can do something that other cells cannot do — they are able to get shorter. Shortening of muscle fibers is called contraction. Nearly all movement in the body is the result of muscle contraction.

Certain muscle movements happen without you thinking about them, while you can control other muscle movements. Muscles that you can control are called voluntary muscles. Muscles that you cannot control are called involuntary muscles.

There are three different types of muscles in the body (Figure below):

1. **Skeletal muscle** is made up of voluntary muscles, usually attached to the skeleton. Skeletal muscles move the body. They can also contract involuntarily by reflexes. For example, you can choose to move your arm, but your arm would move automatically if you were to burn your finger on a stove top.
2. **Smooth muscle** is composed of involuntary muscles found within the walls of organs and structures such as the esophagus, stomach, intestines, and blood vessels. Unlike skeletal muscle, smooth muscle can never be under your control.
3. **Cardiac muscle** is also an involuntary muscle, found only in the heart.
There are three types of muscles in the body: cardiac, skeletal, and smooth. Everyone has the same three types of muscle tissue, no matter their age.

Muscles, Bones, and Movement

Skeletal muscles are attached to the skeleton by tendons. A tendon is a tough band of connective tissue that connects a muscle to a bone. Tendons are similar to ligaments, except that ligaments join bones to each other.

Muscles move the body by contracting against the skeleton. When muscles contract, they get shorter. When they relax, they get longer. By contracting and relaxing, muscles pull on bones and allow the body to move. Muscles work together in pairs. Each muscle in the pair works against the other to move bones at the joints of the body.

For example, the biceps and triceps muscles work together to allow you to bend and straighten your elbow. Your biceps muscle, shown in Figure below, contracts, and at the same time the triceps muscle relaxes. The biceps is the flexor and the triceps is the extensor of your elbow joint. In this way the joints of your body act like levers. This lever action of your joints decreases the amount of energy you have to spend to make large body movements.

---

*Muscle Types* by STEVE JURVETSON / CK-12 / CC-BY-SA 3.0.
Muscles and the Nervous System

Muscles are controlled by the nervous system. Nerves send messages to the muscular system from the brain. Nerves also send messages to the brain from the muscles. For example, when you want to move your foot, electrical messages called impulses move along nerve cells from your brain to the muscles of your foot. At the point at which the nerve cell and muscle cells meet, the electrical message is converted to a chemical message. The muscle cells receive the chemical message, which causes tiny protein fibers inside the muscle cells to get shorter. The muscles contract, pulling on the bones, and your foot moves.

Review

- The body has three types of muscle tissue: skeletal, smooth, and cardiac.
- Muscles move the body by contracting against the skeleton.
- Muscles are controlled by the nervous system.

Vocabulary

**ATP**
Adenosine triphosphate; carries the chemical energy the cell can use; the molecule that provides energy for your cells to perform work.

**cardiac muscle**
Involuntary muscle which forms the walls and foundation of the heart.

**contraction**
Occurs when a muscle lengthens or shortens.

**involuntary muscles**
Muscles which cannot be controlled.

**muscle fibers**
Long, tube-like cells that form muscles.

**muscular system**
An organ system consisting of skeletal, smooth, and cardiac muscles.

**skeletal muscle**
Muscle attached to bone by tendons.

**smooth muscle**
Involuntary muscle found within the walls of organs and other structures; cannot be directly controlled.

**voluntary muscles**
Muscles you can control.

**tendon**
A tough band of tissue that connects muscle to bone.

### 7.4 The Respiratory System

#### Learning Objectives
- Identify the parts of the respiratory system.
- Identify the main function of the respiratory system.
- Describe how breathing works.
- Outline how the respiratory system and the cardiovascular system work together.
- Identify how breathing and cellular respiration are connected.

#### Introduction

Do you remember how uncomfortable you felt the last time you had a cold or a cough?

You usually do not think about your respiratory system or how it works until there is a problem with it. You breathe mostly without thinking about it. Every cell in your body depends on your respiratory system. In this section you will find out how your respiratory systems helps to keep every cell in your body alive.

#### Guided Learning

**Parts of the Respiratory System**

Your *respiratory system* is made up of the tissues and organs that allow oxygen to enter the body and carbon dioxide to leave your body. Organs in your respiratory system include:
- Nose
- Mouth
• Trachea
• Lungs
• Diaphragm

These structures are shown in Figure below.

The respiratory system. Air moves in through the nose and mouth and down the trachea, which is a long, straight tube in the chest.

Structures of the Respiratory System

Figure above shows many of the structures of the respiratory system. Each of the parts has a specific job. The parts of the respiratory system include the following:

• The diaphragm is a sheet of muscle that spreads across the bottom of the rib cage. When the diaphragm contracts, the chest volume gets larger and the lungs take in air. When the diaphragm relaxes, the chest volume gets smaller and air is pushed out of the lungs.
• The nose and nasal cavity filter, warm, and moisten the air you breathe. The nose hairs and mucus produced by the cells in the nose catch particles in the air and keep them from entering the lungs. When particles in the air reach the lungs, what do you think happens?
• The trachea, or windpipe, is a long tube that leads down to the lungs, where it divides into the right and left bronchi. The bronchi branch out into smaller bronchioles in each lung.
• A flap of tissue called the epiglottis closes over the trachea when food is swallowed to prevent choking or inhaling food.
• The bronchioles lead to the alveoli. Alveoli are the little sacs at the end of the bronchioles. They look like little bunches of grapes, as shown in Figure below. Oxygen is exchanged for carbon dioxide in the alveoli. Gas exchange is the name we give to the process that allows oxygen to

10 Respiratory System by THERESA KNOTT / CK-12 / CC-BY-SA 3.0.
enter the blood and carbon dioxide to move out of the blood; the two gases are "exchanged."

The alveoli are the tiny grape-like structures in the lungs and the sites of gas exchange.

How we Breathe

Most of the time, you breathe without thinking about it. Breathing is mostly an involuntary action that is controlled by a part of your brain that also controls your heart beat. If you swim, do yoga, or sing, you know you can also control your breathing. Taking air into the body through the nose and mouth is called inhalation. Pushing air out of the body through the nose or mouth is called exhalation. The man in Figure below is exhaling before he surfaces from the pool water.

---

11 Alveoli by LOUISA HOWARD & MICHAEL BINDER / CK-12 / CC-BY-SA 3.0.
12 Breathing Control by DAVID SHANKBONE / CK-12 / CC-BY-SA 3.0.
Being able to control breathing is important for many activities, such as swimming. The man in the photograph is exhaling before he surfaces from the water.

How do lungs allow air in? As mentioned above, air moves into and out of the lungs by the movement of muscles. The diaphragm and rib muscles contract and relax to move air into and out of the lungs. During inhalation, the diaphragm contracts and moves downward. The rib muscles contract and cause the ribs to move outward. This causes the chest volume to increase. Because the chest volume is larger, the air pressure inside the lungs is lower than the air pressure outside. This difference in air pressures causes air to be sucked into the lungs. When the diaphragm and rib muscles relax, air is pushed out of the lungs. Exhalation is similar to letting the air out of a balloon.

The walls of the alveoli are very thin and allow gases to enter into them. The alveoli are lined with capillaries. These capillaries are shown in Figure below. Oxygen moves from the alveoli to the blood in the capillaries that surround the alveoli. At the same time, carbon dioxide moves in the opposite direction, from capillary blood to the alveoli.

Breathing and Respiration

When you breath in, oxygen is drawn in through the mouth and down into the lungs. The oxygen then passes across the thin lining of the capillaries and into the blood, through the process of diffusion. The oxygen molecules are carried to the body cells by the blood. Carbon dioxide from the body cells is carried by the blood to the lungs where it is released into the air. The process of getting oxygen into the body and

13 Alveoli Capillaries by PATRICK J. LYNCH & CARL JAFFE, M.D. / CK-12 / CC-BY-SA 3.0.
releasing carbon dioxide is called **respiration**. (Figure below).

Sometimes breathing is called respiration, but there is much more to respiration than just breathing. Remember, *cellular* respiration occurs in the mitochondria!

**The Journey of a Breath of Air**

Breathing is only part of the process of bringing oxygen to where it is needed in the body. After oxygen enters the lungs, what happens?

1. The oxygen enters the bloodstream from the alveoli. Then, the oxygen-rich blood returns to the heart.
2. Oxygen-rich blood is then pumped through the aorta.
3. From the aorta, oxygen-rich blood travels to the smaller arteries and finally to the capillaries.
4. The oxygen molecules move out of the capillaries and into the body cells.
5. While oxygen moves from the capillaries and into body cells, carbon dioxide moves from the cells into the capillaries.

![Blood In and Out](image)

*Gas exchange is the movement of oxygen into the blood and carbon dioxide out of the blood.*

**Breathing and Cellular Respiration**

The oxygen that arrives at the cells from the lungs is used by the cells to help release the energy stored in molecules of sugar. Cellular respiration is the process of breaking down glucose to release energy (see the *Cell Functions* chapter). The waste products of cellular respiration include carbon dioxide and water. The carbon dioxide molecules move out of the cells and into the capillaries that surround the cells. As explained above, the carbon dioxide is removed from the body by the lungs.

---

14 *Gas Exchange* by MR TS88 DUEL / CK-12 / CC-BY-SA 3.0.
Summary

- Your respiratory system is made up of the tissues and organs that allow oxygen to enter and carbon dioxide to leave your body.
- Respiratory system organs include your nose, mouth, larynx, pharynx, lungs, and diaphragm.
- During inhalation, the diaphragm contracts and moves downward, and brings air into the lungs. During exhalation, the diaphragm and rib muscles relax and air is pushed out of the lungs.
- Oxygen enters the lungs, then passes through the alveoli and into the blood. The oxygen is carried around the body in blood vessels.
- Carbon dioxide, a waste gas, moves into the blood capillaries and is brought to the lungs to be released into the air during exhalation.
- The oxygen that arrives from the lungs is used by the cells during cellular respiration to release the energy stored in molecules of sugar.

**alveoli**
Tiny air sacs found in the lungs where oxygen and carbon dioxide are exchanged through diffusion.

**bronchi**
One of the two tubes that connect the lungs with the trachea; branches out into smaller bronchioles in each lung.

**diaphragm**
A muscle attached to the lower ribs which allows the lungs to expand and fill with air.

**epiglottis**
A flap of tissue that closes over the trachea when food is swallowed to prevent choking or inhaling food.

**exhalation**
The process of pushing air out of the body through the nose or mouth.

**gas exchange**
The process that allows oxygen to enter the blood and carbon dioxide to leave the blood.

**inhalation**
The process of taking air into the body through the nose and mouth.

**respiration**
The process of getting oxygen into the body and releasing carbon dioxide (not to be confused with cellular respiration).

**respiratory system**
An organ system made up of the tissues and organs that allow oxygen to enter the body and carbon dioxide to leave your body.

**trachea**
The windpipe; a long tube that leads down to the lungs, where it divides into the right and left bronchi.
7.5 The Circulatory System

Learning Objectives
- Identify the main structures of the cardiovascular system.
- Identify three types of blood vessels.
- Describe the differences between the pulmonary and the systemic circulations.

Introduction

Every cell in your body depends on your circulatory system. How can this be?

Your circulatory (cardiovascular) system has many jobs. It acts as a message delivery service, a pump, a heating system, and a protector of the body against diseases. Every cell in your body depends on your circulatory system. In this section, you will learn how your circulatory system works and how it helps to maintain homeostasis.

Guided Learning

Functions of the Circulatory System

The circulatory system shown in Figure below is the organ system that is made up of the heart, the blood vessels, and the blood. It is a closed system meaning that the blood is contained at all times within the vessels. It moves nutrients, hormones, gases (such as oxygen), and wastes (such as carbon dioxide) to and from your cells. It also helps to keep you warm by moving warm blood around your body. To do these tasks, your circulatory system works with other organ systems, such as the respiratory and nervous systems.
The Movement of Gases

The movement of gases, especially oxygen and carbon dioxide, is one of the most important jobs of the circulatory system. The circulatory system cannot do this alone. It must work with other organ systems, especially the respiratory system, to move these gases throughout your body.

Oxygen is needed by every cell in your body. You breathe in oxygen and breathe out carbon dioxide.
through your respiratory system. Once oxygen enters your lungs, it must enter your bloodstream in order to move around your body. Oxygen is moved in your blood by attaching to a protein called **hemoglobin**. The oxygen moves from the blood into the tissues, while carbon dioxide travels in the opposite direction. Carbon dioxide is transported back to the lungs, where it moves out of the blood and into your lungs for release from your body.

**Parts of the Circulatory System**

Your heart pushes the blood around your body through the blood vessels. The heart, shown in **Figure** below, is made of cardiac muscle. The heart is connected to many blood vessels that bring blood all around the body. The cardiac muscle contracts and pumps blood through the blood vessels.

Blood is collected in the heart and pumped out to the lungs, where it releases carbon dioxide and picks up oxygen before it is pumped to the rest of the body.

**Blood Vessels**

The job of the blood vessels is to move the blood around the body. There are three main types of blood vessels in the body.

1. **Arteries** are blood vessels that carry blood **away** from the heart. Arteries have thick walls that have a layer of smooth muscle, as shown in **Figure** below. Arteries usually carry oxygen-rich blood around the body. The blood that is in arteries is under pressure. The contractions of the heart muscle causes blood to push against the walls of the arteries. This "push" is referred to as **blood pressure**. Blood pressure is highest in the arteries and decreases as the blood moves into smaller blood vessels. Thick walls help prevent arteries from bursting under the pressure of blood.

2. **Veins** are blood vessels that carry blood **back** to the heart. Veins have thinner walls than arteries do, as you can see in **Figure** below. The blood in veins is not under pressure. Veins have valves that stop blood from moving backward. Blood is moved forward in veins when the skeletal

---

16 **Heart** by PATRICK LYNCH & CARL JAFFE, M.D. / CK-12 / CC-BY-SA 3.0.
muscles squeeze the veins. Blood that is carried by veins is usually low in oxygen. The only veins that carry oxygen-rich blood are called the pulmonary veins, which carry blood to the heart from the lungs.

3. **Capillaries** these are the tiniest blood vessels in the body. Every cell in the body needs oxygen, but arteries are too large to bring oxygen and nutrients to single cells. Further from the heart, arteries form capillaries. The walls of capillaries are only as thick as a single layer of cells. Capillaries connect arteries and veins together, as shown in Figure below. Capillaries also send water, oxygen and other substances to body cells, while they collect carbon dioxide and other wastes from cells and tissues. Capillaries are so narrow that blood cells must move in single file through them. A capillary bed is the network of capillaries that supply an organ with blood. The more active a tissue or organ is, the more capillaries it needs to get nutrients and oxygen. The water, oxygen, and other substances carried by the capillaries are delivered to the surrounding cells by diffusing through the capillaries and into or out of the cells.

![Arteries are thick-walled vessels with many layers, including a layer of smooth muscle.](Artery by SEBASTIAN KAULITZKI / CK-12 / CC-BY-SA 3.0.)

![The walls of veins are not as thick as artery walls; veins have valves that stop blood from flowing backward.](Simple Vein by PRINCIPAL / CK-12 / CC-BY-SA 3.0.)
Blood

Blood is a body fluid made of blood cells and a liquid called plasma. The main types of cells found in blood are red blood cells and white blood cells.

- Red blood cells carry oxygen. Oxygen-rich blood is bright red and oxygen-poor blood is dark red. Human blood is never blue!
- White blood cells fight against infection and disease.

The circulatory system of humans is “closed.” That means the blood never leaves the blood vessels inside of the body. Some other organisms have blood vessels that interact with the environment.

Two Blood Circulation Systems

The blood is pumped around in two large “loops” within the body. One loop moves blood around the body to the head, limbs, and internal organs. The other loop moves blood to and from the lungs where carbon dioxide is released and oxygen is picked up by the blood. A simple version of these two “loops” is shown in Figure below.

Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart. Pulmonary circulation is the part of the cardiovascular system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

---

19 Capillaries by NCI / CK-12 / CC-BY-SA 3.0.
The double circulatory system. Trace the systemic circulation. Where is the path of pulmonary circulation?

Summary

- Table below summarizes the structures and functions of the circulatory system.

<table>
<thead>
<tr>
<th>System</th>
<th>Structure (organs and tissues)</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulatory</td>
<td>Blood vessels</td>
<td>Transport blood around the body</td>
</tr>
<tr>
<td></td>
<td>Blood</td>
<td>Moves oxygen and nutrients; also carries white blood cells to sites of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>infection and inflammation</td>
</tr>
<tr>
<td></td>
<td>Heart</td>
<td>Pumps blood around the body</td>
</tr>
</tbody>
</table>

- The circulatory system includes the heart, the blood vessels, and the blood.
- There are three main types of blood vessels in the body: arteries, veins, and capillaries.
- Systemic circulation is the part of the circulatory system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart.
- Pulmonary circulation is the part of the circulatory system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

---

20 Double Circulatory System by JOSHUA JOHN LEE / CK-12 / CC-BY-SA 3.0.
Vocabulary

arteries

Blood vessels that carry blood away from the heart; have thick walls that have a layer of smooth muscle.

blood

A body fluid that is made of blood cells and a liquid called plasma.

blood pressure

The "push" that is created by the contractions of the heart muscle, causing blood to push against the walls of the arteries; blood pressure is highest in the arteries and decreases as the blood moves into smaller vessels.

capillaries

The tiniest blood vessels in the body that allow an exchange between blood and cells in tissue.

Closed System

Blood is contained within the blood vessels at all times.

hemoglobin

A protein that attaches to oxygen, which allows it to move throughout the body.

pulmonary circulation

The part of the circulatory system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

red blood cell (RBC)

A type of blood cell that carries oxygen.

systemic circulation

The part of the circulatory system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart.

veins

Blood vessels that carry blood back to the heart.

white blood cell (WBC)

A type of blood cell that fights against infection and disease.
7.6 The Digestive System

Learning Objectives

- List the functions of the digestive system.
- Explain the role of enzymes in digestion.
- Describe the digestive organs and their functions.
- Explain the roles of helpful bacteria in the digestive system.

Introduction

How do the nutrients in food get to your body’s cells?

Nutrients in the food you eat are needed by the cells of your body. What organs and processes break down the foods and make the nutrients available to cells? The organs are those of the digestive system. The processes are digestion and absorption.

Guided Learning

What does the digestive system do?

The digestive system is the body system that breaks down food and absorbs nutrients. It also gets rid of solid food waste. The main organs of the digestive system are shown in Figure below.

Digestion is the process of breaking down food into nutrients. There are two types of digestion,
mechanical and chemical. In **mechanical digestion**, large chunks of food are broken down into small pieces. This is a physical process. In **chemical digestion**, large food molecules are broken down into small nutrient molecules. This is a chemical process.

**Absorption** is the process that allows substances you eat to be taken up by the blood. After food is broken down into small nutrient molecules, the molecules are absorbed by the blood. After absorption, the nutrient molecules travel in the bloodstream to cells throughout the body.

Some substances in food cannot be broken down into nutrients. They remain behind in the digestive system after the nutrients are absorbed. Any substances in food that cannot be digested and absorbed pass out of the body as solid waste. The process of passing solid food waste out of the body is called elimination.

**The Role of Enzymes in Digestion**

Chemical digestion could not take place without the help of digestive enzymes. An **enzyme** is a protein that speeds up chemical reactions in the body. Digestive enzymes speed up chemical reactions that break down large food molecules into small molecules.

Did you ever use a wrench to tighten a bolt? You could tighten a bolt with your fingers, but it would be difficult and slow. If you use a wrench, you can tighten a bolt much more easily and quickly. Enzymes are like wrenches. They make it much easier and quicker for chemical reactions to take place. Like a wrench, enzymes can also be used over and over again. But you need the appropriate size and shape of the wrench to efficiently tighten the bolt, just like each enzyme is specific for the reaction it helps. Digestive enzymes are released, or secreted, by the organs of the digestive system. Examples of digestive enzymes are:

- Amylase, produced in the mouth. It helps break down large starches molecules into smaller sugar molecules.
- Pepsin, produced in the stomach. Pepsin helps break down proteins into amino acids.
- Trypsin, produced in the pancreas. Trypsin also breaks down proteins.
- Pancreatic lipase, produced in the pancreas. It is used to break apart fats.
- Deoxyribonuclease and ribonuclease, produced in the pancreas. They are enzymes that break bonds in nucleic acids like DNA and RNA.

Bile salts are bile acids that help to break down fat. Bile acids are made in the liver. When you eat a meal, bile is secreted into the intestine, where it breaks down the fats. Bile acids also help to remove cholesterol from the body.
Hormones and Digestion

If you are a typical teenager, you like to eat. For your body to break down, absorb and spread the nutrients throughout your body, your digestive system and endocrine system need to work together. The endocrine system sends hormones around your body to communicate between cells like chemical messengers.

Digestive hormones are made by cells lining the stomach and small intestine. These hormones cross into the blood where they can affect other parts of the digestive system. Some of these hormones are listed below.

- Gastrin, which signals the secretion of gastric acid.
- Cholecystokinin, which signals the secretion of pancreatic enzymes.
- Secretin, which signals secretion of water and bicarbonate from the pancreas.
- Ghrelin, which signals when you are hungry.
- Gastric inhibitory polypeptide, which stops or decreases gastric secretion. It also causes the release of insulin in response to high blood glucose levels.

Digestive Organs and their Roles

The mouth and stomach are just two of the organs of the digestive system. Other digestive system organs are the esophagus, small intestine, and large intestine. The digestive organs form a long tube. In adults, this tube is about 30 feet long! At one end of the tube is the mouth. At the other end is the anus. Food enters the mouth and then passes through the rest of the digestive system. Food waste leaves the body through the anus.

The organs of the digestive system are lined with muscles. The muscles contract, or tighten, to push food through the system. This is shown in Figure below. The muscles contract in waves. The waves pass through the digestive system like waves through a slinky. Without this movement, food would not be able to move through the digestive system. This is an involuntary process, which means that it occurs without your conscious control.

This diagram shows how muscles push food through the digestive system. Muscle contractions travel through the system in waves, pushing the food ahead of them. This is called peristalsis.

---

22 Peristalsis by RUTH LAWSON / CK-12 / CC-BY-SA 3.0.
The liver, gallbladder, and pancreas are also organs of the digestive system. They are shown in Figure below. Food does not pass through these three organs. However, these organs are important for digestion. They secrete or store enzymes or other chemicals that are needed to help digest food chemically.

![Diagram of digestive system with key:](image)

*This drawing shows the liver, gallbladder, and pancreas. These organs are part of the digestive system. Food does not pass through them, but they secrete substances needed for chemical digestion.*

**Mouth, Esophagus, and Stomach**

The mouth is the first organ that food enters. But digestion may start even before you put the first bite of food into your mouth. Just seeing or smelling food can cause the release of saliva and digestive enzymes in your mouth.

Once you start eating, saliva wets the food making it easier to break up and swallow. Digestive enzymes, including amylase, start breaking down starches into sugars. Your tongue helps mix the food with the saliva and enzymes.

Your teeth also help digest food. Your front teeth are sharp. They cut and tear food when you bite into it. Your back teeth are broad and flat. They grind food into smaller pieces when you chew. Chewing is part

---

23 *Liver Gall Pancreas* by CK-12 / CC-BY-SA 3.0.
of mechanical digestion. Your tongue pushes the food to the back of your mouth so you can swallow it. When you swallow, the lump of chewed food passes down your throat to your esophagus.

The esophagus is a narrow tube that carries food from the throat to the stomach. At the lower end of the esophagus, a circular muscle controls the opening to the stomach. The muscle relaxes to let food pass into the stomach. Then the muscle contracts again to prevent food from passing back into the esophagus. Some people think that gravity moves food through the esophagus. If that were true, food would move through the esophagus only when you are sitting or standing upright. In fact, food can move through the esophagus no matter what position you are in — even upside down! Just don't actually try to swallow food when you're upside down; you could choke.

The stomach is a sac-like organ at the end of the esophagus. It has thick muscular walls. The muscles contract and relax. This moves the food around and helps break it into smaller pieces. Mixing the food around with the enzyme pepsin and other chemicals helps digest proteins.

Water, salt, and simple sugars can be absorbed into the blood from the stomach. Most other substances are broken down further in the small intestine before they are absorbed. The stomach stores food until the small intestine is ready to receive it. A circular muscle controls the opening between the stomach and small intestine. When the small intestine is empty, the muscle relaxes. This lets food pass from the stomach into the small intestine.

Small Intestine

The small intestine is narrow tube that starts at the stomach and ends at the large intestine (see Figure above). In adults, the small intestine is about 23 feet long. This is where most chemical digestion takes place. Many enzymes and other chemicals are secreted here. This is where most nutrients are absorbed into the blood. The small intestine is lined with tiny “fingers” called villi. A magnified picture of villi is shown in Figure below. Villi contain very tiny blood vessels. Nutrients are absorbed into the blood through these tiny vessels. There are millions of villi, so altogether there is a very large area for absorption to take place. In fact, villi make the inner surface area of the small intestine 1,000 times larger than it would be without them. The entire inner surface area of the small intestine is about as big as a basketball court! From the small intestine, any remaining food waste passes into the large intestine.
This is what the villi lining the small intestine look like when magnified. Each one is actually only about 1 millimeter long. Villi are just barely visible with the unaided eye.

The small intestine is much longer than the large intestine. So why is it called “small”? If you compare the small and large intestines in Figure above, you will see why. The small intestine is smaller in width than the large intestine.

**Large Intestine**

The large intestine is a wide tube that connects the small intestine with the anus. In adults, it is about 5 feet long. Waste enters the large intestine from the small intestine in a liquid state. As the waste moves through the large intestine, excess water is absorbed from it. After the excess water is absorbed, the remaining solid waste is called feces.

Circular muscles control the anus. They relax to let the feces pass out of the body through the anus. After feces pass out of the body, they are called stool. Releasing the stool from the body is referred to as a bowel movement.

**Liver**

The liver has a wide range of functions, a few of which are:

- Removing toxins from the blood.
- Keeping glucose levels stable.
- Creating proteins.
- Producing biochemicals for digestion.

The liver is necessary for survival. You cannot live without a liver. The liver is one of the most important

---

24 [Villi](https://creativecommons.org/licenses/by-sa/3.0/) by SEBASTIAN KAULITZKI / CK-12 / CC-BY-SA 3.0.
organs in the body when it comes to getting rid of toxins, especially from the gut. The liver filters blood from the intestine. This filtering process can remove microorganisms such as bacteria, fungi, viruses, and parasites from the blood. Almost two quarts of blood pass through the liver every minute. Since the liver also ensures that glucose levels remain stable, people with liver problems are at risk for diabetes.

**Bacteria in the Digestive System**

Your large intestine is not just made up of cells. It is also an ecosystem, home to trillions of bacteria. But don't worry. Most of these bacteria are helpful. They have several roles in the body. For example, intestinal bacteria:

- Produce vitamins B₁₂ and K.
- Control the growth of harmful bacteria.
- Break down poisons in the large intestine.
- Break down some substances in food that cannot be digested, such as fiber and some starches and sugars.

**Summary**

- The digestive system breaks down food, absorbs nutrients, and gets rid of food wastes.
- Digestive enzymes speed up the reactions of chemical digestion.
- The main organs of the digestive system are the mouth, esophagus, stomach, small intestine, and large intestine.
- Bacteria in the large intestine produce vitamins and have other roles in the body.

**Vocabulary**

- **absorption**: The process that allows substances you eat to be taken up by the blood.
- **chemical digestion**: Large food molecules are broken down into small nutrient molecules; this is a chemical process.
- **digestion**: Process of breaking down food into nutrients.
- **digestive system**: The body system that breaks down food and absorbs nutrients; also gets rid of solid food waste.
- **enzyme**: A protein that speeds up chemical reactions in the body; digestive enzymes speed up chemical reactions that break down large food molecules into small molecules.
- **esophagus**: A narrow tube that carries food from the throat to the stomach.
- **large intestine**: A wide tube that connects the small intestine with the anus; waste enters the large intestine from the small intestine in a liquid state and as the waste moves through the large intestine, excess
water is absorbed from it.

**mechanical digestion**
Large chunks of food are broken down into small pieces; this is a physical process.

**small intestine**
Narrow tube that starts at the stomach and ends at the large intestine; where most nutrients are absorbed into the bloodstream.

**stomach**
Sac-like organ at the end of the esophagus; it has thick muscular walls that contract and relax, moving the food around and helping break it into smaller pieces.

**villi**
Tiny “fingers” that contain very tiny blood vessels; nutrients are absorbed into the blood through these tiny vessels.

7.7 Nervous System

**Learning Objectives**
- Identify the functions of the nervous system.
- Describe neurons and explain how they carry nerve impulses.
- Describe the structures of the central nervous system.
- List several examples of nerves found in the peripheral nervous system.

**Introduction**

Have you ever almost fallen off your bike, but yet your brain took over and kept you from falling without you even thinking about it?

Michelle was riding her scooter when she hit a hole in the street and started to lose control. She thought she would fall, but in the blink of an eye, she shifted her weight and kept her balance. Her heart was pounding, but at least she didn't get hurt. How was she able to react so quickly? Michelle can thank her nervous system for that (**Figure** below).

Groups of organs are called organ systems. Examples of human organ systems are the skeletal, digestive, and respiratory systems. The nervous system controls all of them!
Staying balanced when riding a scooter requires control over the body’s muscles. The nervous system controls the muscles and maintains balance.

## Guided Learning

### The Nervous System

The nervous system controls all of the systems of the body. Controlling muscles and maintaining balance are just two of its roles. The nervous system also lets you:

- Sense your surroundings with your eyes and other sense organs.
- Sense the environment inside of your body, including temperature.
- Control your internal body systems and keep them in balance.
- Prepare your body to fight or flee in an emergency.
- Think, learn, remember, and use language.

The nervous system works by sending and receiving electrical signals. The signals are carried by nerves in the body, similar to the wires that carry electricity all over a house. For example, when Michelle started to fall off her scooter, her nervous system sensed that she was losing her balance. It responded by sending messages to muscles in her body. Some muscles tightened while others relaxed. As a result, Michelle’s body became balanced again. How did her nervous system do all that in a split second? To answer this question, you need to know how the nervous system carries messages.

### Neurons and Nerve Impulses

The nervous system is made up of nerves. A nerve is a bundle of nerve cells. A nerve cell that carries messages is called a neuron (Figure below). The messages carried by neurons are called nerve impulses. Nerve impulses can travel very quickly because they are electrical impulses.

Think about flipping on a light switch when you enter a room. When you flip the switch, the electricity flows to the light through wires inside the walls. The electricity may have to travel many meters to reach...
the light, but the light still comes on as soon as you flip the switch. Nerve impulses travel just as fast through the network of nerves inside the body.

The axons of many neurons, like the one shown here, are covered with a fatty layer called myelin sheath. The sheath covers the axon, like the plastic covering on an electrical wire, and allows nerve impulses to travel faster along the axon.

What Does a Neuron Look Like?

A neuron has a special shape that lets it pass signals from one cell to another. As shown in Figure above, a neuron has three main parts:

1. The cell body
2. Many dendrites
3. One axon

The cell body contains the nucleus and other organelles. Dendrites and axons connect to the cell body, similar to rays coming off of the sun. Dendrites receive nerve impulses from other cells. Axons pass the nerve impulses on to other cells. A single neuron may have thousands of dendrites, so it can communicate with thousands of other cells.

The Synapse

The place where the axon of one neuron meets the dendrite of another is called a synapse. Synapses are also found between neurons and other type of cells, such as muscle cells. The axon of the sending neuron does not actually touch the dendrite of the receiving neuron. There is a tiny gap between them, the synapse, as shown in Figure below.

This diagram shows a synapse between neurons. When a nerve impulse arrives at the end of the axon, neurotransmitters are released and travel to the dendrite of another neuron, carrying the nerve impulse from one neuron to the next.

Have you ever watch a relay race? After the first runner races, he or she passes the baton to the next runner, who takes over. Neurons are a little like relay runners. Instead of a baton, they pass neurotransmitters to the next neuron. Examples of neurotransmitters are chemicals such as serotonin, dopamine, and adrenaline. For further explanation, watch an animation of nerve impulses and neurotransmitters.

The Central Nervous System

The central nervous system (CNS) is the largest part of the nervous system. As shown in Figure below, it includes the brain and the spinal cord. The bony skull protects the brain. The spinal cord is protected within the bones of the spine, which are called vertebrae.
The Brain

What weighs about 3 pounds and contains up to 100 billion cells? The answer is the human brain. The **brain** is the control center of the nervous system. It’s like the pilot of a plane. It tells other parts of the nervous system what to do.

The brain is also the most complex organ in the body. Each of its 100 billion neurons has synapses connecting it with thousands of other neurons. All those neurons use a lot of energy. In fact, the adult brain uses almost a quarter of the total energy used by the body. The developing brain of a baby uses an even greater amount of the body’s total energy.

The brain is the organ that lets us understand what we see, hear, or sense in other ways. It also allows us to learn, think, remember, and use language. The brain controls the organs in our body and our movements as well. As shown in **Figure** below, the brain consists of three main parts, the cerebrum, the cerebellum, and the brain stem.

1. **The cerebrum** is the largest part of the brain. It sits on top of the brain stem. The cerebrum controls functions that we are aware of, such as problem-solving and speech. It also controls voluntary movements, like waving to a friend. Whether you are doing your homework or jumping hurdles, you are using your cerebrum.

2. **The cerebellum** is the next largest part of the brain. It lies under the cerebrum and behind the brain stem. The cerebellum controls body position, coordination, and balance. Whether you are riding a bicycle or writing with a pen, you are using your cerebellum.

3. **The brainstem** is the smallest of the three main parts of the brain. It lies directly under the cerebrum. The brainstem controls basic body functions such as breathing, heartbeat, and digestion. The brainstem also carries information back and forth between the cerebrum and spinal cord.

![Side View of Brain](Side View of Brain by WASHINGTON IRVING / CK-12 / CC-BY-SA 3.0)

The cerebrum is divided into a right and left half, as shown in **Figure** above. Each half of the cerebrum is called a hemisphere. The two hemispheres are connected by a thick bundle of axons called the corpus callosum. It lies deep inside the brain and carries messages back and forth between the two
hemispheres.
Did you know that the right hemisphere controls the left side of the body, and the left hemisphere controls the right side of the body? By connecting the two hemispheres, the corpus callosum allows this to happen.

Each hemisphere of the cerebrum is divided into four parts, called lobes. The four lobes are the:
1. Frontal
2. Parietal
3. Temporal
4. Occipital

Each lobe has different jobs. Some of the functions are listed in Table below.

<table>
<thead>
<tr>
<th>Lobe</th>
<th>Main Function(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td>Speech, thinking, touch</td>
</tr>
<tr>
<td>Parietal</td>
<td>Speech, taste, reading</td>
</tr>
<tr>
<td>Temporal</td>
<td>Hearing, smell</td>
</tr>
<tr>
<td>Occipital</td>
<td>Sight</td>
</tr>
</tbody>
</table>

The Spinal Cord

The spinal cord is a long, tube-shaped bundle of neurons. It runs from the brainstem to the lower back. The main job of the spinal cord is to carry nerve impulses back and forth between the body and brain. The spinal cord is like a two-way highway. Messages about the body, both inside and out, pass through the spinal cord to the brain. Messages from the brain pass in the other direction through the spinal cord to tell the body what to do.

The Peripheral Nervous System

There are other nerves in your body that are not found in the brain or spinal cord. The peripheral nervous system (PNS) contains all the nerves in the body that are found outside of the central nervous system. The network of nerves that make up the peripheral system is shown in Figure below. They include nerves of the hands, arms, feet, legs, and trunk. They also include nerves of the scalp, neck, and face. Nerves that send and receive messages to the internal organs are also part of the peripheral
The blue lines in this drawing represent nerves of the peripheral nervous system. Every peripheral nerve is connected directly or indirectly to the spinal cord.

Summary

- The nervous system controls all of the other systems of the body.
- Neurons are nerve cells that carry nerve impulses. The central nervous system is made up of the brain and spinal cord.
- The peripheral nervous system consists of all the rest of the nerves in the body.

Peripheral Nervous System by PERSIAN POET GAL / CK-12 / CC-BY-SA 3.0.
Vocabulary

axon
A part of a neuron that passes the nerve impulses on to other cells.

brain
The control center of the nervous system by telling other parts of the nervous system what to do

brainstem
The smallest of the three main parts of the brain, which lies directly under the cerebrum and controls basic body functions such as breathing, heartbeat, and digestion, and also carries information back and forth between the cerebrum and spinal cord.

cell body
A part of a neuron that contains the nucleus and other organelles; connects to axon and dendrites.

central nervous system
The largest part of the nervous system; includes the brain and the spinal cord.

cerebellum
The second largest part of the brain, the cerebellum lies under the cerebrum and behind the brainstem and controls body position, coordination, and balance.

cerebrum
The largest part of the brain, the cerebrum sits on top of the brain stem and controls functions that we are aware of, such as problem-solving, speech, and voluntary movements.

dendrite
A part of a neuron that receives nerve impulses from other cells.

nerve
A bundle of nerve cells.

nerve impulse
An electrical impulse carried by neurons.

nervous system
An organ system that controls all of the systems of the body by sending and receiving electrical signals.

neuron
A nerve cell that carries messages, then neuron has three main parts: cell body, axon, and many dendrites.

peripheral nervous system
Contains all the nerves in the body that are found outside of the central nervous system.

spinal cord
A long, tube-shaped bundle of neurons; runs from the brainstem to the lower back and carries nerve impulses back and forth between the body and brain.

synapse
The place where the axon of one neuron meets the dendrite of another neuron.
7.8 The Skin System

Learning Objectives

- List the functions of skin.
- Describe the structure of skin.
- Describe the structure of hair and nails.
- Identify two types of skin problems.
- Describe two ways to take care of your skin.

Introduction

Did you know that you see the largest organ in your body every day?

You wash it, dry it, cover it up to stay warm, or uncover it to cool off. In fact, you see it so often it is easy to forget the important role your skin plays in keeping you healthy.

Guided Learning

Your Skin and Homeostasis

Your skin is part of your integumentary system (Figure below), which is the outer covering of your body. The integumentary system is made up of your skin, hair, and nails. Your integumentary system has many roles in homeostasis, including protection, the sense of touch, and controlling body temperature.

![Skin](image)

*Skin acts as a barrier that stops water and other things, like soap and dirt, from getting into your body.*

Functions of Skin

---

31 *Skin* by BEN SMITH / CK-12 / CC-BY-SA 3.0.
Your skin covers the entire outside of your body. Your skin is your body's largest organ, yet it is only about two millimeters thick. It has many important functions. The skin:

- Provides a barrier. It keeps organisms that could harm the body out. It stops water from leaving the body, and stops water from getting into the body.
- Controls body temperature. It does this by making sweat, a watery substance that cools the body when it evaporates.
- Gathers information about your environment. Special nerve endings in your skin sense heat, pressure, cold and pain.
- Helps the body get rid of some types of waste, which are removed in sweat.
- Acts as a sun block. A chemical called melanin is made by certain skin cells when they are exposed to sunlight. Melanin blocks sunlight from getting to deeper layers of skin cells, which are easily damaged by sunlight.

Structure of Skin

Your skin is always exposed to your external environment, so it gets cut, scratched, and worn down. You also naturally shed many skin cells every day. Your body replaces damaged or missing skin cells by growing more of them. Did you know that the layer of skin you can see is actually dead? The dead cells are filled with a tough, waterproof protein called keratin. As the dead cells are shed or removed from the upper layer, they are replaced by the skin cells below them.

As you can see in Figure below, two different layers make up the skin — the epidermis and the dermis. A fatty layer, called subcutaneous tissue, lies under the dermis, but it is not part of your skin.
Skin is made up of two layers, the epidermis on top and the dermis below. The tissue below the dermis is called the hypodermis, but it is not part of the skin.

The color, thickness, and texture of skin vary over the body. There are two general types of skin:

1. Thin and hairy, which is the most common type on the body.
2. Thick and hairless, which is found on parts of the body that experience a lot of contact with the environment such as the palms of the hands or the soles of the feet.

The Epidermis

The epidermis is the outermost layer of the skin. It forms the waterproof, protective wrap over the body's surface. The epidermis is divided into several layers of epithelial cells. The epithelial cells are formed by mitosis in the lowest layer. These cells move up through the layers of the epidermis to the top. Although the top layer of epidermis is only about as thick as a sheet of paper, it is made up of 25 to 30 layers of cells.

The epidermis also contains cells that produce melanin. Melanin is the brownish pigment that gives skin and hair their color. Melanin-producing cells are found in the bottom layer of the epidermis.

The epidermis does not have any blood vessels. The lower part of the epidermis receives blood by diffusion from blood vessels of the dermis.

32 Skin Layers by NCI / CK-12 / CC-BY-SA 3.0.
The Dermis

The dermis is the layer of skin directly under the epidermis. It is made of a tough connective tissue that contains the protein collagen. Collagen is a long, fiber-like protein that is very strong. The dermis is tightly connected to the epidermis by a thin wall of collagen fibers.

As you can see in Figure above, the dermis contains hair follicles, sweat glands, oil glands, and blood vessels. It also holds many nerve endings that give you your sense of touch, pressure, heat, and pain.

Do you ever notice how your hair stands up when you are cold or afraid? Tiny muscles in the dermis pull on hair follicles which cause hair to stand up. The resulting little bumps in the skin are commonly called "goosebumps," shown in Figure below.

Goosebumps are caused by tiny muscles in the dermis that pull on hair follicles, which causes the hairs to stand up straight.

Oil Glands and Sweat Glands

Glands and follicles open out into the epidermis, but they start in the dermis. Oil glands release, or
secrete, an oily substance, called sebum, into the hair follicle. An oil gland is shown in Figure above. Sebum “waterproofs” hair and the skin surface to prevent them from drying out. It can also stop the growth of bacteria on the skin. It is odorless, but the breakdown of sebum by bacteria can cause odors. If an oil gland becomes plugged and infected, it develops into a pimple. Up to 85% of teenagers get pimples, which usually go away by adulthood. Frequent washing can help decrease the amount of sebum on the skin.

**Sweat glands** open to the skin surface through skin pores. They are found all over the body. Evaporation of sweat from the skin surface helps to lower skin temperature. This is why sweat can help maintain homeostasis. The skin also releases excess water, salts, and other wastes in sweat. A sweat gland is shown in Figure above.

**Nails and Hair**

Nails and hair are made of the same types of cells that make up skin. Hair and nails contain the tough protein keratin.

**Nails**

Fingernails and toenails both grow from nail beds. A nail bed is thickened to form a lunula, or little moon, which you can see in Figure below. Cells forming the nail bed are linked together to form the nail. As the nail grows, more cells are added at the nail bed. Older cells get pushed away from the nail bed and the nail grows longer. There are no nerve endings in the nail, which is a good thing, otherwise cutting your nails would hurt a lot!

Nails act as protective plates over the fingertips and toes. Fingernails also help in sensing the environment. The area under your nail has many nerve endings, which allow you to receive more information about objects you touch. Nails are made up of many different parts, as shown in Figure below.
The structure of fingernails is similar to toenails. The free edge is the part of the nail that extends past the finger, beyond the nail plate. The nail plate is what we think of when we say “nail,” the hard portion made of the tough protein keratin. The lunula is the crescent shaped whitish area of the nail bed. The cuticle is the fold of skin at the end of the nail.

Hair

Hair sticks out from the epidermis, but it grows from the dermis, as shown in Figure below. Hair is also made of keratin, the same protein that makes up skin and nails. Hair grows from inside the hair follicle. New cells grow in the bottom part of the hair, called the bulb. Older cells get pushed up, and the hair grows longer. Similar to nails and skin, the cells that make up the hair strand are dead and filled with keratin.

Hair color is caused by different types of melanin in the hair cells. In general, the more melanin in the cells, the darker the hair color; the less melanin, the lighter the hair color.

34 Fingernail by MARK POPROCKI / CK-12 / CC-BY-SA 3.0.
Hair helps to keep the body warm. When you feel cold, your skin gets a little bumpy. These bumps are caused by tiny muscles that pull on the hair, causing the hair to stick out. The erect hairs help to trap a thin layer of air that is warmed by body heat. In mammals that have much more hair than humans, the hair traps a layer of warm air near the skin and acts like a warm blanket. Hair also protects the skin from ultraviolet (UV) radiation from the sun.

Hair also acts as a filter. Nose hair helps to trap particles in the air that may otherwise travel to the lungs. Eyelashes shield eyes from dust and sunlight. Eyebrows stop salty sweat and rain from flowing into the eye.

**Keeping Skin Healthy**

Some sunlight is good for health. Vitamin D is made in the skin when it is exposed to sunlight. But getting too much sun can be unhealthy. A **sunburn** is a burn to the skin that is caused by overexposure to UV radiation from the sun’s rays or tanning beds.

Light-skinned people, like the girl in Figure below, get sunburned more quickly than people with darker skin. This is because melanin in the skin acts as a natural sunblock that helps to protect the body from UV radiation. When exposed to UV radiation, certain skin cells make melanin, which causes skin to tan. Children and teens who have gotten sunburned are at a greater risk of developing skin cancer later in life.

Long-term exposure to UV radiation is the leading cause of skin cancer. About 90 percent of skin cancers are linked to sun exposure. UV radiation damages the genetic material of skin cells. This damage can cause the skin cells to grow out of control and form a tumor. Some of these tumors are very difficult to cure. For this reason you should always wear sunscreen with a high sun protection factor (SPF), a hat, and clothing when out in the sun. As people age, their skin gets wrinkled. Wrinkles are caused mainly by UV radiation and by the loosening of the connective tissue in the dermis due to age.
Sunburn is caused by overexposure to UV rays. Getting sunburned as a child or a teen, especially sunburn that causes blistering, increases the risk of developing skin cancer later in life.

**Injury**

Your skin can heal itself even after a large cut. Cells that are damaged or cut away are replaced by cells that grow in the bottom layer of the epidermis and the dermis. When an injury cuts through the epidermis into the dermis, bleeding occurs. A blood clot and scab soon forms. After the scab is formed, cells at the bottom of the epidermis begin to divide by mitosis and move to the edges of the scab. A few days after the injury, the edges of the wound are pulled together.

If the cut is large enough, the production of new skin cells will not be able to heal the wound. Stitching the edges of the injured skin together can help the skin to repair itself. The person in Figure below had a large cut that needed to be stitched together. When the damaged cells and tissues have been replaced, the stitches can be removed.

36 Sunburn by KELLY SUE DECONNICK / CK-12 / CC-BY-SA 3.0.
Sewing the edges of a large cut together allows the body to repair the damaged cells and tissues, and heal the tear in the skin.

Summary

- Skin acts as a barrier that keeps particles and water out of the body.
- The skin helps to cool the body in hot temperatures, and keep the body warm in cool temperatures.
- Skin is made up of two layers, the epidermis and the dermis.
- Pimples occur when the skin produces too much sebum.
- Hair and nails are made of keratin, the same protein as skin.
- Nails grow from nail beds and hairs grow from hair follicles in the skin.
- Skin cancer can be caused by excess exposure to ultraviolet light from the sun or tanning beds.
- Frequent bathing helps keep the skin clean and healthy.
- Wearing sun block and a hat when outdoors can help prevent skin cancer.

Vocabulary

dermis

The layer of skin directly under the epidermis; made of a tough connective tissue that contains the protein collagen.

epidermis

Outermost layer of the skin; forms the waterproof, protective wrap over the body's surface.

integumentary system

The outer covering of your body that is made up of skin, hair, and nails; has many roles in homeostasis, including protection, sense of touch, and controlling body temperature.

37 Stitches by JOE BELANGER / CK-12 / CC-BY-SA 3.0.
keratin
A tough, waterproof protein found in dead skin cells.

melanin
Brownish pigment that gives skin and hair their color.

oil gland
A structure that secretes, an oily substance, called sebum, into the hair follicle; sebum “waterproofs” hair and the skin surface to prevent them from drying out and can also stop the growth of bacteria on the skin.

sunburn
A burn to the skin that is caused by overexposure to UV radiation from the sun's rays or tanning beds; may lead to an increased risk of skin cancer.

sweat gland
Small structures of the skin that secrete sweat; found all over the body.

7.9 The Urinary System

Learning Objectives
- Describe the parts of urinary system.
- Outline how the kidneys filter blood.
- Describe what urine is and how it is formed.

Introduction
One of the most important ways your body maintains homeostasis is by keeping the right amount of water and salts inside your body. If you have too much water in your body, your cells can swell and burst. If you have too little water in your body, your cells can shrivel up like an old apple. Both of these situations occur because of the process of osmosis! Either extreme can cause illness and death of cells, tissues, and organs. The organs of your urinary system help to keep the correct balance of water and salts within your body.

Guided Learning

The Urinary System
The urinary system is the organ system that makes, stores, and gets rid of urine. It includes:
- Two kidneys
- Two ureters
- One bladder
- One urethra
The urinary system is shown in Figure below.

The kidneys filter the blood that passes through them and the urinary bladder stores the urine until it is released from the body.

Organs of the Urinary System

1. As you can see from Figure above, the kidneys are two bean-shaped organs. Kidneys filter and clean the blood and form urine. They are about the size of your fists and are found near the middle of the back, just below your rib cage.
2. Ureters are tube-shaped and bring urine from the kidneys to the urinary bladder.
3. The urinary bladder is a hollow and muscular organ. It is shaped a little like a balloon. It is the organ that collects urine.
4. Urine leaves the body through the urethra.

What is Urine?

Urine is a liquid that is formed by the kidneys when they filter wastes from the blood. Urine contains mostly water, but also contains salts and nitrogen-containing molecules. The amount of urine released from the body depends on many things. Some of these include the amounts of fluid and food a person consumes and how much fluid they have lost from sweating and breathing. Urine ranges from colorless to dark yellow, but is usually a pale yellow color. Light yellow urine contains mostly water. The darker the urine, the less water it contains.

The urinary system also removes a type of waste called urea from your blood. Urea is a nitrogen-containing molecule that is made when foods containing protein, such as meat, poultry, and certain vegetables, are broken down in the body. Urea and other wastes are carried in the bloodstream to the kidneys, where they are removed and form urine.

How the Kidneys Filter Wastes

The kidneys are important organs in maintaining homeostasis. Kidneys perform a number of homeostatic
functions.

- They maintain the volume of body fluids.
- They maintain the balance of salt ions in body fluids.
- They excrete harmful nitrogen-containing molecules, such as urea, ammonia, and uric acid.

There are many blood vessels in the kidneys, as you can see in Figure below. The kidneys remove urea from the blood through tiny filtering units called nephrons. **Nephrons** are tiny, tube-shaped structures found inside each kidney. A nephron is shown in Figure below. Each kidney has up to a million nephrons. Each nephron collects a small amount of fluid and waste from a small group of capillaries.

If the body is in need of more water, water is removed from the fluid inside the nephron and is returned to the blood. The fluid within nephrons is carried out into a larger tube in the kidney called a ureter, which you can see in Figure below. Urea, together with water and other wastes, forms the urine as it passes through the nephrons and the kidney.

*Structures of the kidney: fluid leaks from the capillaries and into the nephrons where the fluid forms urine then moves to the ureter and on to the bladder.*

39 Kidney Structures by PIOTR MICHAL JAWORSKI / CK-12 / CC-BY-SA 3.0.
The location of nephrons in the kidney. The fluid collects in the nephron tubules, and moves to the bladder through the ureter.

Formation of Urine

The process of urine formation is as follows:

1. Blood flows into the kidney through the renal artery, shown in Figure below. The renal artery connects to capillaries inside the kidney. Capillaries and nephrons lie very close to each other in the kidney.
2. The blood pressure within the capillaries causes water, salts, sugars, and urea to leave the capillaries and move into the nephron.
3. The water and salts move along through the tube-shaped nephron to a lower part of the nephron.
4. The fluid that remains in the nephron at this point is called urine.
5. The blood that leaves the kidney in the renal vein has much less waste than the blood that entered the kidney.
6. The urine is collected in the ureters and is moved to the urinary bladder, where it is stored.

Nephrons filter about $\frac{1}{4}$ cup of body fluid per minute. In a 24-hour period, nephrons filter 180 liters of fluid, and 1.5 liters of the fluid is released as urine. Urine enters the bladder through the ureters. Similar to a balloon, the walls of the bladder are stretchy. The stretchy walls allow the bladder to hold a large amount of urine. The bladder can hold about $1\frac{1}{2}$ to $2\frac{1}{2}$ cups of urine, but may also hold more if the urine cannot be released immediately.

How do you know when you have to urinate? Urination is the process of releasing urine from the body. Urine leaves the body through the urethra. Nerves in the bladder tell you when it is time to urinate. As the
bladder first fills with urine, you may notice a feeling that you need to urinate. The urge to urinate becomes stronger as the bladder continues to fill up.

Brain Control

The kidneys never stop filtering waste products from the blood, so they are always producing urine. The amount of urine your kidneys produce is dependent on the amount of fluid in your body. Your body loses water through sweating, breathing, and urination. The water and other fluids you drink every day help to replace the lost water. This water ends up circulating in the blood because blood plasma is mostly water.

The filtering action of the kidneys is controlled by the pituitary gland. The pituitary gland is about the size of a pea and is found below the brain, as shown in Figure below. The pituitary gland is also part of the endocrine system. The pituitary gland releases hormones, which help the kidneys to filter water from the blood.

The movement of water back into blood is controlled by a hormone called antidiuretic hormone (ADH). ADH is released from the pituitary gland in the brain. One of the most important roles of ADH is to control the body’s ability to hold onto water. If a person does not drink enough water, ADH is released. It causes the blood to reabsorb water from the kidneys. If the kidneys remove less water from the blood, what will the urine look like? It will look darker, because there is less water in it.

When a person drinks a lot of water, then there will be a lot of water in the blood. The pituitary gland will then release a lower amount of ADH into the blood. This means less water will be reabsorbed by the blood. The kidneys then produce a large volume of urine. What color will this urine be?
The pituitary gland is found directly below the brain and releases hormones that control how urine is produced.

**Summary**

- The organs of the urinary system remove wastes. They also maintain the proper levels of water, salts, and nutrients in the body.
- The urinary system is made up of the kidneys, the ureters, the bladder, and the urethra.
- The filtering parts of the kidneys are the nephrons.
- Water and waste molecules move out of the blood capillaries and into the nephrons. Most of the water returns to the blood.
- Urine collects in the nephron and moves to the urinary bladder through the ureters.
- The filtering action of the kidneys is controlled by the pituitary gland.
- ADH is the hormone released by the pituitary gland and controls the how water is reabsorbed by the blood from the kidneys.

**Vocabulary**

**kidney**

An organ that filters and cleans the blood and forms urine; about the size of a fist and are found near the middle of the back, just below your rib cage.

**nephron**

A tiny, tube-shaped structure found inside each kidney that collects a small amount of fluid and
waste from a small group of capillaries; up to a million nephrons are found in each kidney.

**urinary bladder**
A hollow and muscular organ that collects urine and is shaped like a little balloon.

**urinary system**
The organ system that makes, stores, and gets rid of urine; consists of kidneys, ureters, bladder, and urethra.

**urination**
The process of releasing urine from the body; urine leaves the body through the urethra and nerves in the bladder tell you when it is time to urinate.

**urine**
A liquid that is formed by the kidneys when they filter wastes from the blood; contains mostly water, but also contains salts and nitrogen-containing molecules.

### 7.10 Immune System Defenses

**Learning Objectives**
- Describe the immune system.
- Explain how lymphocytes respond to pathogens.
- Define immunity and vaccination.

**Introduction**

If pathogens get through the body’s first two lines of defense, a third line of defense takes over. What do you suppose this third line of defense consists of?

This third line of defense involves the immune system. It is called an **immune response**. The immune system has a special response for each type of pathogen.

The **immune system** is also part of the lymphatic system - named for **lymphocytes**, which are the type of white blood cells involved in an immune response. You can see the parts of the immune system in **Figure** below. They include several lymph organs, lymph vessels, lymph, and lymph nodes.
This diagram shows the parts of the immune system. The immune system includes several organs and a system of vessels that carry lymph. Lymph nodes are located along the lymph vessels.

**Lymph Organs**

The lymph organs are the red bone marrow, thymus gland, spleen, and tonsils. Each organ has a different job in the immune system. They are described in the **Figures** below.

*Red bone marrow is found inside many bones, including the femur shown here. Red bone marrow makes lymphocytes.*

---


43. [*Femur*](https://www.gray.org) by HENRY GRAY / CK-12 / CC-BY-SA 3.0.
The thymus gland is in the chest behind the breastbone. It stores lymphocytes while they grow older.

The spleen is in the abdomen below the lungs. Its job is to filter the toxins out of the blood. Any pathogens that are filtered out of the blood are destroyed by lymphocytes in the spleen.

The tonsils are in the throat. They trap pathogens that enter the body through the mouth or nose. Lymphocytes in the tonsils destroy the trapped pathogens.

Lymph and Lymph Vessels

Lymph vessels make up a circulatory system that is similar to the cardiovascular system. Lymph vessels are like blood vessels, except they move lymph instead of blood.

Lymph is a yellowish liquid that leaks out of tiny blood vessels into spaces between cells in tissues. Where there is more inflammation, there is usually more lymph in tissues. This lymph may contain many pathogens.

The lymph that collects in tissues slowly passes into tiny lymph vessels. It then travels from smaller to larger lymph vessels. Lymph is not pumped through lymph vessels like blood is pumped through blood vessels by the heart. Instead, muscles around the lymph vessels contract and squeeze the lymph through the vessels. The lymph vessels also contract to help move the lymph along. The lymph finally reaches the main lymph vessels in the chest. Here, the lymph drains into two large veins. This is how the lymph returns to the bloodstream.
Before lymph reaches the bloodstream, pathogens are removed from it at lymph nodes. **Lymph nodes** are small, oval structures located along the lymph vessels. They act like filters. Any pathogens filtered out of the lymph at lymph nodes are destroyed by lymphocytes in the nodes.

**Lymphocytes**

Lymphocytes (white blood cells) are the key cells of an immune response. A photograph of a lymphocyte is shown in **Figure** below. There are trillions of lymphocytes in the human body. They make up about one quarter of all white blood cells. Usually, fewer than half of the body's lymphocytes are in the blood. The rest are in the lymph, lymph nodes, and lymph organs.

![Image of a lymphocyte](https://example.com/lymphocyte.jpg)

*This image of a lymphocyte was made with an electron microscope. The lymphocyte is shown 10,000 times its actual size.*

There are two main types of lymphocytes:

1. **B cells.**
2. **T cells.**

Both types of lymphocytes are produced in the red bone marrow. They are named for the sites where they grow larger. The "B" in B cells stands for "bone." B cells grow larger in red bone marrow.

The "T" in T cells stands for "thymus." T cells mature in the thymus gland. B and T cells must be "switched on" in order to fight a specific pathogen. Once this happens, they produce an army of cells ready to fight that particular pathogen.

How can B and T cells recognize specific pathogens? Pathogens have proteins, often located on their cell surface. These proteins are called antigens. An **antigen** is any protein that causes an immune response, because it is unlike any protein that the body makes. Antigens are found on bacteria, viruses, and other pathogens. They are also found on other cells, like allergens, that enter the body and on cancer cells.

**Immune Responses**

47 [Lymphocyte](https://example.com/lymphocyte) by DR. TRICHE / CK-12 / CC-BY-SA 3.0.
There are two different types of immune responses. One type involves B cells. The other type involves T cells. You can watch a video of both types of immune responses.

B Cell Response

B cells respond to pathogens and other cells from outside the body in the blood and lymph. Most B cells fight infections by making antibodies. An antibody is a large, Y-shaped protein that binds to an antigen. Each antibody can bind with just one specific type of antigen. They fit together like a lock and key. Once an antigen and antibody bind together, they signal for a phagocyte to destroy them. A diagram of an antibody binding with an antigen is shown in Figure below.

![Antibody Antigen Binding](https://example.com/antibody-antigen-binding.png)

This diagram shows how an antibody binds with an antigen. The antibody was produced by a B cell. It binds with just one type of antigen. Antibodies produced by different B cells bind with other types of antigens.

T Cell Response

There are different types of T cells, including killer T cells and helper T cells. Killer T cells destroy infected, damaged, or cancerous body cells. How a killer T cell destroys an infected cell is shown in Figure below. When the killer T cell comes into contact with the infected cell, it releases poisons. The poisons make tiny holes in the cell membrane of the infected cell. This causes the cell to burst open. Both the infected cell and the viruses inside it are destroyed.

---

48 Antibody Antigen Binding by FVASCONCELLOS / CK-12 / CC-BY-SA 3.0.
In this diagram, a killer T cell recognizes a body cell infected with a virus. After the killer T cell makes contact with the infected cell, it releases poisons that cause the infected cell to burst. This kills both the infected cell and the viruses inside it.

Helper T cells do not destroy infected or damaged body cells. But they are still necessary for an immune response. They help by releasing chemicals that control other lymphocytes. The chemicals released by helper T cells “switch on” both B cells and killer T cells so they can recognize and fight specific pathogens.

Immunity and Vaccination

Most B and T cells die after an infection has been brought under control. But some of them survive for many years. They may even survive for a person’s lifetime.

These long-lasting B and T cells are called memory cells. They allow the immune system to “remember” the pathogen after the infection is over. If the pathogen invades the body again, the memory cells will start dividing in order to fight on the disease.

They will quickly produce a new army of B or T cells to fight the pathogen. They will begin a faster, stronger attack than the first time the pathogen invaded the body. As a result, the immune system will be able to destroy the pathogen before it can cause an infection. Being able to attack the pathogen in this way is called immunity.

Immunity can also be caused by vaccination. Vaccination is the process of exposing a person to a pathogen on purpose in order to develop immunity. In vaccination, the pathogen is usually injected under
the skin by a shot. Only part of the pathogen is injected, or a weak or dead pathogen is used. It sounds
dangerous, but the shot causes an immune response without causing the actual illness. Diseases you
have probably been vaccinated against include measles, mumps, and chickenpox.

Summary

- The immune system includes lymph organs, lymph vessels, lymph, and lymph nodes.
- B cells produce antibodies against pathogens in the blood and lymph.
- Killer T cells destroy body cells infected with pathogens.
- Immunity is the ability to resist a particular pathogen.
- Vaccination is deliberate exposure to a pathogen in order to bring about immunity.

Vocabulary

antigen
Any protein that causes an immune response.

immune response
Your body’s third line of defense against infection; how your body recognizes and defends itself
against viruses, bacteria, and other foreign substances.

immune system
An organ system consisting of the cells and tissues that recognize and attack foreign substances
in the body.

immunity
The ability to resist or recover from disease.

lymph
A yellowish liquid that leaks out of tiny blood vessels into spaces between cells in tissues.

lymph nodes
Small, oval structures located along the lymph vessels that act like filters; any pathogens filtered
out of the lymph at lymph nodes are destroyed by lymphocytes in the nodes.

lymphocytes
A type of white blood cells involved in an immune response (B and T cells are the two main
types).

vaccination
The process of exposing a person to a pathogen on purpose in order to develop immunity; the
pathogen is usually injected under the skin by a shot and only part of the pathogen is injected, or
a weak or dead pathogen is used.