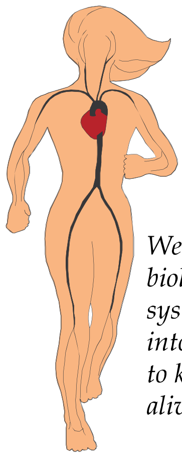
Introduction

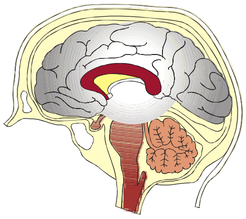
Every moment, waking or sleeping, we depend on biological systems built into our bodies to keep us alive. We define life itself by the signs that these systems are working. For example, our respiratory system allows us to breathe; our circulatory system gives us a pulse. Our respiratory and circulatory systems—along with many other systems—allow us to have the experience we call *life*. Most healthy people are lucky enough never to have to think about the processes that keep them going. They put a pizza into their digestive systems and forget about it. Their nervous systems help them dodge a bad driver in a parking lot, and they don't think twice. In this unit we will see how all of our body systems operate and interact to help us survive.



We depend on biological systems built into our bodies to keep us alive.

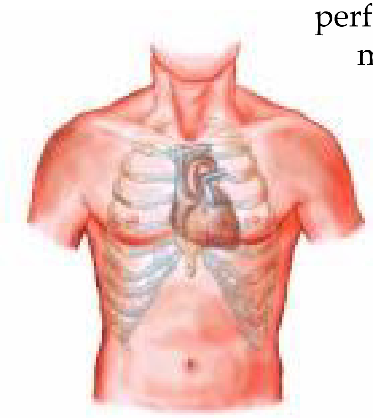
Major Organs

If we're going to survey the biological systems that run the human body, perhaps we should take some time to get our bearings. What are the really important parts of the human body?

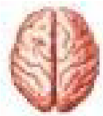
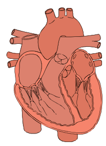
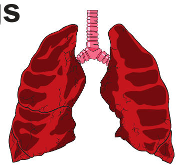
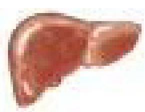
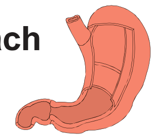
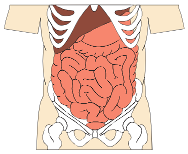


The brain is in the head and directs the nervous system.

People usually refer to these important pieces as "major organs." An **organ** is a body structure made up of a number of cell tissues that work as a unit to perform a specific function. Some major *organs* are easy to think of and locate. For example, the brain is in the head and directs the nervous system. The heart is in the chest and serves as the main pump for the circulatory system. The function and location of other major organs are less obvious. On the following page is a table that lists some major organs, gives a rough idea of their locations in the human body, and describes which body system depends on them.

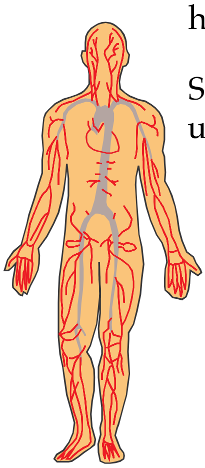


The heart is in the chest and serves as the main pump for the circulatory system.

Major Organs of the Body		
Organ	**Location**	**Function**
brain 	head	analyzes signals from the sensory organs and directs the central *nervous system*
heart 	chest, slightly left of the center	pumps blood; is the central structure of the *circulatory system*
lungs 	both sides of the chest	provide a place for blood to take in oxygen and give up carbon dioxide; are the central structures of the *respiratory system*
liver 	upper right abdomen	secretes bile to dissolve fats as food is broken down; filters out some toxins taken in with food and drink before nutrients are distributed throughout the body; part of the *digestive systems*
stomach 	upper left midsection	carries out rough breakdown of food; central structure of the *digestive system*
intestines 	central and lower abdomen	finish the breakdown of food and absorb the nutrients; part of the *digestive system*
kidneys 	lower back, each side of the spine	remove waste materials and toxins from the blood; central structures of the *excretory system*

Body Systems

What exactly is a body system? We have learned that an organ is a body structure that performs a specific function. A body system also performs a specific function, but it is made up of one or more organs plus all of their support structures. For example, the circulatory system is made up of the heart plus all of the veins, capillaries, and arteries.



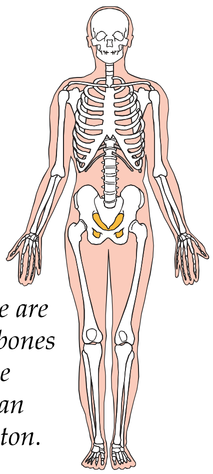
The circulatory system is a body system made up of the heart plus all of the veins, capillaries, and arteries.

Since there are so many body systems, this book uses two units to cover them. But there really is no neat dividing line for grouping body systems into two categories. All human body systems maintain life; all of them enable us to survive. Otherwise we wouldn't have them. Also, all of our body systems function together. Though we'll study them one by one, it's important to remember—and impossible to ignore—how they are all intertwined with one another.

The systems included in this unit are the skeletal, muscular, circulatory, respiratory, excretory, and digestive systems.

Skeletal System

The human skeleton is familiar to most of us from Halloween costumes, if for no other reason. Most people even know the common names of some of their **bones**: for example, the skull, ribs, and backbone. Yet the adult human skeleton is more complex than it might first appear. There are 206 *bones*, in all—22 in the skull alone! While most of us realize that the skeleton is the framework that supports the rest of the body, it's important to realize that it serves other functions as well.

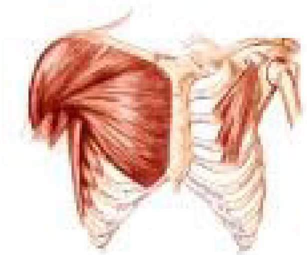


There are 206 bones in the human skeleton.

Functions of the Skeleton

1. Acts as framework for the body.
2. Anchors the muscles by providing places for attachment.
3. Makes blood cells.
4. Stores calcium.

Along with acting as a framework for the body, the bones serve as anchors for the muscles. Because the ends of our muscles are attached to bones by **tendons**, the contraction, or shortening, moves the bones.

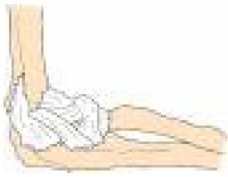


The bones serve as anchors for the muscles.

You might think of bones as just a bunch of brittle, white pipes buried deep in our bodies. In fact, bone is *living tissue*. Bone cells produce and store many products the body needs. The soft center of the bones, *marrow*, makes blood cells. The bones also store calcium, a mineral that makes bones strong and also helps the body in other ways.

Bone Structure

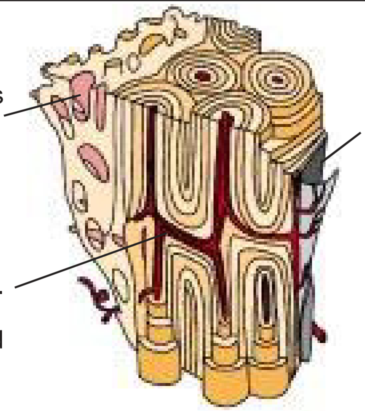
Bone first develops in humans as **cartilage**, a softer, more flexible substance. As humans grow older, most of the *cartilage* hardens into bone. Some parts of our bodies remain cartilage throughout our lives, such as the tip of the nose and the outside of the ears. Cartilage is also found at the ends of bones at joints. There it acts as a cushion, or shock absorber, between the bones. At moveable joints, such as the elbow and the knee, you'll also find **ligaments**, tough fibers that help hold bones together.



At moveable joints, you'll find ligaments—tough fibers that help hold bones together.

Covering the outside of the bone is a tough layer of tissue called the **periosteum**. It provides a place for muscles to attach to the bone. It also contains nerves as well as blood vessels that supply the bone with blood. These blood vessels and nerves penetrate to the inside of the bone through tiny channels that pass through the bone.

Bones are made up of two types of bone: **solid bone** and **spongy bone**. As the storage place for calcium, *solid bone* is very dense and strong. It is usually found around the edges of bones. *Spongy bone*, as its name would lead you to believe, has many small holes. Though it's strong, like solid bone, it is much more lightweight. Spongy bone is usually found at the end of bones. At the middle of the bone is a central cavity filled with marrow. It also contains nerves and blood vessels.

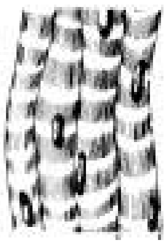


Muscular System

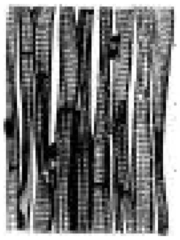
Every moment of our lives we're using muscle. We rub our eyes or scratch our backs and dozens of muscles act in concert to achieve these motions. Even as you read these words, muscles are moving your eyes from left to right and back again. In fact, the muscles involved in the movements mentioned up to now are examples of just the **voluntary muscles**—you could choose not to rub your eyes, scratch your back, or move your eyes to read. We have not even begun to consider **involuntary muscles**—those that operate completely outside of our conscious thought. *Involuntary muscles* include muscles that run the heart, the stomach, the intestines, and the blood vessels—constantly, every moment of our lives.

Three Kinds of Muscle

Skeletal muscles are the muscles that move the bones of the skeleton. We move our arms, legs, and neck, for example, with *skeletal muscles*. These are *voluntary* muscles. When seen under a microscope, skeletal muscle seems striped with light and dark bands.



Skeletal muscles are the muscles that move the bones of the skeleton.



Cardiac muscle makes up our most tireless muscle, the heart.

Cardiac muscle makes up our most tireless muscle, the heart. It also appears striped under magnification. But in *cardiac muscle*, the striping is finer and closer together so that the muscle looks sort of like a tightly woven basket. The heart is the only muscle made of cardiac muscle. This muscle is *involuntary*.

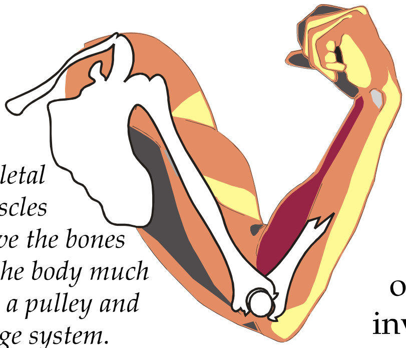
Smooth muscle can be found in many parts of the body. It does not appear at all striped but does, in fact, look smooth. This type of muscle is also involuntary. The stomach, intestines, and blood vessels are examples of body parts that contain *smooth muscle*.

The stomach, intestines, and blood vessels are examples of body parts that contain smooth muscle.

How Muscles Work

Muscles move by shortening or contracting. This happens when the long, slender cells that make up muscle are supplied with energy and activated by a nerve impulse. The process of how these cells actually shorten themselves still isn't clear to biologists. However, the most common theory to explain muscle contraction is that fibers in the muscle cells slide over one another and thus cause the cell to shorten. As the fibers return to their original position, the contractions subside.

Skeletal muscles move the bones in the body much like a pulley and hinge system. For instance, to bend the knee, the rear thigh muscle, which is attached to both the thigh bone and upper shin bone, shortens. This brings the shin and thigh bones closer together, thus bending the hinge of the knee. Each major hinge in the body is usually operated by a pair of muscles, one that controls its bend and one that straightens it again. The muscles involved in these systems are attached to the bones by strong fibers called *tendons*.



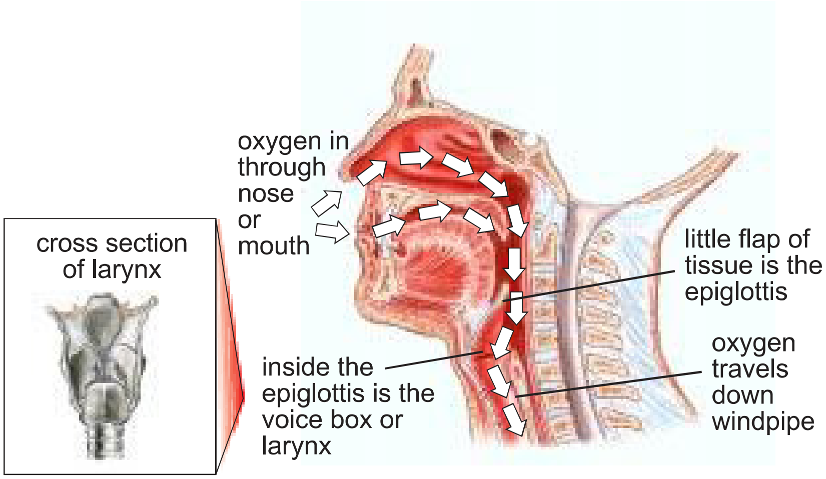
Skeletal muscles move the bones in the body much like a pulley and hinge system.

Respiratory System

As you know, human beings must breathe oxygen to survive. This is because oxygen is an element that is crucial to burning the energy we have taken in as food and stored as fats and sugars in our bodies. The chemical process that changes food to energy for our bodies takes place in the cells. However, many of our cells are buried deep inside our bodies far from any oxygen source. So how can each cell in the body receive oxygen?

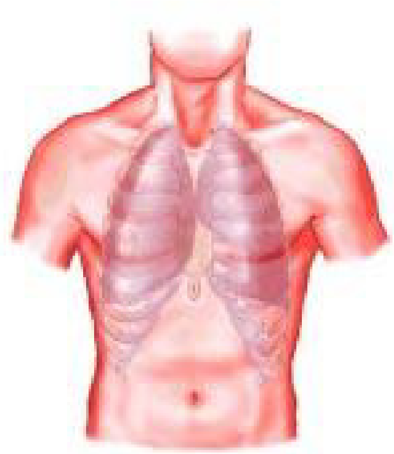
One part of the answer is the respiratory system. This system is as familiar to us as the noses on our faces, but obviously there is much more to it that we can't see. We take in oxygen through the mouth or nose, which filters and warms it. From there the oxygen travels down the windpipe. The windpipe descends from the back of the throat and is protected by a little flap of tissue called the **epiglottis.** Just inside the *epiglottis* is the voice box or **larynx**. The vocal cords of the *larynx* vibrate with passing air to make sound.

The vocal cords of the larynx vibrate with passing air to make sound.



Human beings must breathe oxygen to survive.

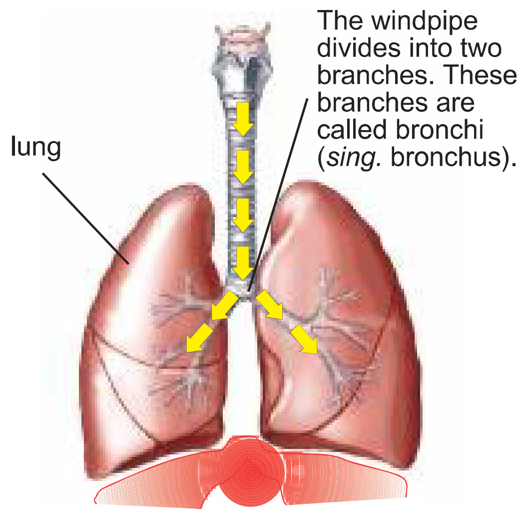
Below this point, at the top of the chest, the windpipe divides into two branches. These branches are called **bronchi** (*sing*. bronchus). One of the *bronchi* leads to the right lung and one leads to the left lung. From there the bronchi branch into millions of smaller tubes, each of which leads to a small air sac. Each air sac is surrounded by tiny blood vessels called **capillaries** through which the blood passes. These *capillaries* are so narrow that the blood can only pass one blood cell at a time. As these blood cells pass by the air sac, they give up the carbon dioxide they have picked up from body cells as a waste product in exchange for a fresh load of oxygen. Then the blood returns to the heart, which pumps it back out to the body to deliver oxygen to waiting body cells.



Our lungs in our body.

How We Breathe

By breathing, we draw air containing oxygen into our lungs and push air containing carbon dioxide out. How does this work? In many ways, our breathing equipment functions like a big syringe, with the plunger moving out and in, out and in.



The diaphragm, the dome-shaped muscle at the base of the chest cavity, goes in and pushes carbon dioxide and other gases out of the lungs.

As we take in a breath, the muscles of the ribs contract, pulling the ribs up and out. Then the **diaphragm,** the dome-shaped muscle at the base of the chest cavity, contracts and lowers. The *diaphragm* functions like the plunger in a syringe. As it lowers, the area of the lungs increases, and oxygen moves in to fill up the space. Then, as the diaphragm relaxes and returns to its original position, the area in the lungs decreases again. The diaphragm—plunger—goes in and pushes carbon dioxide and other gases out of the lungs.

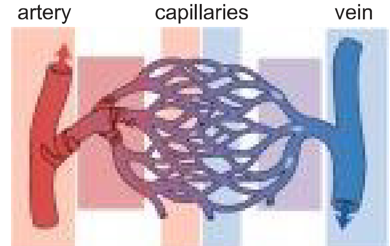
Circulatory System

One way to imagine the circulatory system is as a vast highway system with little delivery trucks traveling around on it. The highway system is *blood vessels*. The delivery trucks are *red blood cells*. The delivery trucks do not move by their own power but are pushed along in small bursts of speed. The power behind them is the *pumping of the heart*.

In studying the respiratory system, we saw how red blood cells picked up carbon dioxide—a waste product from burning food—from the body cells. In the lungs, the red blood cells exchanged their load of carbon dioxide for a load of oxygen. The blood cells also pick up other wastes from body cells and leave them in the kidneys, which filter blood. They move on to other pickup points to load up with products of the digestive system—food nutrients—to deliver to the body cells.

Blood vessels are divided into three types: **arteries**, **capillaries**, and **veins**.

- *Arteries* are blood vessels leading *away* from the heart.
- *Capillaries* are tiny blood vessels where *pickup* of wastes and delivery of oxygen and food takes place.
- *Veins* are blood vessels that *connect* with the *capillaries* to take blood *back to* the heart.

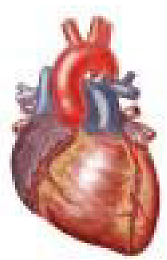


Blood vessels are divided into three types: arteries, capillaries, *and* veins.

This pickup and delivery system would not work without the powerful pumping of the heart, which pushes blood cells through the blood vessels. How does the heart work?

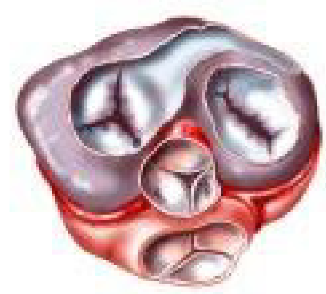
The Heart—A Two-Sided Pump

The heart is a muscle with two sides completely walled off from one another. Each side has a top chamber, the **atrium** (*pl.* atria) and a bottom chamber, the **ventricle**. First the top chambers contract, squeezing blood into the bottom chambers. Then the bottom chambers contract, squeezing blood out of the heart into the



The heart is a muscle.

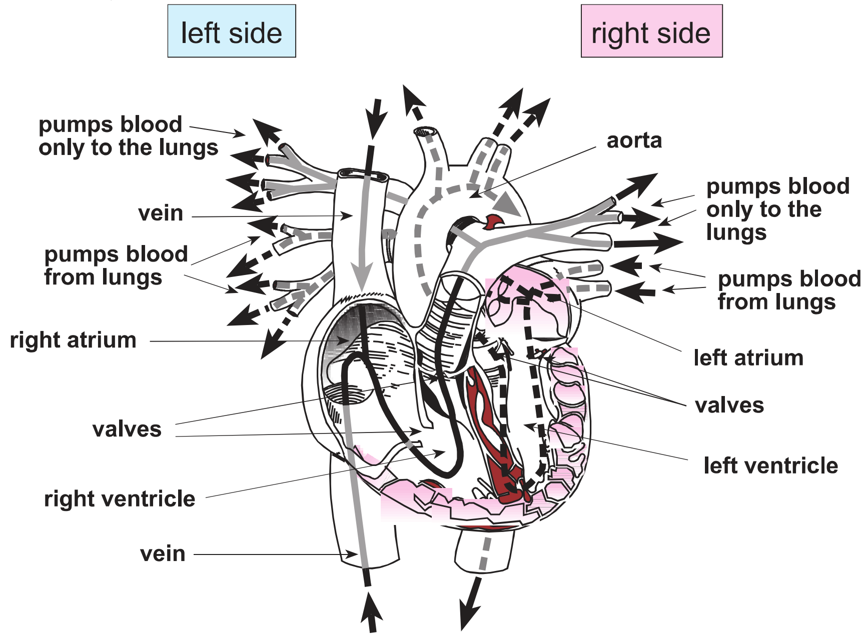
arteries that lead out of the bottom chambers. After each contraction empties one set of chambers, the heart relaxes pressure on the other set of chambers. This increases the space inside, and new blood is sucked in to fill the space. Thus the two sets of chambers take turns being filled and emptied with blood—one set fills as the other set empties. Valves at the out-gates of the atria and *ventricles* prevent the backflow of the blood. It's these two sets of valves closing—first one set, then the other—that we hear as a heartbeat.



Valves at the out-gates of the atria and ventricles prevent the backflow of the blood.

Each side of the heart has a special job.

- The *right* side of the heart pumps blood only *to the lungs*. Receiving blood from the body that contains lots of carbon dioxide and little oxygen, the right side of the heart pumps this blood to the lungs for gas exchange.
- The blood returns to the *left* side of the heart *from the lungs*. There it gets a new push to make its trip back out into the blood vessels of the body.



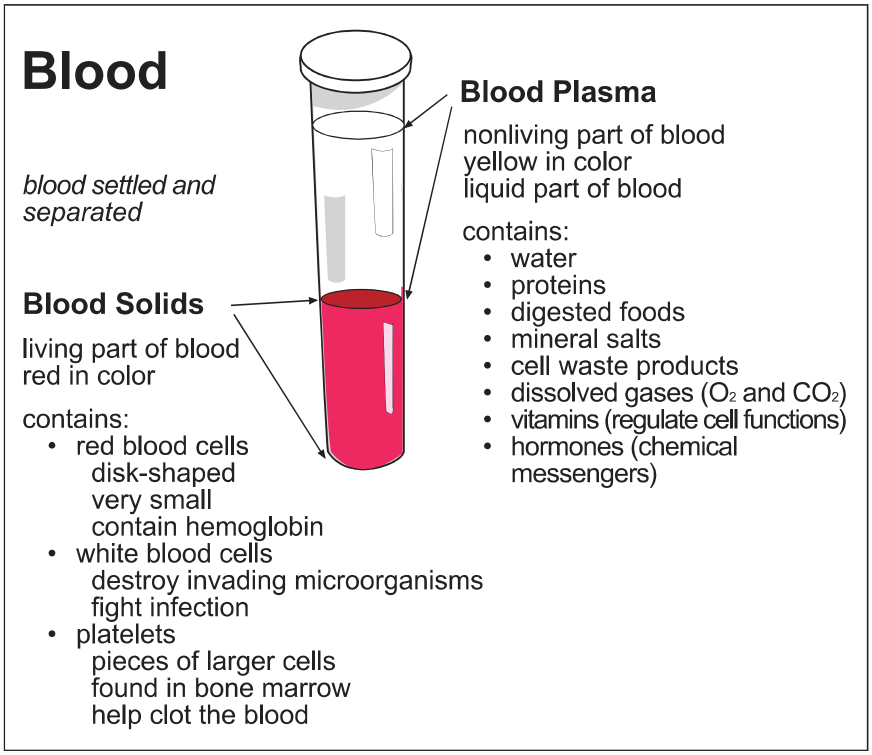
Heart

oxygen-rich blood	- - - - -	enters heart from lungs and goes out to body
oxygen-poor blood	———	enters heart from body and goes out to lungs

The Structure of Blood

We tend to think of blood as liquid, but in fact blood is made up of a liquid part and a solid part. The liquid part of the blood, called **plasma**, makes up about 55 percent of the total volume. The solid part, blood solids, makes up about 45 percent of the total volume.

Plasma is 90 percent water. Otherwise, it contains the substances listed on the chart below. Proteins in plasma give blood the ability to clot and form scabs, which are necessary to stop bleeding. Proteins also give blood the ability to regulate the amount of fluid contained in cells and the ability to recognize and fight disease. Digested foods float around in the plasma in the form of glucose and fats. Wastes (such as *urea*, which ultimately exits the body in the form of *urine*) are also found in the blood.



Blood solids fall into three categories. **Red blood cells** are disk-shaped and very small. They contain the protein **hemoglobin**, which combines easily with oxygen and carbon dioxide. This is what makes *red blood cells* such good pickup and delivery trucks for these gases throughout the body and in the lungs. **White blood cells** are larger than red blood cells. Their most important function is to surround and destroy microorganisms that invade the body. Thus, when there is an infection in the body, the number of *white blood cells* increases to fight it off. **Platelets** are not really whole cells. They're pieces of larger cells formed in the bone marrow. They have no nuclei and are even smaller than red blood cells. *Platelets* work with proteins in the plasma to clot the blood.

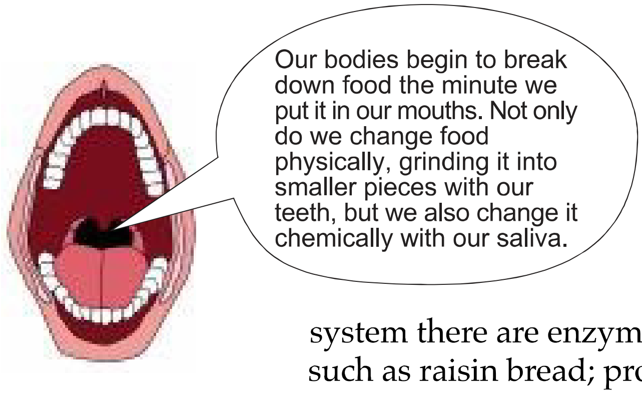
Digestive System

Oxygen and food are the two main things body cells need to carry out their many varied missions, whether they're muscle cells contracting to move bones or white blood cells fighting off invading microorganisms or any other type of cell. We've seen how the respiratory system provides oxygen to cells. But how is raisin bread, beans, or a chocolate bar processed into the tiny molecules that cells need to burn for energy? And how do these molecules reach cells all over the body?

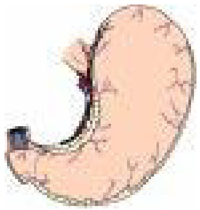
These are the jobs of the digestive system: breaking down food into a form cells can use and aiding or getting this refined food to the cells.

Physical and Chemical Changes That Break Down Food

Our bodies begin to break down food the minute we put it in our mouths. Not only do we change food physically, grinding it into smaller pieces with our teeth, but we also change it chemically with our **saliva**. *Saliva*, a fluid released from glands in the mouth, soaks into the food and helps turn it into a paste. If the food is a carbohydrate, such as raisin bread, saliva begins to change the chemical makeup of the bread with an enzyme. **Enzymes** are proteins that speed up the breakdown of food into molecules. *Enzymes* are very specific to the type of food they affect. In the human digestive system there are enzymes specific to carbohydrates, such as raisin bread; proteins, such as beans or fat.



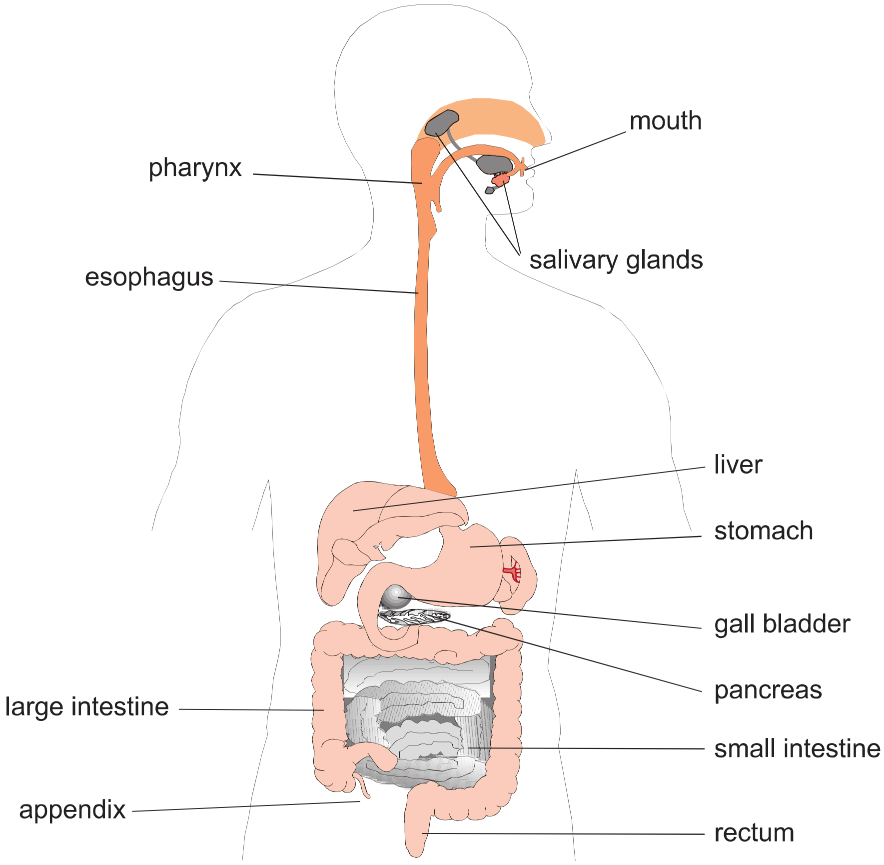
When we swallow, muscles in the throat push the bite of food into the **esophagus**. This is the tube that carries food to the stomach. The *esophagus* also has muscles that push the food down toward the stomach.



The stomach is a muscular bag that holds and works on food for about four hours.

The stomach is a muscular bag that holds and works on food for about four hours. Cells inside the stomach make chemicals which include hydrochloric acid and enzymes. After the stomach is finished with the food, it pushes it into the small intestine.

The small intestine is a tube-shaped organ that's about seven meters long. This is where most of the food processing known as *digestion* occurs. Enzymes from the liver and pancreas work with enzymes produced by the small intestine to break down foods from all three food groups—carbohydrates, proteins, and fat. **Bile**, a substance produced in the liver and stored in the gall bladder, works specifically on fat. The small intestine may handle food for as long as 10 hours before the remnants of what's left pass through.

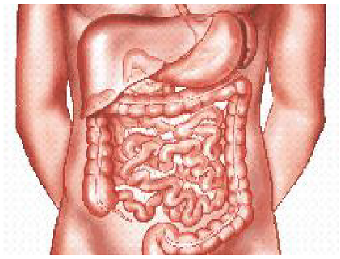


digestive system

The large intestine is a larger tube whose main job is to remove water from the undigested remains of the food that entered the mouth. By this point, all of the usable nutrients in the food have been removed. Undigested food and wastes pass from the large intestine out of the body through the rectum.

How the Body Absorbs Food

The small intestine breaks food down into molecules that cells can use. But how do these molecules get from the small intestine to the cells?



seven meters worth of small intestine

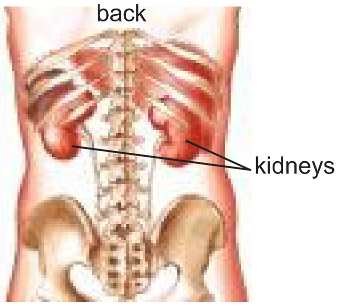
Food molecules are absorbed through the very thin lining of the small intestine into blood passing through underlying capillaries. From there the blood travels to the liver for filtering before it circulates throughout the body. But even seven meters worth of small intestine would not provide enough space to absorb all of the available food molecules if the lining of the intestine were not constructed in a way that maximizes absorption area. The inside of the small intestine is not smooth. It is puckered up into millions of fingerlike knobs called *villi*. This puckering or knobby wrinkling of the small intestine lining increases the amount of area with which food comes into contact.

Excretory System

The excretory system is the body's garbage service. Through the excretory organs, the human body gets rid of waste products that could slow down and even poison its other systems. One of these waste products is **urea**, a substance that is made up of leftover parts of used proteins and is high in nitrogen. Another waste product is carbon dioxide.

Though we think of lungs as part of the respiratory system, they're an excretory organ in that they remove carbon dioxide from the body. The skin also excretes some *urea* with water and salt when we perspire, although the main purpose of perspiration is to cool the body.

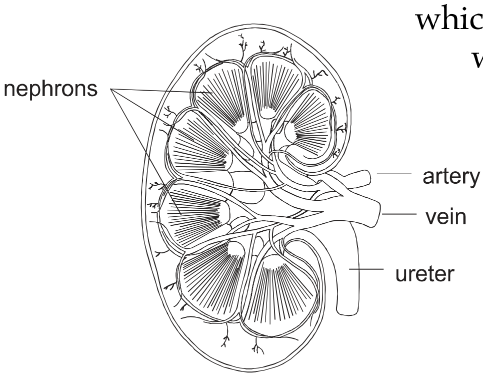
Kidneys—The Major Excretory Organs



The kidneys are found on either side of the spine in the small of the back.

The kidneys are the major excretory organs. They are found on either side of the spine in the small of the back, looking like a pair of giant kidney beans.

Each kidney is made up of many tiny filtering units called **nephrons**. Each *nephron* is made up of a cuplike structure mounted on a tube that leads out of the kidney. The cup holds a tightly coiled capillary. Pressure inside this capillary is very high because the heart pumps blood directly into the arteries that lead to the kidney. Because of this pressure, everything is forced out of the blood except the blood cells. This includes water, mineral salts, food, and urea—much of which the blood needs to keep. But not to worry: all of these things run down into the nephron tube, which the capillary wraps around. The capillary reabsorbs the food as well as the proper amounts of water and mineral salts. The urea and everything else continues down the nephron tube. Eventually they leave the kidney, are gathered in the bladder as **urine**, and leave the body through the **urethra**.



Kidney

Summary

The human body depends on many biological systems to function and survive. All of these systems interact and overlap with one another.

Major organs include the brain, heart, lungs, liver, stomach, intestines, and kidneys. All of these organs play central roles in the systems that run the human body.

The skeleton provides a framework for the body and also accomplishes other important jobs. The muscles move the bones of the skeleton and contribute to the make up and function of most major organs.

The respiratory system provides a place for blood to take up oxygen and give off carbon dioxide: the lungs. The circulatory system allows blood to deliver oxygen and food molecules to body cells and to pick up waste products. The heart pushes blood through the body so that it can accomplish these tasks.

The digestive system breaks down food into molecules that cells can use. The liver and pancreas contribute enzymes to this process. The small intestine is the place where the blood absorbs these molecules.

The excretory system is the human body's garbage service. The kidneys are the main excretory organs. They remove waste products from the blood and regulate the amount of water and mineral salts that blood contains.