CHAPTER 4

Organization and Regulation of Body Systems

Bladder cancer. The words sounded so ominous when Barbara heard her doctor say them. Given her long-term history of smoking, she would not have been surprised by a diagnosis of lung cancer, but bladder cancer? It's highly correlated with smoking, her doctor said.

The next thing Barbara knew, she was scheduled for surgery to have her bladder removed. Fortunately, her team of surgeons planned to create a substitute "bladder" from a section of her large intestine. Having a new internal "bladder" meant that wearing an external bag for collecting urine would be unnecessary.

In Chapter 3, we learned that cells are specialized to carry out specific functions; now it is time to consider that tissues and organs are specialized, too. The specific tissues of an organ, such as the bladder, enables it to perform its intended function.

Organs are a part of organs systems, all of which contribute to the maintenance of homeostasis. The bladder is part of the urinary system that works to maintain the water-salt balance and the acid-base balance of the blood, among other functions. When the urinary system doesn't function properly, imbalances will occur, and the results could be devastating or life threatening.

In this chapter, you will learn about the characteristics of different tissues and where they are found in the body. You'll also read about the various organ systems and what they do to maintain homeostasis. Future chapters will provide greater insight into how the interactions of cells and tissues in organs allow an organ system to perform its function and play a role in homeostasis.

CHAPTER CONCEPTS

4.1 Types of Tissues
The body contains four types of tissues: connective tissue, muscular tissue, nervous tissue, and epithelial tissue.

4.2 Connective Tissue Connects and Supports
Connective tissues, which join together other tissues, can be classified into three types: fibrous connective tissue, supportive connective tissue, and fluid connective tissue.

4.3 Muscular Tissue Moves the Body
Skeletal muscle is attached to the skeleton; smooth muscle is in the walls of internal organs; and cardiac muscle is in the wall of the heart.

4.4 Nervous Tissue Communicates
Nervous tissue, found in the brain, spinal cord, and nerves, contains neurons and support cells (neuroglia).

4.5 Epithelial Tissue Protects
Epithelial tissues, which line cavities and cover surfaces, are named according to the shape of the cell and can occur in a single layer or multiple layers.

4.6 Cell Junctions
Cell junctions, consisting of tight junctions, adhesion junctions, and gap junctions, help tissues perform their various functions.

4.7 Integumentary System
The skin and its accessory organs have many functions important to homeostasis.

4.8 Organ Systems
Each of the organ systems have functions that contribute to homeostasis, the relative constancy of the internal environment.

4.9 Homeostasis
Homeostasis is maintained by various physiological mechanisms.

4.1 Types of Tissues

Recall the biological levels of organization. Cells are composed of molecules; a tissue has like cells; an organ contains several types of tissues; and several organs are found in an organ system. In this chapter, we consider the tissue, organ, and organ system levels of organization.

A **tissue** is composed of specialized cells of the same type that perform a common function in the body. The tissues of the human body can be categorized into four major types:

Connective tissue binds and supports body parts.
Muscular tissue moves the body and its parts.
Nervous tissue receives stimuli and conducts nerve impulses.
Epithelial tissue covers body surfaces and lines body cavities.

Cancers are classified according to the type of tissue from which they arise. Sarcomas are cancers arising in muscle or connective tissue (especially bone or cartilage); leukemias are cancers of the blood; lymphomas are cancers of lymphoid tissue, and **carcinomas,** the most common type, are cancers of epithelial tissue. The chance of developing cancer in a particular tissue shows a positive correlation to the rate of cell division; epithelial cells reproduce at a high rate, and 2,500,000 new blood cells appear each second. Thus, carcinomas and leukemias are common types of cancers.

Check Your Progress 4.1

1. What are the four major tissue types found in the human body?

4.2 Connective Tissue Connects and Supports

Connective tissue is quite diverse in structure and function, but, even so, all types have three components: specialized cells, ground substance, and protein fibers, which are shown in diagrammatic representation of loose fibrous connective tissue (Fig. 4.1). The term **matrix** includes ground substance and fibers. The ground substance is a noncellular material that separates the cells and varies in consistency from solid to semifluid to fluid. The fibers are of three possible types. White **collagen fibers** contain collagen, a protein that gives them flexibility and strength. **Reticular fibers** are very thin collagen fibers that are highly branched and form delicate supporting networks. Yellow **elastic fibers** contain elastin, a protein that is not as strong as collagen but is more elastic. X-ref

Inherited connective tissue disorders arise when people inherit genes that lead to malformed fibers in connective tissue. These disorders range from bones that are too brittle to joints that are too loose. The skin can be too loose and blood vessel walls can be too fragile. Overly long or short bones can affect height.

Fibrous Connective Tissue

Both loose fibrous and dense fibrous connective tissues have cells called **fibroblasts** that are located some distance from one another and are separated by a jellylike matrix containing white collagen fibers and yellow elastic fibers (Fig. 4.2). X-ref

Loose fibrous connective tissue, also called areolar tissue, supports epithelium and also many internal organs . Its presence in lungs, arteries, and the urinary bladder allows these organs to expand. It forms a protective covering enclosing many internal organs, such as muscles, blood vessels, and nerves.

Adipose tissue is a special type of loose connective tissue in which the cells enlarge and store fat. The body uses this stored fat for energy, insulation, and organ protection. Adipose tissue is found beneath the skin, around the kidneys, and on the surface of the heart.

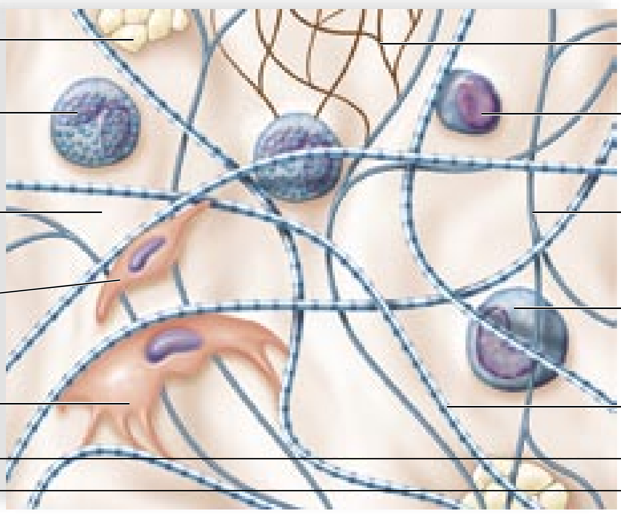


Figure 4.1 Diagram of loose fibrous connective tissue.

Dense fibrous connective tissue contains many collagen fibers that are packed together. This type of tissue has more specific functions than does loose connective tissue. For example, dense fibrous connective tissue is found in **tendons,** which connect muscles to bones, and in **ligaments,** which connect bones to other bones at joints.

Supportive Connective Tissue

In **cartilage,** the cells lie in small chambers called lacunae (sing., **lacuna**), separated by a matrix that is solid yet flexible. Unfortunately, because this tissue lacks a direct blood supply, it heals very slowly. There are three types of cartilage, distinguished by the type of fiber in the matrix.

X-ref **Hyaline cartilage** (Fig. 4.2), the most common type of cartilage, contains only very fine collagen fibers. The matrix has a glassy, translucent appearance. Hyaline cartilage is found in the nose and at the ends of the long bones and the ribs, and it forms rings in the walls of respiratory passages. The fetal skeleton also is made of this type of cartilage. Later, the cartilaginous fetal skeleton is replaced by bone.

Elastic cartilage has more elastic fibers than hyaline cartilage. For this reason, it is more flexible and is found, for example, in the framework of the outer ear.

Fibrocartilage has a matrix containing strong collagen fibers. Fibrocartilage is found in structures that withstand tension and pressure, such as the disks between the vertebrae in the backbone and the wedges in the knee joint.

Bone

Bone is the most rigid connective tissue. It consists of an extremely hard matrix of inorganic salts, notably calcium salts, deposited around protein fibers, especially collagen fibers. The inorganic salts give bone rigidity, and the protein fibers provide elasticity and strength, much as steel rods do-in reinforced concrete.

Compact bone makes up the shaft of a long bone (Fig. 4.2). It consists of cylindrical structural units called osteons (Haversian systems). The central canal of each osteon is surrounded by rings of hard matrix. Bone cells are located in spaces called lacunae between the rings of matrix. Blood vessels in the central canal carry nutrients that allow bone to-renew itself. Thin extensions of bone cells within canaliculi (minute canals) connect the cells to each other and to the central canal.

The ends of a long bone contain spongy bone, which has an entirely different structure. **Spongy bone** appears as an open, bony latticework with numerous bony bars and plates, separated by irregular spaces. Although lighter than compact bone, spongy bone is-still designed for strength. Just as braces are used for support in buildings, the solid portions of spongy bone follow lines of stress.

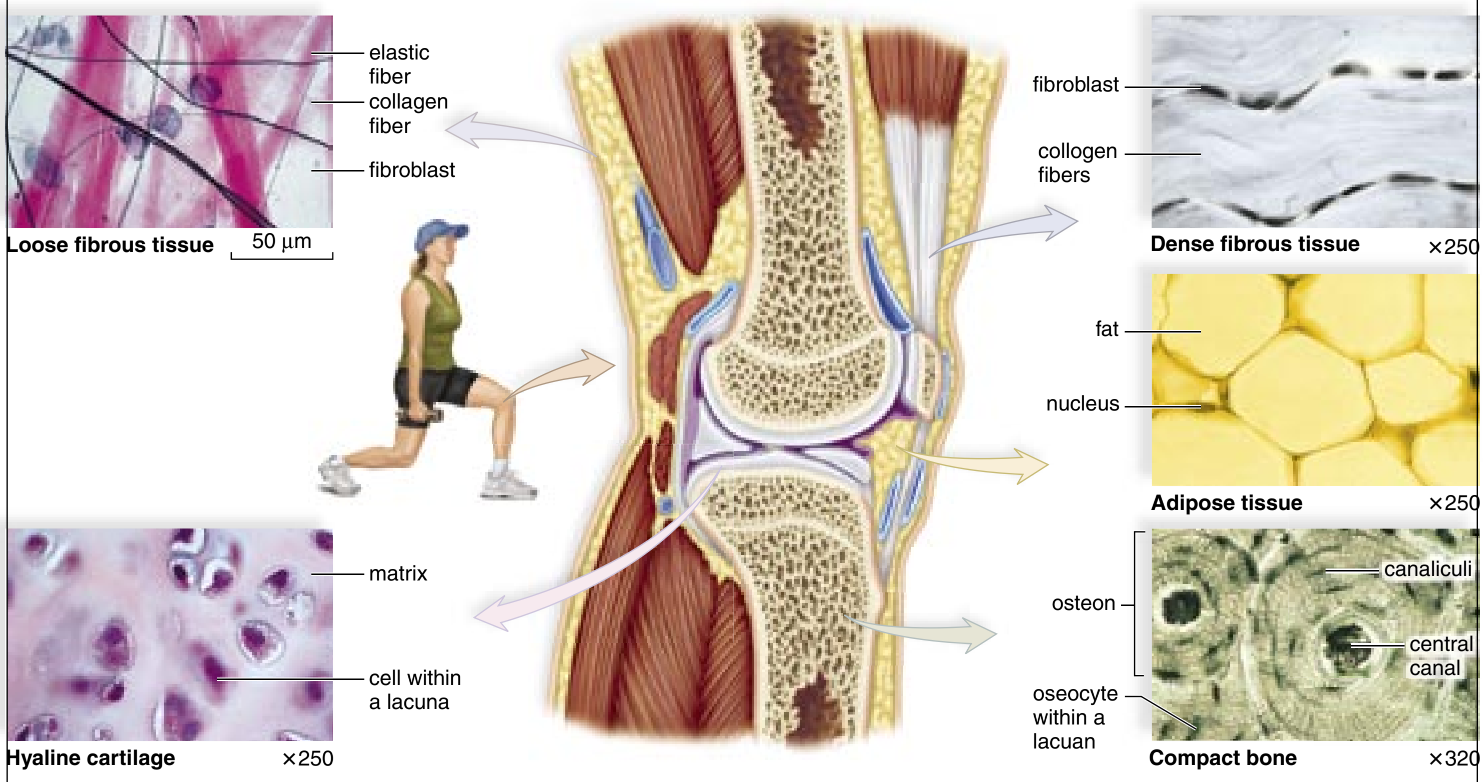


Figure 4.2 Connective tissues associated with the knee.
The human knee provides examples of most types of connective tissue.

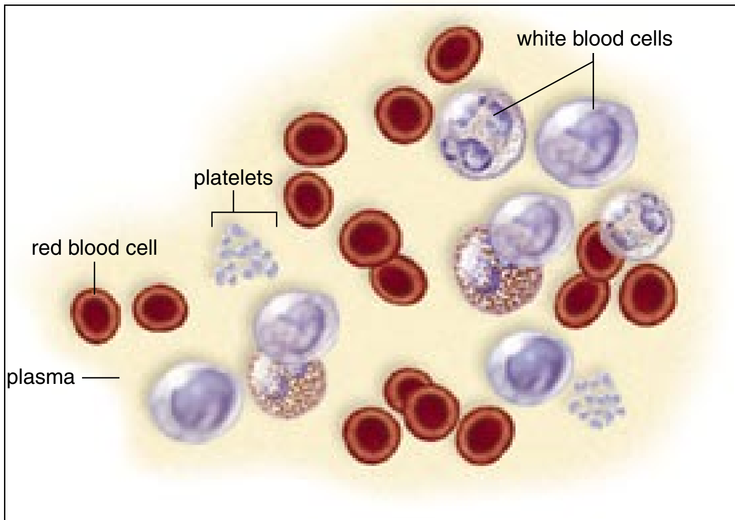


Figure 4.3 **Formed elements in blood.**
Red blood cells, which lack a nucleus, transport oxygen. Each type of white blood cell has a particular way to fight infections. Platelets, which are fragments of a particular cell, function in helping to seal injured blood vessels.

Fluid Connective Tissues

Blood, which consists of formed elements (Fig. 4.3) and plasma, is a fluid connective tissue located in blood vessels. Some people do not classify blood as connective tissue; instead, they suggest a separate tissue category called vascular tissue.

Body tissues are bathed in **tissue fluid.** The systems of the body help keep blood composition and chemistry within normal limits, and blood, in turn, creates tissue fluid. Blood transports nutrients and oxygen to tissue fluid and removes carbon dioxide and other wastes. It helps distribute heat and also plays a role in fluid, ion, and pH balance. The formed elements, discussed below, each have specific functions.

The **red blood cells (erythrocytes)** are small, biconcave, disk-shaped cells without nuclei. The presence of the red pigment hemoglobin makes the cells red and, in turn, makes the blood red.-Hemoglobin is composed of four units; each unit is composed of the protein globin and a complex iron-containing structure called heme. The iron forms a loose association with oxygen, and in this way, red blood cells transport oxygen.

White blood cells (white blood cells) may be distinguished from red blood cells by the fact that they are usually larger, have a nucleus, and without staining would appear translucent. White blood cells characteristically vary from mostly bluish to pink because they have been stained. White blood cells fight infection, primarily in two ways. Some white blood cells are phagocytic and engulf infectious **pathogens.** Other white blood cells either produce antibodies, molecules that combine with foreign substances to inactivate them, or they kill cells outright.

Platelets (thrombocytes) are not complete cells; rather, they are fragments of giant cells present only in bone marrow. When a blood vessel is damaged, platelets form a plug that seals the-vessel, and injured tissues release molecules that help the clotting process.

Lymph is also a fluid connective tissue. Lymph is a clear, watery, sometimes faintly yellowish fluid derived from tissue fluid that contains white blood cells. Lymphatic vessels absorb excess tissue fluid and various dissolved solutes in the tissues and transport lymph to particular vessels of the cardiovascular system. Special lymphatic capillaries, called lacteals, absorb fat molecules from the small intestine. Lymph nodes, composed of fibrous connective tissue, occur along the length of lymphatic vessels. Lymph is cleansed as it passes through lymph nodes, in particular, because white blood cells congregate there. Lymph nodes and other types of lymphatic tissues supply lymph with lymphocytes, which can be classified as a type of connective tissue cell. Lymphatic nodes enlarge when you have an infection.

Check Your Progress 4.2

1. a. What are the three types of connective tissue, and b. what are some examples of each type (Fig. 4.4)?
2. Contrast loose fibrous connective tissue with dense fibrous connective tissue.
3. Contrast spongy bone with compact bone.
4. Contrast blood with lymph.

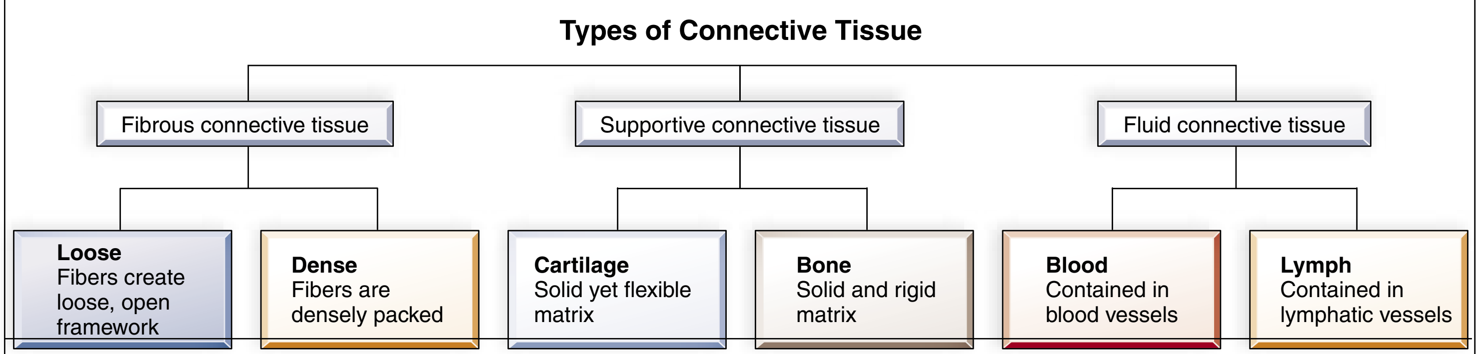


Figure 4.4 **Types of connective tissue.**

4.3 Muscle Tissue Moves the Body

Muscular (contractile) tissue is composed of cells called muscle fibers. Muscle fibers contain protein filaments, called actin and myosin filaments, whose interaction accounts for movement. The three types of vertebrate muscular tissue are skeletal, smooth, and cardiac.

Skeletal muscle, also called voluntary muscle (Fig. 4.5*a*), is attached by tendons to the bones of the skeleton, and when it contracts, body parts move. Contraction of skeletal muscle is under voluntary control-and occurs faster than in the other muscle types. Skeletal muscle fibers are cylindrical and quite long—sometimes they run the length of the muscle. They arise during development when several cells fuse, resulting in one fiber with multiple nuclei. The nuclei are located at the-periphery of the cell, just inside the plasma membrane.-The fibers have alternating light and dark bands that give them a **striated,** or striped, appearance. These bands are due to the placement of actin filaments and myosin filaments in the cell.

Smooth (visceral) muscle is so named because the cells lack striations. The spindle-shaped cells form layers in which the thick middle portion of one cell is opposite the thin ends of adjacent cells. Consequently, the nuclei form an irregular pattern in the tissue (Fig. 4.5*b*). Smooth muscle is not under voluntary control, and therefore is said to be involuntary. Smooth muscle, found in the walls of viscera (intestine, bladder, and other internal organs) and blood vessels, contracts more slowly than skeletal muscle but can remain contracted for a longer time. When the smooth muscle of the bladder contracts, urine is sent into a tube called the urethra, which takes it to the outside. When the smooth muscle of the blood vessels contracts, blood vessels constrict, helping to raise blood pressure.

Cardiac muscle (Fig. 4.5*c*) is found only in the walls of the heart. Its contraction pumps blood and accounts for the heartbeat. Cardiac muscle combines features of both smooth and skeletal muscle. Like skeletal muscle, it has striations, but the contraction of the heart is involuntary for the most part. Cardiac muscle cells also differ from skeletal muscle cells in that they usually have a single, centrally placed nucleus. The cells are branched and seemingly fused one with another, and the heart appears to be composed of one large interconnecting mass of muscle cells. Actually, cardiac muscle cells are separate and individual, but they are bound end to end at **intercalated disks,** areas where folded plasma membranes between two cells contain adhesion junctions and gap junctions (see page 70).

Check Your Progress 4.3

1. How does the structure and function of skeletal, smooth, and cardiac muscle differ?
2. Where do you find these muscles in the body?

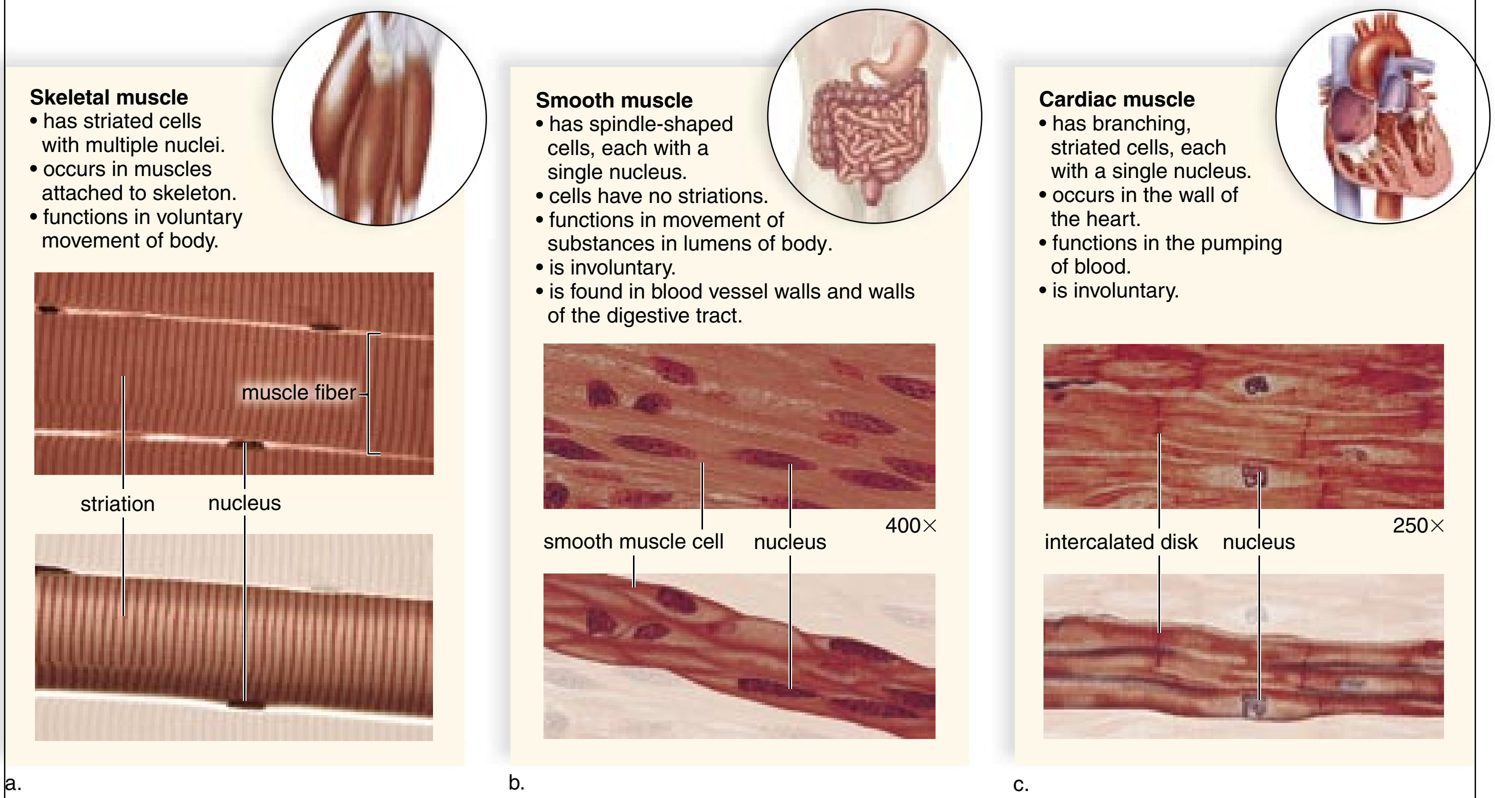


Figure 4.5 **Muscular tissue.**
a. Skeletal muscle is voluntary and striated. **b.** Smooth muscle is involuntary and nonstriated. **c.** Cardiac muscle is involuntary and striated. Cardiac muscle cells branch and fit together at intercalated disks.

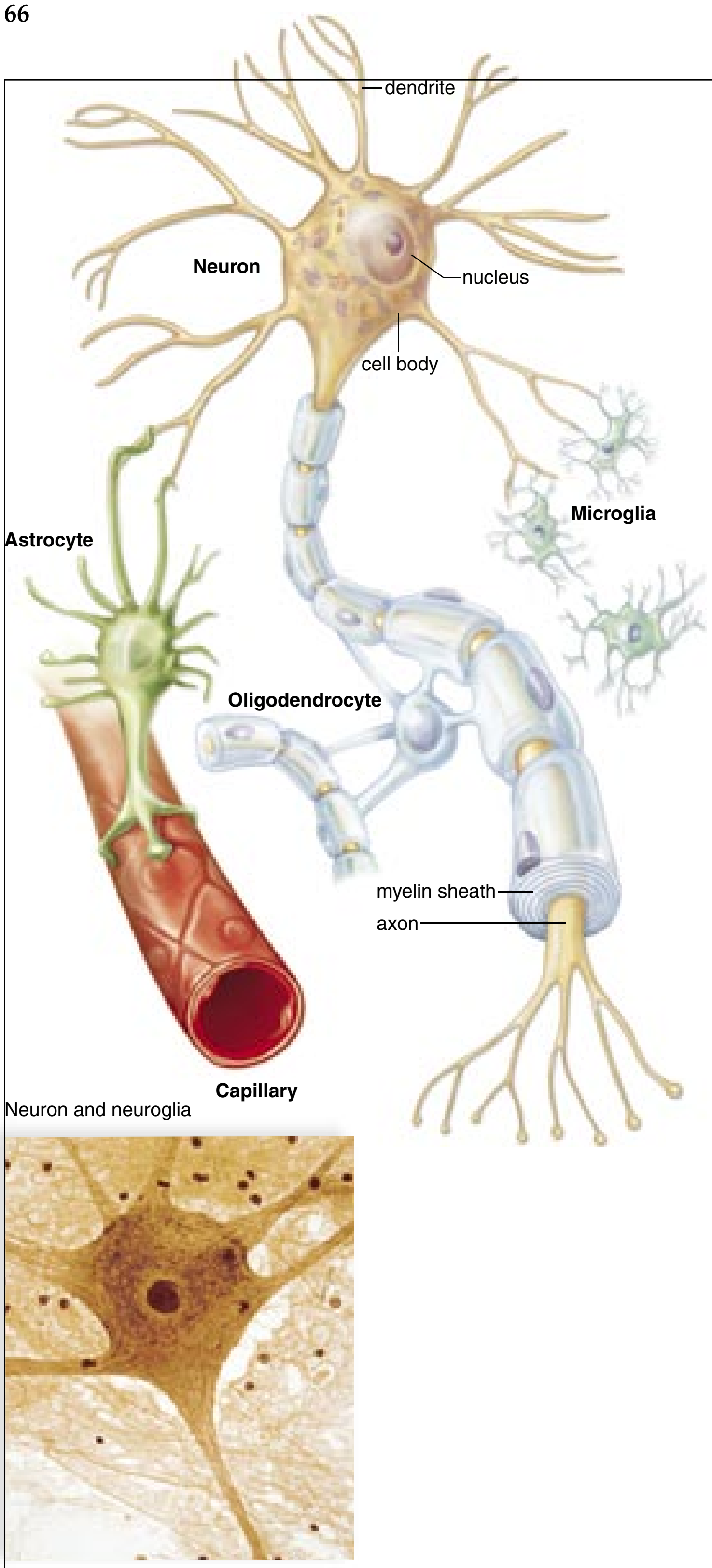


Figure 4.6 **Neurons and neuroglia in the brain.** Neurons conduct nerve impulses. Neuroglia consists of cells that support and service neurons and have various functions: Microglia are a type of neuroglia that become mobile in response to inflammation and phagocytize debris. Astrocytes lie between neurons and a capillary; therefore, substances entering neurons from the blood must first pass through astrocytes. Oligodendrocytes form the myelin sheaths around fibers in the brain and spinal cord.

4.4 Nervous Tissue Communicates

Nervous tissue consists of nerve cells, called neurons, and neuroglia, the cells that support and nourish the neurons.

Neurons

A **neuron** is a specialized cell that has three parts: dendrites, a cell body, and an axon (Fig. 4.6, *top*). A dendrite is an extension that receives signals from sensory receptors or other neurons. The cell body contains most of the cell's cytoplasm and the nucleus. An axon is an extension that conducts nerve impulses. Long axons are covered by myelin, a white fatty substance. The term *fiber*[1] is used here to refer to an axon along with its myelin sheath, if it has one. Outside the brain and spinal cord, fibers bound by connective tissue form **nerves.** X-ref

The nervous system has just three functions: sensory input, integration of data, and motor output. Nerves conduct impulses from sensory receptors to the spinal cord and the brain, where integration occurs. The phenomenon called sensation occurs only in the brain, however. Nerves also conduct nerve impulses away from the spinal cord and brain to the muscles and glands, causing them to contract and secrete, respectively. In this way, a coordinated response to the stimulus is achieved.

Neuroglia

In addition to neurons, nervous tissue contains neuroglia. **Neuroglia** are cells that outnumber neurons nine to one and take up more than half the volume of the brain. Although the primary function of neuroglia is to support and nourish neurons, research is currently being conducted to determine how much they directly contribute to brain function. Types of neuroglia found in the brain are, for example, microglia, astrocytes, and oligodendrocytes (Fig. 4.6, *bottom*). Microglia, in addition to supporting neurons, engulf bacterial and cellular debris. Astrocytes provide nutrients to neurons and produce a hormone known as glia-derived growth factor, which someday might be used as a cure for Parkinson disease and other diseases caused by neuron degeneration. Oligodendrocytes form the myelin sheaths around fibers in the brain and spinal cord. Outside the brain, Schwann cells are the type of neuroglia that encircle long nerve fibers and form a myelin sheath. Neuroglia do not have a long extension, but even so, researchers are now beginning to gather evidence that they do communicate among themselves and with neurons.

Check Your Progress 4.4

1. a. What are the three parts of a neuron, and b. what does each part do?
2. What are some specific functions of neuroglia?

[1] In connective tissue, a fiber is a component of the matrix; in muscle tissue, a fiber is a muscle cell; in nervous tissue, a fiber is an axon.

Science Focus

Nerve Regeneration

In humans, axons outside the brain and spinal cord can regenerate, but not those inside these organs (Fig. 4A). After injury, axons in the human central nervous system (CNS) degenerate, resulting in permanent loss of nervous function. Not so in cold-water fishes and amphibians, where axon regeneration in the CNS does occur. So far, investigators have identified several proteins that seem to be necessary to axon regeneration in the CNS of these animals, but even so, it may be a long time before biochemistry can offer a way to bring about axon regeneration in the human CNS. Still, it's possible that these proteins might one day be used as drugs or that following gene therapy humans might produce these same proteins when CNS injuries occur.

In the meantime, some accident victims are trying other ways to bring about a cure. In 1995, Christopher Reeve, best known for his acting role as "Superman," was thrown headfirst from his horse, crushing the spinal cord just below the neck's top two vertebrae. Immediately, his brain lost almost all communication with the portion of his body below the site of damage, and he could not move his arms and legs. Many years later, Reeve could move his left index finger slightly and could take tiny steps while being held upright in a pool. He had sensation throughout his body and could feel his wife's touch.

Reeve's improvement was not the result of cutting-edge drugs or gene therapy—it was due to exercise (Fig. 4B)! Reeve exercised as much as five hours a day, especially using a recumbent bike outfitted with electrodes that made his leg muscles contract and relax. The bike cost him $16,000. It could cost less if commonly used by spinal cord injury patients in their own homes. Reeve, who was an activist for the disabled, was pleased that insurance would pay for the bike about 50% of the time.

It's possible that Reeve's advances were the result of improved strength and bone density, which lead to stronger nerve signals. Normally, nerve cells are constantly signaling one another, but after a spinal cord injury, the signals cease. Perhaps Reeve's intensive exercise brought back some of the normal communication between nerves. Reeve's physician, John McDonald, a neurologist at Washington University in St. Louis, is convinced that his axons were regenerating. Fred Gage, a neuroscientist at the Salk Institute in La Jolla, California, has shown that exercise does enhance the growth of new cells in adult brains.

For himself, Reeve was convinced that stem cell therapy would one day allow him to be off his ventilator and functioning normally; however, Reeve died in 2004. The Bioethical Focus on page 57 discusses the promise of stem cell research.

a.

b.

Figure 4B Treatment today for spinal cord injuries. **a.** Reeve suffered a spinal cord injury when horseback riding in 1995. **b.** He exercised many hours a day, including aqua therapy. Reeve died in 2004.

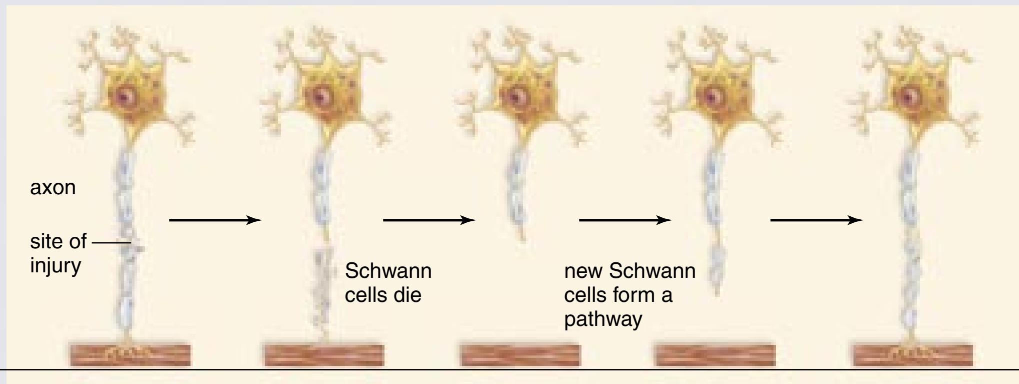


Figure 4A Nerve regeneration. Outside the CNS, nerves regenerate because new neuroglia called Schwann cells form a pathway for axons to reach a muscle. In the CNS, comparable neuroglia called oligodencrocytes do not do this.

4.5 Epithelial Tissue Protects

Epithelial tissue, also called epithelium (pl., epithelia), consists of tightly packed cells that form a continuous layer.-Epithelial tissue covers surfaces and lines body cavities. Usually, it has a protective function, but it can also be modified to carry out secretion, absorption, excretion, and filtration.

Epithelial cells are exposed to the environment on one side, and on the other side, they are bounded by a **basement membrane.** The basement membrane should not be confused with the plasma membrane or the body membranes we will be discussing. It is simply a thin layer of various types of carbohydrates and proteins that anchors the epithelium to underlying connective tissue.

Simple Epithelia

Epithelial tissue is either simple or stratified. Simple epithelia have only a single layer of cells (Fig. 4.7) and are classified according to cell type. **Squamous epithelium,** which is composed of flattened cells, is found lining the air sacs of lungs and walls of blood vessels. Its shape and arrangement permit exchanges of substances in these locations. Oxygen and carbon dioxide exchange occurs in the lungs, and nutrient-for-waste exchange occurs across blood vessels in the tissues.

Cuboidal epithelium consists of a single layer of cube-shaped cells. This type of epithelium is frequently found in glands, such as salivary the glands, the thyroid gland, and the pancreas. Simple cuboidal epithelium also covers the ovaries and lines kidney tubules, the portion of the kidney in which urine is formed. When cuboidal cells are involved in absorption, they have microvilli (minute cellular extensions of the plasma membrane), which increase the surface area of the cells. And when cuboidal cells function in active transport, they contain many mitochondria.

Columnar epithelium has cells resembling rectangular pillars or columns, with nuclei usually located near the bottom of each cell. This epithelium is found lining the digestive tract, where microvilli expand the surface area and aid in absorbing the products of digestion. Ciliated columnar epithelium is found lining the oviducts, where it propels the egg toward the uterus, or womb.

Pseudostratified Columnar Epithelium

Pseudostratified columnar epithelium is so named because it appears to be layered (*pseudo,* false; *stratified,* layers). However, true layers do not exist because each cell touches the basement membrane. In particular, the irregular placement of the nuclei creates the appearance of several layers, where only one exists. The lining of the windpipe, or trachea, is pseudostratified ciliated columnar epithelium. A secreted covering of mucus traps foreign particles, and the upward motion of the cilia carries the mucus to the back of the throat, where it may either be swallowed or expectorated. Smoking can cause a change in mucous secretion and inhibit ciliary action, resulting in a chronic inflammatory condition called bronchitis.

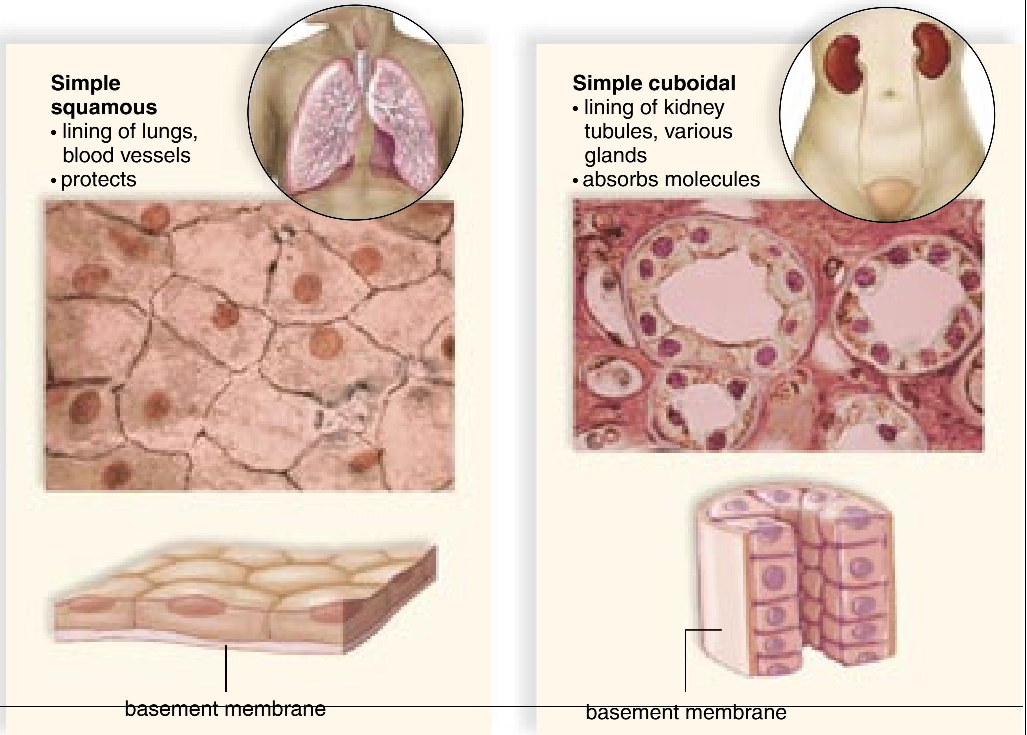


Figure 4.7 **Types of epithelia.** Basic epithelial tissues found in humans are shown, along with locations of the tissue and the primary function of the tissue at these locations.

Transitional Epithelium

The term transitional epithelium implies changeability and this tissue changes in response to tension. It forms the lining of the urinary bladder, the ureters (tubes that carry urine from the kidneys to the bladder), and part of the urethra (the single tube that carries urine to the outside). All are organs that may need to stretch. When the bladder is distended, this epithelium stretches, and the outer cells take on a squamous appearance.

Transitional epithelium is enough like columnar epithelium, and vice versa, that surgeons were able to reconstruct a bladder for Barbara, from the opening story, from a piece of intestine sewn to the urethra. This allowed Barbara to urinate normally.

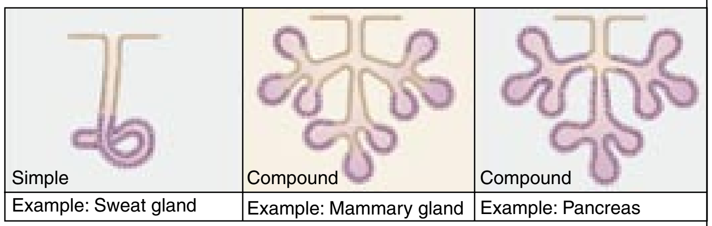
Stratified Epithelia

Stratified epithelia have layers of cells piled one on top of the-other. Only the bottom layer touches the basement membrane. The nose, mouth, esophagus, anal canal, the outer portion of the cervix (adjacent to the vagina), and vagina are all lined with stratified squamous epithelium. Cancer of the cervix is detectable by doing a *pap smear*. Cells lining the cervix are smeared onto a slide that is latter examined to detect any abnormalities.

As-we shall see, the outer layer of skin is also stratified squamous epithelium, but the cells have been reinforced by-keratin, a protein that provides strength. Stratified cuboidal and stratified columnar epithelia also are found in the body.

Glandular Epithelia

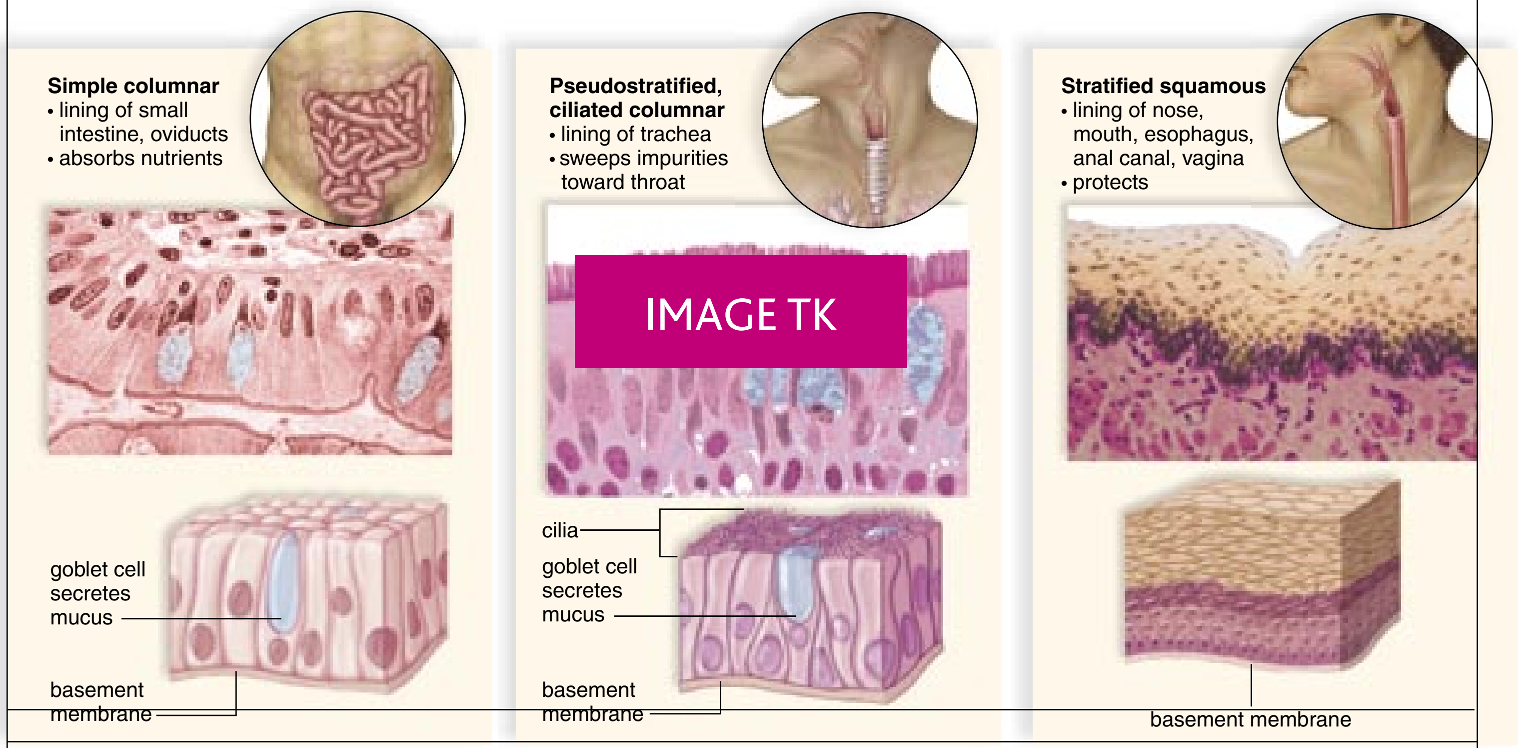
When an epithelium secretes a product, it is said to be glandular. A **gland** can be a single epithelial cell, as in the case of mucus-secreting goblet cells, or a gland can contain many cells. Glands with ducts that secrete their product onto the outer surface (e.g., sweat glands and mammary glands) or into a cavity (e.g., pancreas) are called **exocrine glands.** Ducts can be simple or compound:



Glands that have no duct are appropriately known as the ductless glands, or endocrine glands. **Endocrine glands** (e.g., pituitary gland and thyroid) secrete hormones internally, so they are transported by the bloodstream.

Check Your Progress 4.5

1. Distinguish between the three types of simple epithelium and give a location for each.
2. a. How would you recognized pseudostratified epithelium, and b. what function does this tissue perform in the trachea?
3. a. What is stratified epithelium, and b. where would it be found?



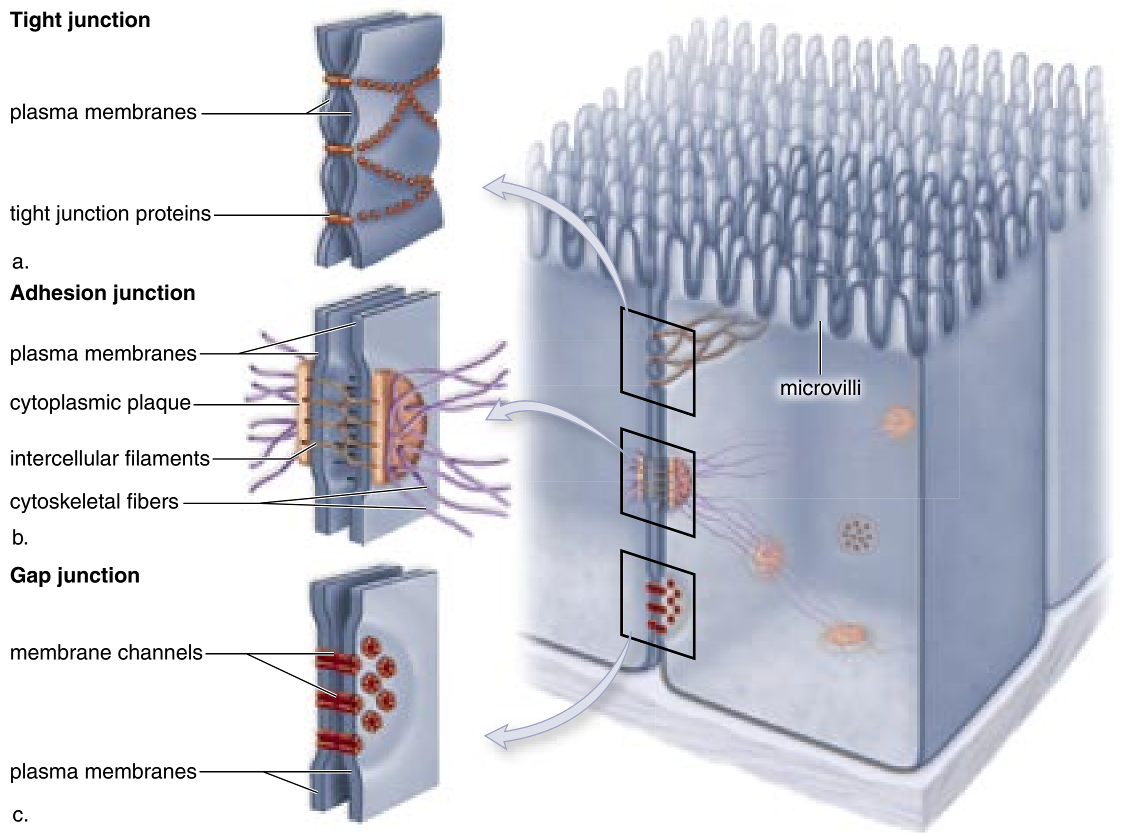


Figure 4.8 **Cell junction types.**
Not all epithelial cells are joined by all three types of junctions illustrated. **a.** Tight junctions allow epithelial cells to form a layer that prevents leakage from one side of the sheet to the other. **b.** Adhesion junctions keep cells anchored to one another, but the layer of cells can still bend and stretch. **c.** Gap junctions allow the passage of small molecules and ions from one cell to the other.

4.6 Cell Junctions

The epithelial cells, and sometimes the muscle and nerve cells, of a tissue are connected by cell junctions, and these junctions help a tissue perform its particular function. Just as cement holds bricks together, so do cell junctions join cells together into a cohesive hold. Cell junctions arise when plasma membranes are joined in these particular ways:

- **Tight junctions** allow epithelial cells to form a layer that covers the surface of organs and lines body cavities. The layer of cells becomes an impermeable barrier because adjacent plasma membrane proteins actually join, producing a zipperlike fastening X-ref (Fig. 4.8*a*). In the stomach and intestines, digestive secretions do not leak between the cells into the body, and in the kidneys, the urine stays within kidney tubules because epithelial cells are joined by tight junctions.
- **Adhesion junctions** firmly attach cytoskeletal fibers of one cell to that of another cell. In the desmosome featured in Figure 4. 8*b*, the cytoskeletal fibers are anchored to a cytoplasmic plaque adjacent to the plasma membrane. Adhesion junctions are common in tissues subject to mechanical stress. They allow the skin, for example, to stretch and bend in response to mechanical stress.
- **Gap junctions** occur when adjacent plasma membranes converge and leave a tiny channel between them. Small molecules and ions can diffuse through a gap junction from the cytoplasm of one cell to another. During development, signaling molecules pass between embryonic cells at gap junctions and influence the differentiation of cells. Gap junctions between cardiac muscle cells at intercalated disks allow the heart to beat as a coordinated whole.

Check Your Progress 4.6

1. **a.** What are the three types of junctions between cells, and **b.** how do they differ in structure and function?
2. Why would you expect cell junctions more often in epithelia than in other types of tissues?
3. **a.** Which type of cell junction would you expect to find between muscle cells in the heart wall? **b.** Why?

4.7 Integumentary System

Specific tissues are associated with particular organs. For example, nervous tissue is associated with the brain. But actually, an **organ** is composed of two or more types of tissues working together to perform particular functions. The skin is comprised of all four tissue types: epithelial, connective, muscle, and nervous tissue. An **organ system** contains many different organs that cooperate to carry out a process, such as the digestion of food. The skin has several accessory organs (hair, nails, sweat glands, and sebaceous glands), and, therefore, it is sometimes referred to as the **integumentary system.**

Skin is the most conspicuous system in the body because it covers the body. In an adult, the skin has a surface area of about 1.8 square meters (20.83 square feet) and accounts for nearly 15% of the weight of an average human. The skin has numerous functions. It protects underlying tissues from physical trauma, pathogen invasion, and water loss; it also helps regulate body temperature. Therefore, skin plays a significant role in homeostasis. The skin even synthesizes certain chemicals that affect the rest of the body. Because skin contains sensory receptors, skin also helps us to be aware of our surroundings and to communicate with others through touch.

Regions of the Skin

The skin has two regions: the epidermis and the dermis (Fig. 4.9). A **subcutaneous layer** is found between the skin and any underlying structures, such as muscle or bone.

The Epidermis

The **epidermis** is made up of stratified squamous epithelium. New epidermal cells for the renewal of skin are derived from stem (basal) cells. The importance of these stem cells is observed when an injury to the skin is deep enough to destroy stem cells. As soon as possible, the damaged tissue

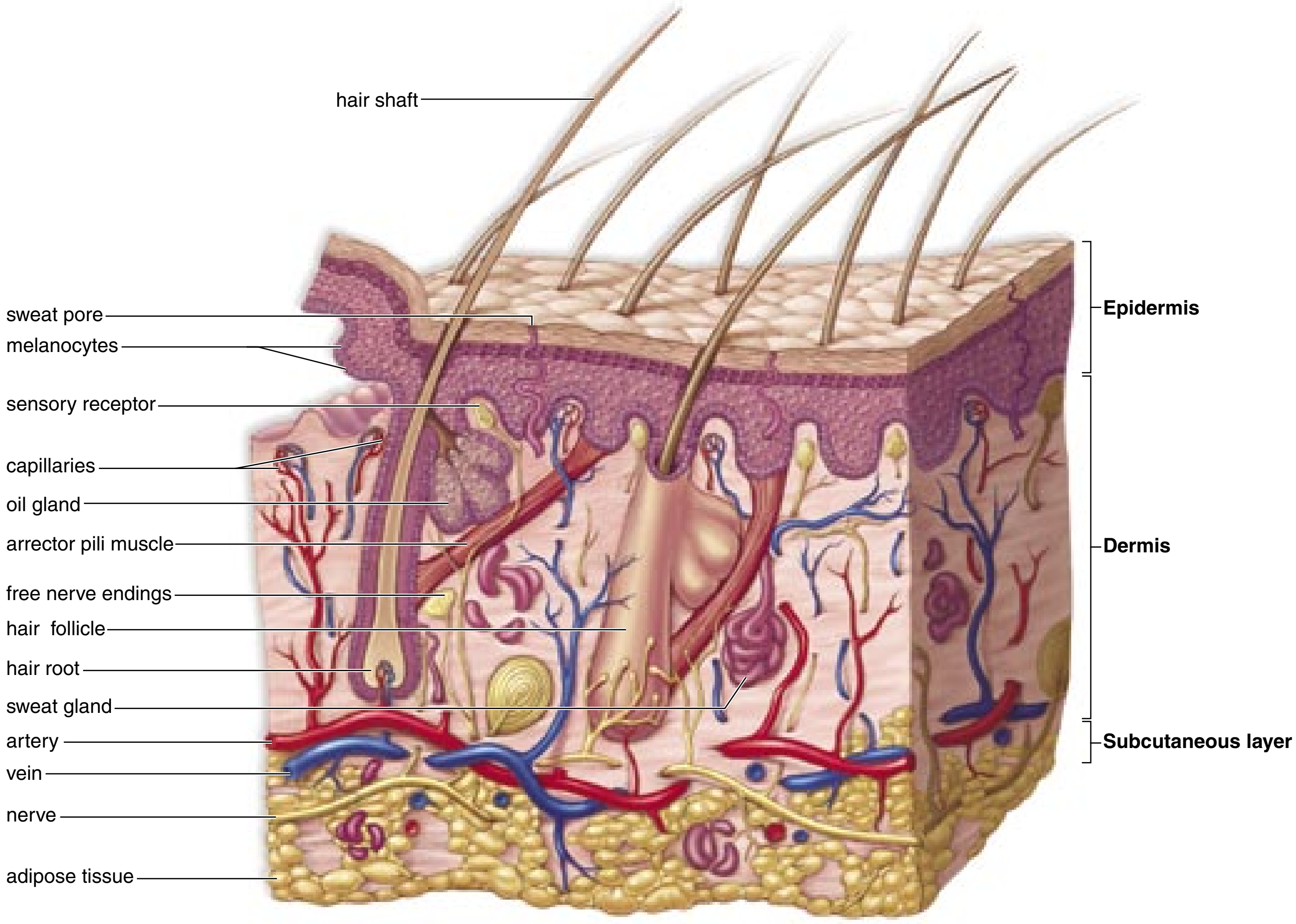
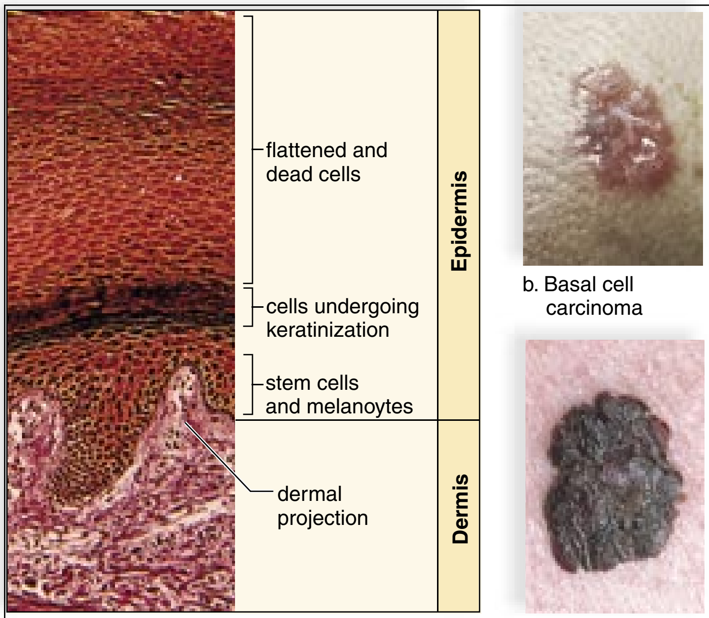


Figure 4.9 Human skin anatomy.
Skin consists of two regions: the epidermis and the dermis. A subcutaneous layer lies below the dermis. Skin has numerous functions. For example, it forms a protective covering over the entire body, safeguarding underlying parts from trauma, pathogen invasion, and water loss. The skin contains sensory receptors that communicate with the central nervous system and make us aware of external conditions. The skin also produces vitamin D, which has important metabolic functions, and the skin helps regulate body temperature.



a. Photomicrograph of skin

b. Basal cell carcinoma

c. Melanoma

Figure 4.10 The epidermis.
a. Epidermal ridges following dermal projections are clearly visible. Stem cells and melanocytes are in this region. **b.** Basal cell carcinoma derived from stem cells and **c.** melanoma derived from melanocytes are types of skin cancer.

is removed, and skin grafting is begun. The skin needed for grafting is usually taken from other parts of the patient's body. This is called autografting, as opposed to heterografting, in which the graft is received from another person. Autografting is preferred because rejection rates are very low. If the damaged area is quite extensive, it may be difficult to acquire enough skin for autografting. In that case, small amounts of epidermis are removed and cultured in the laboratory to produce thin sheets of skin that can be transplanted back to the patient.

X-ref Newly generated skin cells become flattened and hardened as they push to the surface (Fig. 4.10*a*). Hardening takes place because the cells produce keratin, a waterproof protein. Dandruff occurs when the rate of keratinization in the skin of the scalp is two or three times the normal rate. A thick layer of dead keratinized cells, arranged in spiral and concentric patterns, forms fingerprints and footprints that are genetically unique. Since outer skin cells are dead and keratinized, the skin is waterproof, thereby preventing water loss. The skin's waterproofing also prevents water from entering the body when the skin is immersed.

Two types of specialized cells are located deep in the epidermis. **Langerhans cells** are macrophages, a type of white blood cell that phagocytize pathogens and then travel to lymphatic organs, where they stimulate the immune system to react to the pathogen. **Melanocytes,** lying deep in the epidermis, produce melanin, the main pigment responsible for skin color. Since the number of melanocytes is about the same in all individuals, variation in skin color is due to the amount of melanin produced and its distribution. When skin is exposed to the sun, melanocytes produce more melanin to protect the skin from the damaging effects of the ultraviolet (UV) radiation in sunlight. The melanin is passed to other epidermal cells, and the result is tanning, or in some people, the formation of patches of melanin called freckles. Another pigment, called carotene, is present in epidermal cells and in the dermis and gives the skin of certain Asians its yellowish hue. The pinkish color of fair-skinned people is due to the pigment hemoglobin in the red blood cells in the blood vessels of the dermis. Some ultraviolet radiation does serve a purpose, however.

Certain cells in the epidermis convert a steroid related to cholesterol into **vitamin D** with the aid of ultraviolet radiation. Only a small amount of UV radiation is needed. Vitamin D leaves the skin and helps regulate both calcium and phosphorus metabolism in the body. Calcium and phosphorus are very important to the proper development and mineralization of the bones.

Skin Cancer While we tend to associate a tan with health, actually it signifies that the body is trying to protect itself from the dangerous rays of the sun. Too much ultraviolet radiation is dangerous and can lead to skin cancer. Basal cell carcinoma (Fig. 4.10*b*), derived from stem cells gone awry, is the more common type of skin cancer and the most curable. Melanoma (Fig. 4.10*c*), the type of skin cancer derived from melanocytes, is extremely serious. To prevent skin cancer, you should stay out of the sun altogether between the hours of 10 A.M. and 3 P.M. When you are in the sun

- use a broad-spectrum sunscreen that protects from both UV-A and UV-B radiation and has a sun protection factor (SPF) of at least 15. (This means that if you usually burn, for example, after a 20-minute exposure, it will take 15 times longer, or 5 hours, before you will burn.)
- wear protective clothing. Choose fabrics with a tight weave and wear a wide-brimmed hat.
- wear sunglasses that have been treated to absorb both UV-A and UV-B radiation.
- avoid tanning machines because, even if they use only high levels of UV-A radiation, the deep layers of the skin will become more vulnerable to UV-B radiation.

The Dermis

The **dermis** is a region of dense fibrous connective tissue beneath the epidermis. (Dermatology is a branch of medicine that specializes in diagnosing and treating skin disorders.) The dermis contains collagen and elastic fibers. The collagen fibers are flexible but offer great resistance to overstretching; they prevent the skin from being torn. The elastic

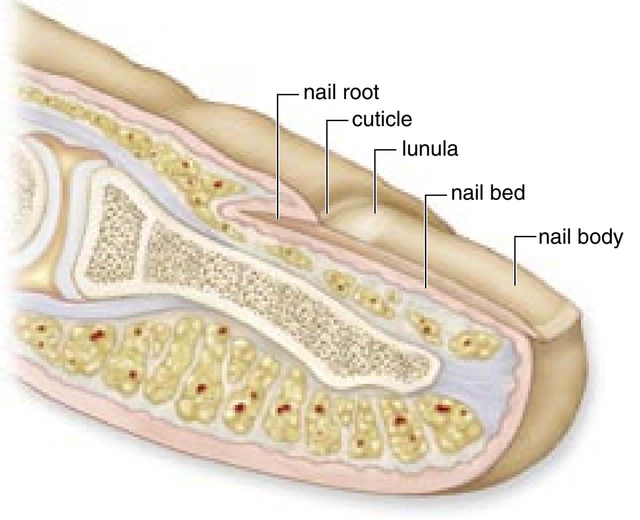


Figure 4.11 **Nail anatomy.**
Cells produced by the nail root become keratinized, forming the nail body.

fibers maintain normal skin tension but also stretch to allow movement of underlying muscles and joints. (The number of collagen and elastic fibers decreases with age and with exposure to the sun, causing the skin to become less supple and more prone to wrinkling.) The dermis also contains blood vessels that nourish the skin. When blood rushes into these vessels, a person blushes, and when blood is minimal in them, a person turns "blue." Blood vessels in the dermis play a role in temperature regulation. If body temperature starts to rise, the blood vessels in the skin will dilate. As a result, more blood is brought to the surface of the skin for cooling. If the outer temperature cools, the blood vessels constrict, so less blood is brought to the skin's surface.

The sensory receptors primarily in the dermis are specialized for touch, pressure, pain, hot, and cold. These receptors supply the central nervous system with information about the external environment. The sensory receptors also account for the use of the skin as a means of communication between people. For example, the touch receptors play a major role in sexual arousal.

The Subcutaneous Layer

Technically speaking, the subcutaneous layer beneath the dermis is not a part of skin. A common site for injections, this layer is composed of loose connective tissue and adipose tissue, which stores fat. Fat is a stored source of energy in the body. Adipose tissue helps to thermally insulate the body from either gaining from-the outside or losing heat from the inside. A well-developed subcutaneous layer gives the body a rounded appearance and provides protective padding against external assaults. Excessive development of the subcutaneous layer accompanies obesity.

Accessory Organs of the Skin

Nails, hair, and glands are structures of epidermal origin, even though some parts of hair and glands are largely found in the dermis.

Nails are a protective covering of the distal part of fingers and toes, collectively called digits (Fig. 4.11). Nails grow from special epithelial cells at the base of the nail in the portion called the nail root. The cuticle is a fold of skin that hides the-nail root. The whitish color of the half-moon-shaped base, or *lunula,* results from the thick layer of cells in this area. The cells of a nail become keratinized as they grow out-over the nail bed. X-ref

Hair follicles begin at a bulb in the dermis and continue through-the epidermis where the hair shaft extends beyond the skin. A dark hair color is largely due the production of true melanin by melanocytes present in the bulb. If the melanin contains iron and sulfur, hair is blond or red. Graying occurs when melanin cannot be produced, but white hair is due to bubbles in the hair shaft.

Contraction of the arrector pili muscles attached to-hair follicles causes the hairs to "stand on end" and goose-bumps to develop. Epidermal cells form the root of a hair, and their division causes a hair to grow. The cells become keratinized and die as they are pushed farther from the root.

Each hair follicle has one or more **oil glands,** also called-sebaceous glands, which secrete sebum, an oily substance that lubricates the hair within the follicle and-the skin itself. The oil secretions from sebaceous glands are acidic and retard the growth of bacteria. If the sebaceous glands fail to discharge, the secretions collect and form "whiteheads" or "blackheads." The color of blackheads is due to oxidized sebum. **Acne** is an inflammation of the sebaceous glands that most often occurs during adolescence due to hormonal changes.

Sweat glands, also called sudoriferous glands, are quite-numerous and are present in all regions of skin. A sweat gland is a tubule that begins in the dermis and either opens into a hair follicle, or more often opens onto the surface of the skin. Sweat glands play a role in modifying body-temperature. When body temperature starts to rise, sweat glands become active. Sweat absorbs body heat as it evaporates. Once body temperature lowers, sweat glands are no longer active.

Check Your Progress 4.7

1. Compare the structure and function of the epidermis and dermis.
2. a. What factors are involved in skin color, and b. how can you protect skin from the ultraviolet rays of the sun?
3. a. Contrast the location and function of sweat glands and oil glands. b. How do oil glands protect us from bacteria?
4. a. Explain why the subcutaneous layer is not considered a part of the skin. b. What is its function?

4.8 Organ Systems

This text has several illustrations, such as the one on page 79, that show how the various systems cooperate to maintain homeostasis, the relative constancy of the internal environment. In one sense, it is arbitrary to assign a particular organ to one system when it also assists the functioning of many other systems. The functions of the various systems of the body are listed in Figure 4.12.

Integumentary System

The integumentary system contains skin and also includes nails; hairs; muscles that move hairs; the oil and sweat glands; blood vessels; and nerves leading to sensory receptors. As discussed in Section 4.7, this system has many homeostatic functions.

Cardiovascular System

In the **cardiovascular system,** the heart pumps blood and sends it out under pressure into the blood vessels. In humans, the blood is always contained in blood vessels, never running free unless the body suffers an injury.

While blood is moving throughout the body, it distributes heat produced by the muscles. Blood transports nutrients and oxygen to the cells and removes their waste molecules, including carbon dioxide. Despite the movement of molecules into and out of the blood, it has a fairly constant volume and pH, particularly due to exchanges in the lungs, the digestive tract, and the kidneys. The red blood cells in blood transport oxygen, while the white blood-cells fight infections. Platelets are involved in blood clotting.

Lymphatic and Immune Systems

The **lymphatic system** consists of lymphatic vessels, lymph nodes, the spleen, and other lymphatic organs. This system collects excess tissue fluid and plays a role in absorbing lipoproteins (fats combined with proteins) and transporting lymph to cardiovascular veins. It also purifies lymph and stores lymphocytes, the white blood cells that produce antibodies.

The **immune system** consists of all the cells in the body that protect us from disease. The lymphocytes, in particular, belong to this system.

Digestive System

The **digestive system** consists of the mouth, esophagus, stomach, small intestine, and large intestine (colon), along with these associated organs: teeth, tongue, salivary glands, liver, gallbladder, and pancreas. This system receives food and digests it into nutrient molecules, which can enter the cells of the body. The nondigested remains are eventually eliminated.

Respiratory System

The **respiratory system** consists of the lungs and the tubes that take air to and from them. The respiratory system brings oxygen into the body and removes carbon dioxide from the

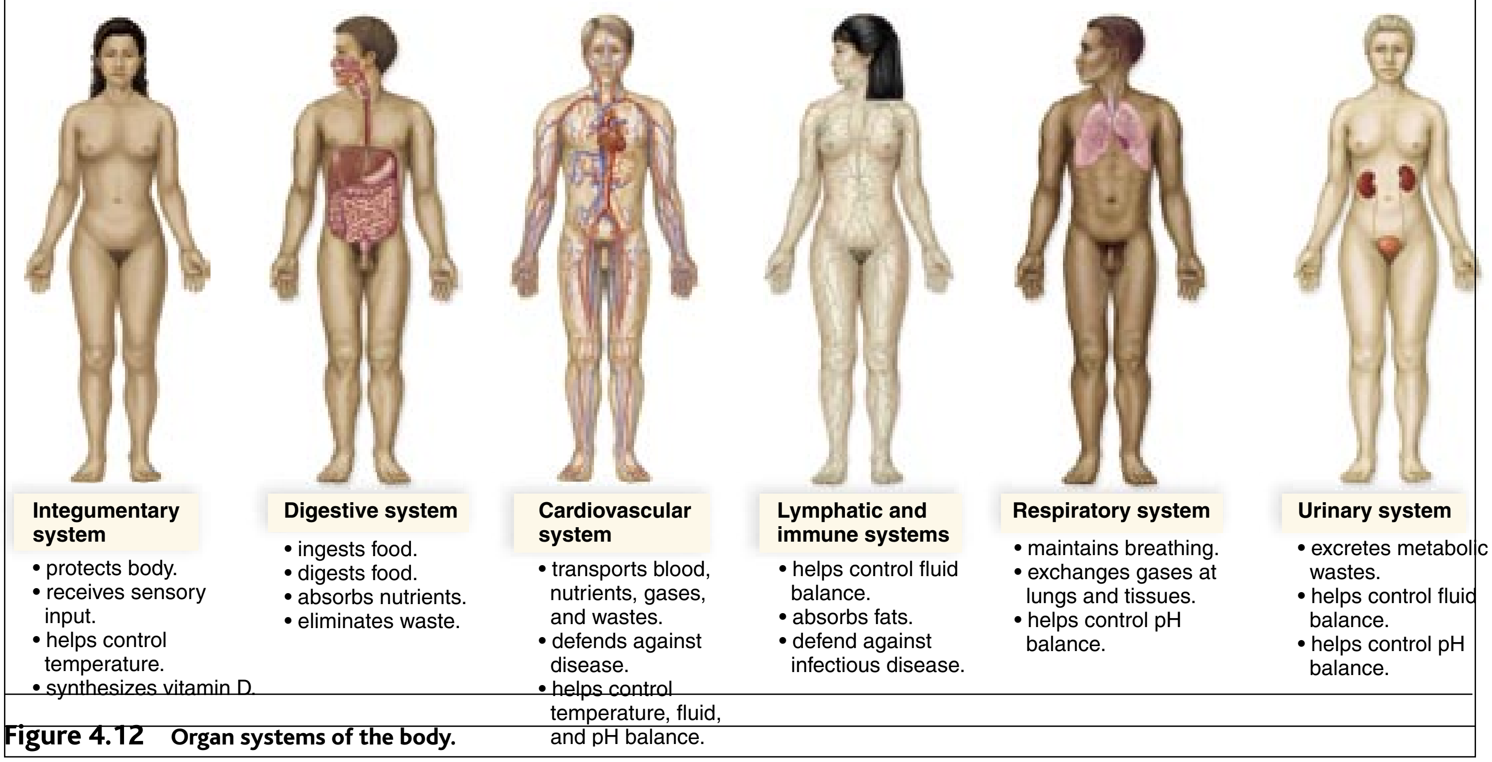


Figure 4.12 **Organ systems of the body.**

body at the lungs. The removal of carbon dioxide helps adjust the acid-base balance of the blood.

Urinary System

The **urinary system** contains the kidneys, the urinary bladder, and the tubes that carry urine. The kidneys rid the body of metabolic wastes, particularly nitrogenous wastes, and help regulate the salt-water balance and acid-base balance of the blood. Fortunately for Barbara, the job of the bladder is to store urine, and a substitute bladder, made from a piece of the intestine, will not affect the kidney's ability to carry out its homeostatic functions.

Skeletal System

The bones of the **skeletal system** protect body parts. For example, the skull forms a protective encasement for the brain, as does the rib cage for the heart and lungs. The skeleton helps move the body because it serves as a place of attachment for the skeletal muscles.

The skeletal system also stores minerals, notably calcium, and it produces blood cells within red bone marrow.

Muscular System

In the **muscular system,** skeletal muscle contraction maintains posture and accounts for the movement of the body and its parts. Cardiac muscle contraction results in the heartbeat. The walls of internal organs, such as the bladder, contract due to the presence of smooth muscle. Muscle contraction releases heat, which helps warm the body.

Nervous System

The **nervous system** consists of the brain, spinal cord, and associated nerves. The nerves conduct nerve impulses from sensory receptors to the brain and spinal cord, where integration occurs. Nerves also conduct nerve impulses from the brain and spinal cord to the muscles and glands, allowing us to respond to both external and internal stimuli.

Endocrine System

The **endocrine system** consists of the hormonal glands, which secrete chemical messengers, called hormones, into the bloodstream. Hormones have a wide range of effects, including regulation of cellular metabolism, regulation of fluid and pH balance, and helping us respond to stress. Both the nervous and endocrine systems coordinate and regulate the functioning of the body's other systems. The endocrine system also helps maintain the functioning of the male and female reproductive organs.

Reproductive System

The **reproductive system** has different organs in the male and female. The male reproductive system consists of the testes, other glands, and various ducts that conduct semen to and through the penis. The testes produce sex cells called sperm. The female reproductive system consists of the ovaries, oviducts, uterus, vagina, and external genitals. The ovaries produce sex cells called eggs. When a sperm fertilizes an egg, an offspring begins development.

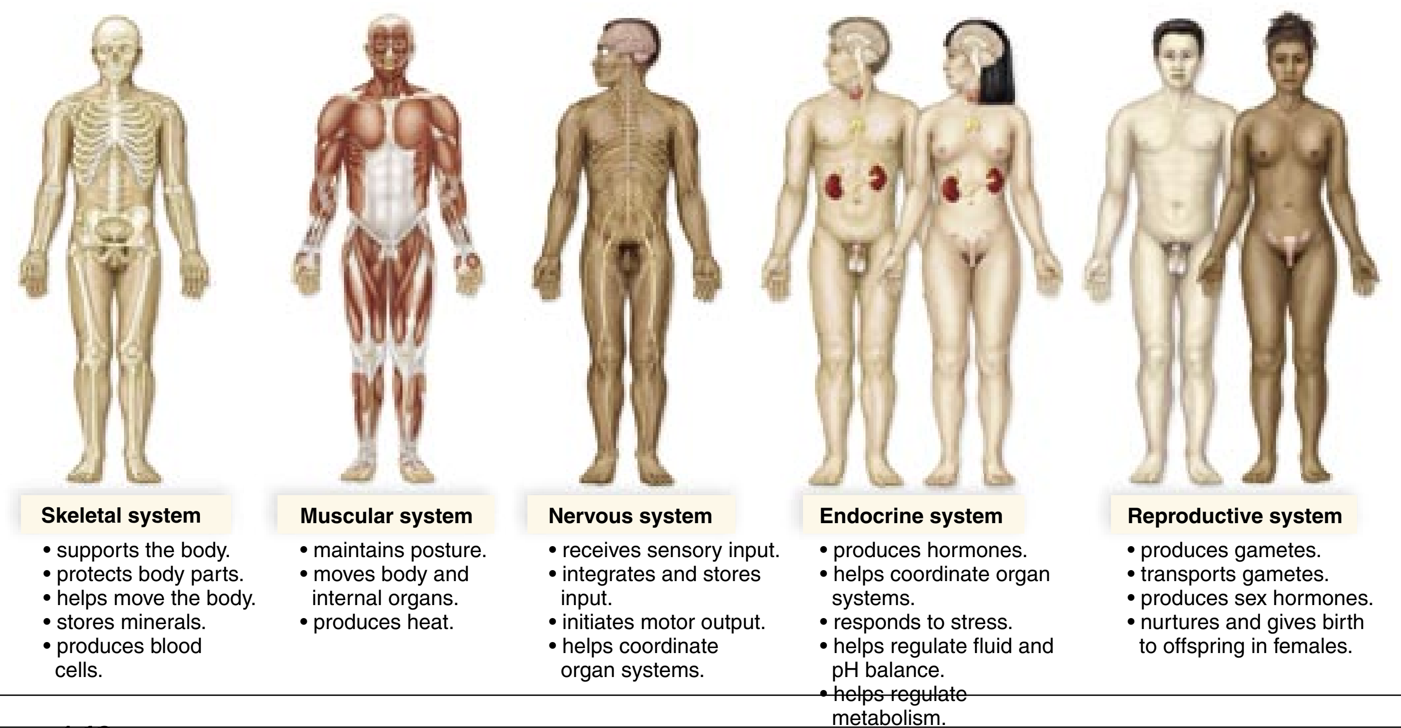


Figure 4.12 **Organ systems of the body—continued**

Health Focus

To Have or Not Have Botox

More and more studies indicate that a youthful, virile appearance is important for success in all aspects of life, especially in the workplace. In a never-ending quest to stop or even turn back the hands of time, millions of people have turned to Botox.

Botox Is a Drug

Botox is a drug used to reduce the appearance of facial wrinkles and lines. Botox is the trade name for a derivative of botulinum toxin A, a protein toxin produced by the bacterium *Clostridium botulinum.* This bacterium was once only associated with the scourge of botulism, a type of food poisoning, which is no longer a serious problem with modern food-processing techniques.

Botox interferes with the ability of the nervous system to properly communicate with the muscles of the body, causing muscle paralysis. Scientists isolated the toxin, and using modern biotechnology, mass produced it and marketed it as the drug Botox. Although originally developed for the treatment of muscular spasms in patients with disorders such as cerebral palsy and muscular dystrophy, the entrepreneurial spirit took hold when it was realized that it could alleviate facial lines and wrinkles. After numerous studies, Botox was approved by the U.S. Food and Drug Administration for use as a cosmetic treatment for facial and neck wrinkles in 2002.

Botox treatments are performed by direct injection of the toxin under the skin with a syringe, where it causes facial muscle paralysis. The injections reduce the appearance of wrinkles and lines that appear as a result of normal facial muscle movement. This muscle movement is normally used to create the vast array of facial expressions that we humans are capable of producing. Botox treatment can also weaken these muscles to provide an additional longer-term cosmetic benefit. The effects are noticeable within days, reach a maximum benefit after one to two weeks, and can last for nearly three to six months in most cases. Since the cosmetic use of Botox has been studied for well over 20 years, dosage and injection techniques are well developed. Botox has also been studied for the treatment of other conditions, including eczema, excessive sweating, and other skin conditions.

The Benefits and Risks of Botox

Botox has become so popular, in fact, that over 2.5 million women and 300,000 men underwent treatment in 2003, and numbers are still increasing, even today. It has become so popular in some areas that “Botox parties” are conducted in doctors’ offices, workplaces, and individual homes, where friends and co-workers are treated in a relaxed group setting under the supervision of a doctor at a discount price. Because of its low price, rapid results, and relatively low risk, many people have turned to Botox as a reasonable alternative to more costly, invasive procedures such as cosmetic surgery.

Despite its benefits when administered by a qualified doctor, Botox treatment is not without side effects. Fortunately, most are mild, such as excessive drooling or a slight rash around the injection site that may reduce the cosmetic benefits of the treatment. Spreading of Botox from the injection site may also paralyze facial muscles unintended for treatment, and in a few cases, muscle pain and weakness have resulted.

While quite rare, more serious side effects may also occur. Because it is capable of stimulating a response from the immune system, there is a risk of severe allergic reactions. Botox treatment is also risky for women who are pregnant, individuals who are taking certain medications, or patients with certain musculoskeletal disorders.

Even though Botox has been approved by the FDA, not all in the medical profession are convinced that it should be available for such widespread use. Since overuse of Botox can lessen the body’s response to it, requiring more frequent injections of larger amounts of the drug, some health-care professionals are concerned about the possibility that some users may become psychologically addicted or may be harmed by excessive doses. Others are concerned that the procedure is sometimes performed outside of a health-care facility, where an unmonitored patient might have a severe reaction or emergency that could be fatal or cause permanent harm. Still others protest the possibility of unqualified personnel administering the treatment. Finally, cases have been documented in which diluted or fake Botox was used, raising the possibility of fraud.

When performed in a medical facility by a licensed physician, Botox treatment is generally considered safe and effective, but it is not without risks. Ultimately, it is up to the individual to weigh the benefits against the risks when considering such treatments. But in many segments of society where appearances are of the utmost importance, many people are willing to take these risks to obtain the more youthful facial appearance that this newfound “fountain of youth” promises.

Body Cavities

The human body is divided into two main categories: the ventral cavity and the dorsal cavity (Fig. 4.13*a*). Called the coelom in early development, the ventral cavity later becomes the thoracic and abdominal cavities. The thoracic cavity contains the right and left lungs and the heart. The thoracic cavity is separated from the abdominal cavity by a horizontal muscle called the **diaphragm.** The stomach, liver, spleen, gallbladder, and most of the small and large intestines are in the upper portion of the abdominal cavity. The lower portion contains the rectum, the urinary bladder, the internal reproductive organs, and the rest of the small and large intestine. Males have an external extension of the abdominal wall, called the scrotum, containing the testes.

The dorsal cavity also has two parts: The cranial cavity, within the skull, contains the brain, while the vertebral canal, formed by the vertebrae, contains the spinal cord.

Body Membranes

Body membranes line cavities and the internal spaces of-organs and tubes that open to the outside. The body membranes are of four types: mucous, serous, synovial, and meninges.

Mucous membranes line the tubes of the digestive, respiratory, urinary, and reproductive systems. They are composed of an epithelium overlying a loose fibrous connective tissue layer. The epithelium contains goblet cells that secrete mucus. This mucus ordinarily protects the body from invasion by bacteria and viruses; hence, more mucus is secreted and expelled when a person has a cold and has to blow her/his nose. In addition, mucus usually protects the walls of the stomach and small intestine from digestive juices, but this protection breaks down when a person develops an ulcer.

Serous membranes line and support the lungs, the heart, and the abdominal cavity and its internal organs (Fig. 4.13*b*). X-ref They secrete a watery fluid that keeps the membranes lubricated. Serous membranes support the internal organs and compartmentalize the large thoracic and abdominal cavities.

Serous membranes have specific names according to their location. The pleurae (sing., **pleura**) line the thoracic cavity and cover the lungs; the pericardium forms the pericardial sac and covers the heart; the peritoneum lines the abdominal cavity and covers its organs. A double layer of peritoneum, called mesentery, supports the abdominal organs and attaches them to the abdominal wall. **Peritonitis** is a life-threatening infection of the peritoneum.

Synovial membranes composed only of loose connective tissue line the cavities of freely movable joints. They secrete synovial fluid into the joint cavity; this fluid lubricates the ends of the bones so that they can move freely. In rheumatoid arthritis, the synovial membrane becomes inflamed and grows thicker, restricting movement.

The **meninges** are membranes found within the dorsal cavity. They are composed only of connective tissue and serve as a protective covering for the brain and spinal cord. **Meningitis** is a life-threatening infection of the meninges.

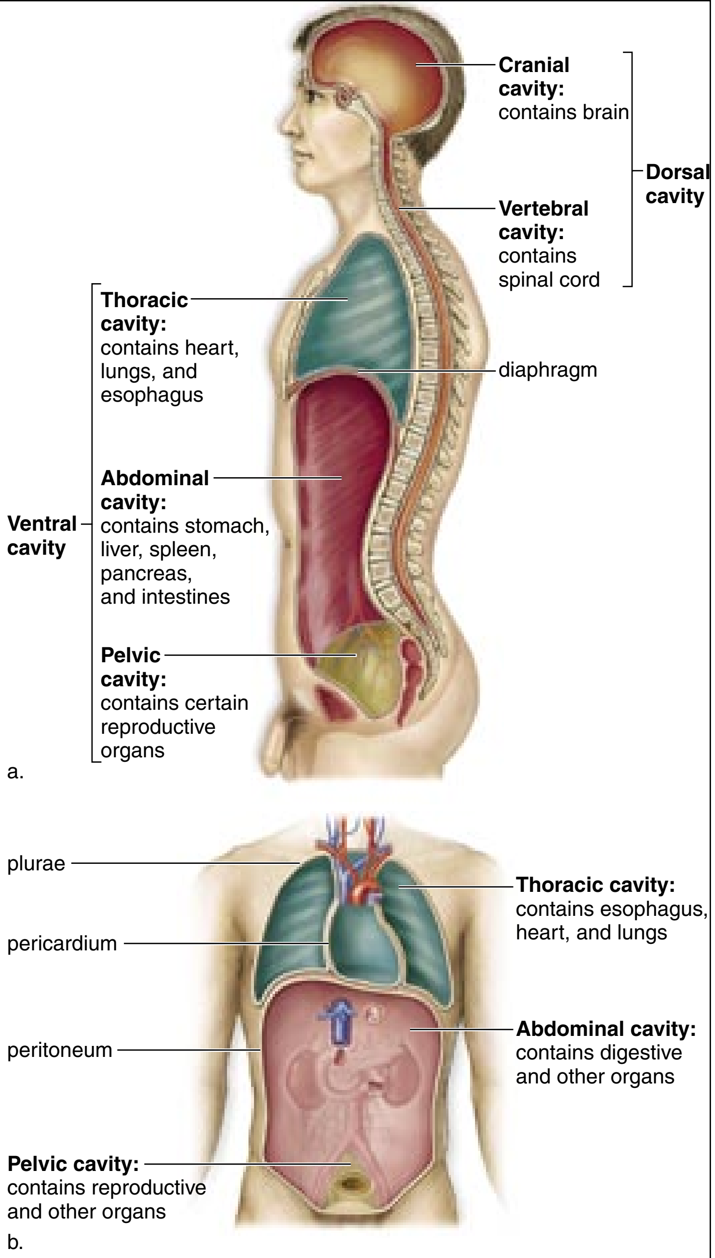


Figure 4.13 **Human body cavities.**
a. Side view. The dorsal (toward the back) cavity contains the cranial cavity and the vertebral canal. The brain is in the cranial cavity, and the spinal cord is in the vertebral canal. The well-developed ventral (toward the front) cavity is divided by the diaphragm into the thoracic cavity and the abdominal cavity. The heart and lungs are in the thoracic cavity, and most other internal organs are in the abdominal cavity. **b.** Frontal view of the thoracic cavity, showing serous membranes.

Check Your Progress 4.8

1. What is the overall function of each of the body systems?
2. **a.** What are the two major body cavities? **b.** What two cavities are in each of these?
3. What are four types of body membranes?

4.9 Homeostasis

Homeostasis is the body's ability to maintain a relative constancy of its internal environment by adjusting its physiological processes. Even though external conditions may change dramatically, we have physiologic mechanisms that respond to disturbances and limit the amount of internal change so that conditions usually stay within a narrow range of normality (Fig. 4.14). For example, blood glucose, pH levels, and body temperature typically fluctuate during the day, but not greatly. If internal conditions should change to any great degree, illness results.

Figure 4.14 Liv Arnesen and Ann Bancroft.
Liv Arnesen and Ann Bancroft needed all their body systems to function properly when they decided to hike to the South Pole. Antarctica is very inhospitable to people. It's the coldest place on Earth, the windiest, and, strange to say, the driest. There are no plants and no animals to eat. It's desolate, dangerous, and nothing but ice. Ice bridges just large enough for a sled stretch across deep crevasses, and if you fall into the water below, you freeze in minutes. You can get frostbitten if your skin is exposed to the subfreezing air. The mechanisms for maintaining homeostasis can be overwhelmed, so it's best to take protective measures to assist the body.

You can be sure that Liv and Ann wore the latest in protective clothing, drank plenty of water, and ate regularly to keep their muscles supplied with glucose. Sleep was necessary to refresh the brain, because while all the body's systems contribute, the brain coordinates their functioning in order to maintain homeostasis, the relative constancy of the internal environment. Swim the English Channel, climb Mt. Washington, cross the Sahara desert by camel, or hike the South Pole, if you are healthy, your body temperature will stay at just about 37°C (98.6°F) because the brain has mechanisms that maintain homeostasis.

The Internal Environment

The internal environment has two parts: blood and tissue fluid. Blood delivers oxygen and nutrients to the tissues and-carries carbon dioxide and wastes away. Tissue fluid, not blood, actually bathes all of the body's cells. Therefore, tissue fluid is the medium through which substances are exchanged between cells and blood. Oxygen and nutrients pass through tissue fluid on their way to tissue cells from the blood, and then carbon dioxide and wastes are carried away from the tissue cells by the tissue fluid, where they are brought back into the blood. The cooperation of body systems is required to keep these substances within the range of normality in blood and tissue fluid.

The Body Systems and Homeostasis

The nervous and endocrine systems are particularly important in coordinating the activities of all the other organ systems as they function to maintain homeostasis (Fig. 4.15). The nervous system is able to bring about rapid responses to any changes in the internal environment. It issues commands by electrochemical signals that are rapidly transmitted to effector organs, which can be muscles, such as skeletal muscles, or glands, such as sweat and salivary glands. The endocrine system brings about responses that are slower to occur but generally have more lasting effects. Glands of the endocrine system, such as the pancreas or the thyroid, release hormones. Hormones, such as insulin from the pancreas, are chemical messengers that must travel through the blood and tissue fluid in order to reach their targets.

The nervous and endocrine systems together direct numerous activities that maintain homeostasis, but all the organ systems must do their part in order to keep us alive and healthy. Picture what would happen if, say, the cardiovascular, respiratory, digestive, or urinary system failed (Fig. 4.15). If someone is having a heart attack, the heart is unable to pump the blood to supply cells with oxygen. Or think of a person who is choking. Since the trachea (or windpipe) is blocked, no air can reach the lungs for uptake by the blood. Unless the obstruction is removed quickly, cells will begin to die as the blood's supply of oxygen is depleted. When the lining of the digestive tract is damaged, as in a severe bacterial infection, nutrient absorption is impaired and cells face an energy crisis. It is important not only to maintain adequate nutrient levels in the blood, but also to eliminate wastes and toxins. The liver makes urea, a nitrogenous end product of protein metabolism, but urea and other metabolic wastes are excreted by the kidneys, the urine-producing organs of the body. The kidneys rid the body of nitrogenous wastes and also help to adjust the blood's water-salt and acid-base balances.

A closer examination of how the blood glucose level is maintained helps us understand homeostatic mechanisms. When a healthy person consumes a meal and glucose enters the blood, the pancreas secretes the hormone insulin. Now glucose is removed from the blood as cells take it up. In the liver, glucose is stored in the form of glycogen. This storage is beneficial because later, if blood glucose levels drop, glycogen can be broken down to ensure that the blood level remains constant. Homeostatic mechanisms can fail. In diabetes mellitus, the pancreas cannot produce enough insulin, or the body cells cannot respond appropriately to it. Therefore, glucose does not enter the cells and they must turn to other molecules, such as fats and proteins, in order to survive. This, along with too much glucose in the blood, leads to the numerous complications of diabetes mellitus.

Another example of homeostasis is the ability of the body to regulate the acid-base balance of the body. When carbon dioxide enters the blood, it combines with water to form carbonic acid. However, the blood is buffered, and pH stays within normal range as long as the lungs are busy excreting carbon dioxide. These two mechanisms are backed up by the kidneys, which can rid the body of a wide range of acidic and basic substances and, in that way, adjust the pH.

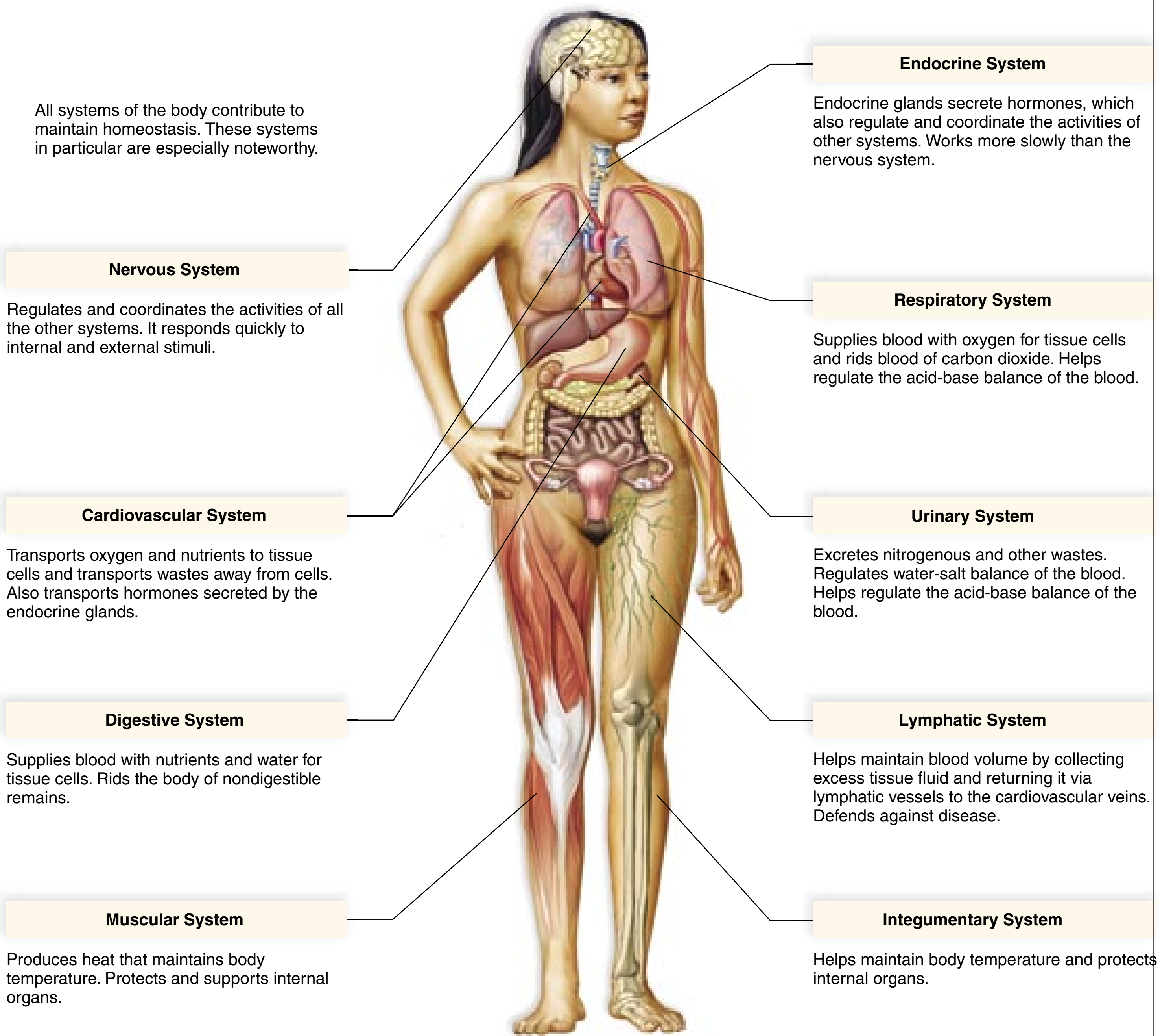


Figure 4.15 **How the organ systems of the body contribute to homeostasis.**
All the organ systems contribute to homeostasis in many ways. Some of the main contributions of each system are given in this illustration.

Negative Feedback

Negative feedback is the primary homeostatic mechanism that keeps a variable, such as the blood glucose level, close to a particular value, or set point. A homeostatic mechanism has at least two components: a sensor and a control center (Fig. 4.16). The sensor detects a change in the internal environment; the control center then brings about an effect to bring conditions back to normal again. Now, the sensor is no longer activated. In other words, a negative feedback mechanism is present when the output of the system dampens the-original stimulus. For example, when the pancreas detects that the blood glucose level is too high, it secretes insulin, the hormone that causes cells to take up glucose. Now, the blood sugar level returns to normal, and the pancreas is no longer stimulated to secrete insulin.

X-ref

Mechanical Example

A home heating system is often used to illustrate how a more complicated negative feedback mechanism works (Fig. 4.17). You set the thermostat at, say, 68°F. This is the *set point*. The thermostat contains a thermometer, a sensor that detects when the room temperature is above or below the set point. The thermostat also contains a control center; it turns the furnace off when the room is warm and turns it on when the room is cool. When the furnace is off, the room cools a bit, and when the furnace is on, the room warms a bit. In other words, typical of negative feedback mechanisms, there is a fluctuation above and below normal.

X-ref

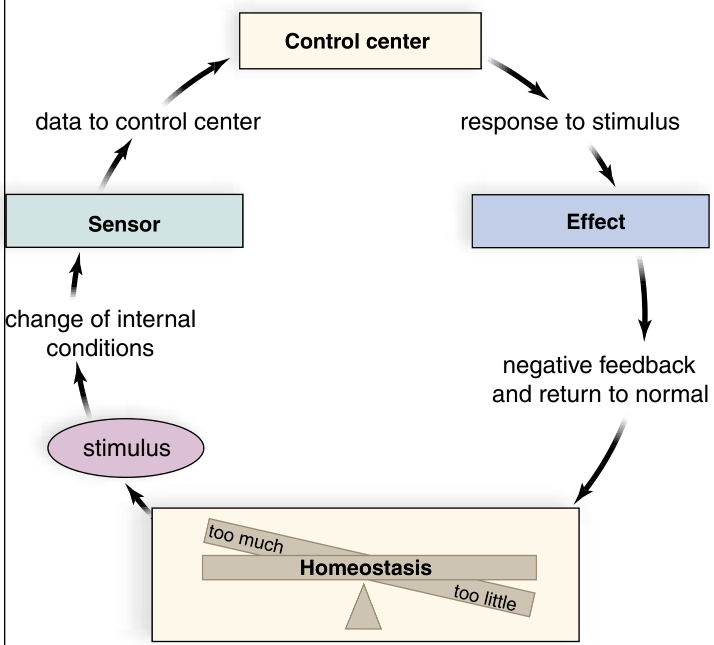


Figure 4.16 Negative feedback mechanism.
This diagram shows how the basic elements of a feedback mechanism work. A sensor detects the stimulus, and a control center brings about an effect that dampens the stimulus.

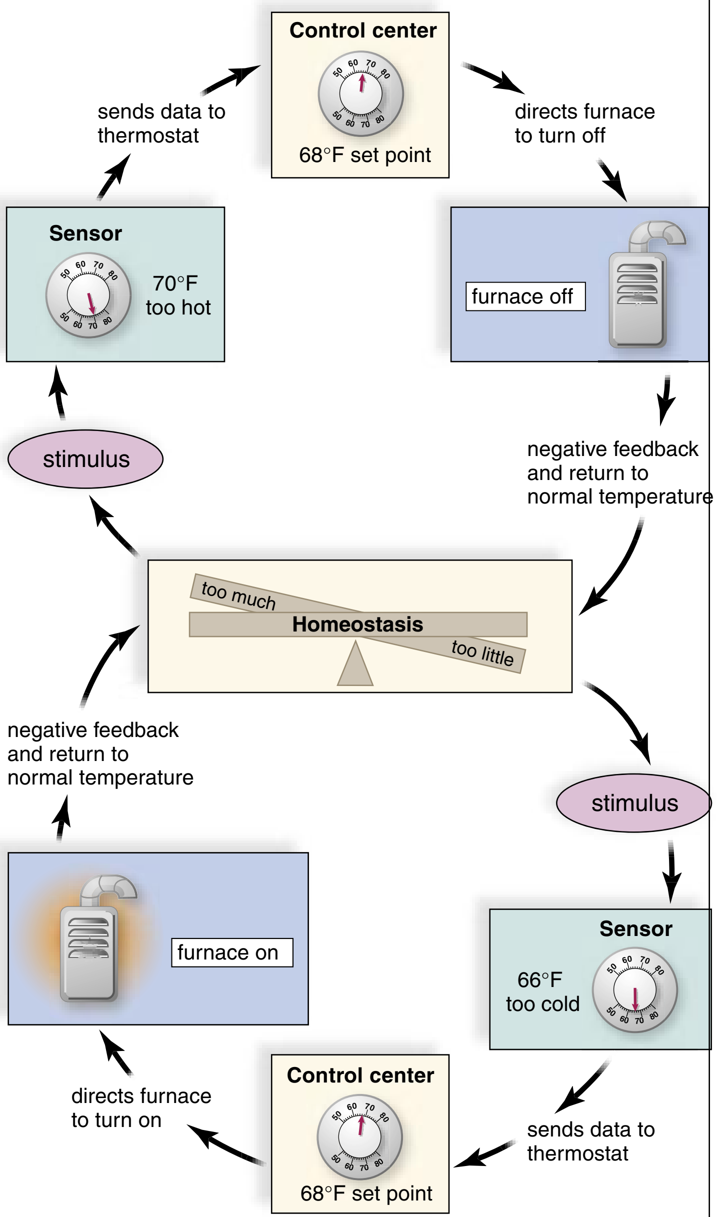


Figure 4.17 Complex negative feedback mechanism.
This diagram shows how room temperature is returned to normal when the room becomes too hot (*above*) or too cold (*below*). The thermostat contains both the sensory and the control center. *Above:* The sensor detects that the room is too hot, and the control center turns the furnace off. The stimulus is no longer present when the temperature returns to normal. *Below:* The sensor detects that the room is too cold, and the control center turns the furnace on. The stimulus is no longer present when the temperature returns to normal.

Human Example: Regulation of Body Temperature

The sensor and control center for body temperature is located in a part of the brain called the hypothalamus. Notice that a negative feedback mechanism prevents change in the same direction; body temperature does not get warmer and warmer because warmth brings about a change toward a lower body temperature. Also, body temperature does not get colder and colder because a body temperature below normal brings about a change toward a warmer body temperature.

Above Normal Temperature When the body temperature is above normal, the control center directs the blood vessels of the skin to dilate. This allows more blood to flow-near the surface of the body, where heat can be lost to the environment. In addition, the nervous system activates the sweat glands, and the evaporation of sweat helps lower-body temperature. Gradually, body temperature decreases to 98.6°F.

Below Normal Temperature When the body temperature falls below normal, the control center directs (via nerve impulses) the blood vessels of the skin to constrict (Fig. 4.18). This conserves heat. If body temperature falls even lower, the control center sends nerve impulses to the-skeletal muscles, and shivering occurs. Shivering generates heat, and gradually body temperature rises to 98.6°F. When the temperature rises to normal, the control center is inactivated.

Positive Feedback

Positive feedback is a mechanism that brings about an ever greater change in the same direction. When a woman is giving birth, the head of the baby begins to press against the cervix, stimulating sensory receptors there. When nerve impulses reach the brain, the brain causes the pituitary gland to secrete the hormone oxytocin. Oxytocin travels in the blood and causes the uterus to contract. As labor continues, the cervix is ever more stimulated, and uterine contractions become ever stronger until birth occurs.

A positive feedback mechanism can be harmful, as when a fever causes metabolic changes that push the fever still higher. Death occurs at a body temperature of 113°F because cellular proteins denature at this temperature and metabolism stops. Still, positive feedback loops such as those involved in childbirth, blood clotting, and the stomach's digestion of protein assist the body in completing a process that has a definite cut-off point.

Check Your Progress 4.9

1. a. What is homeostasis, and b. why is it important to body function?
2. How do body systems contribute to homeostasis?
3. How do negative feedback and positive feedback contribute to homeostasis?

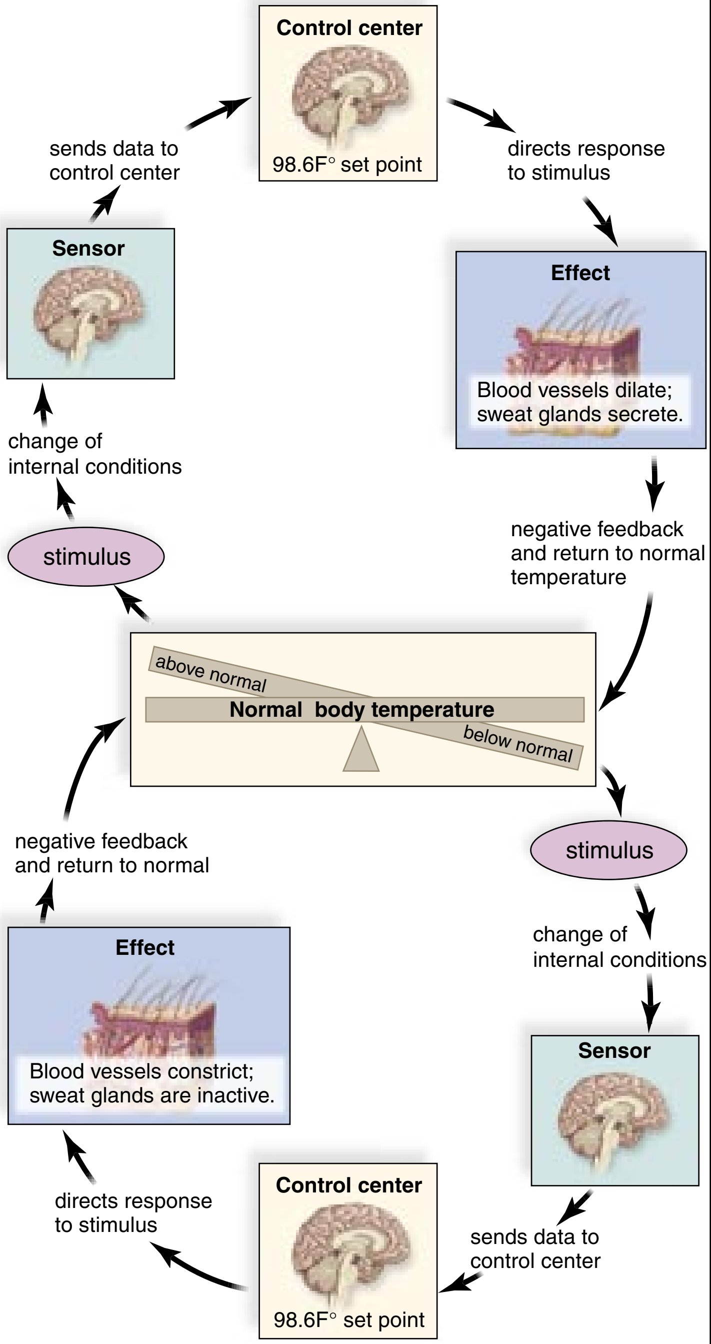


Figure 4.18 Regulation of body temperature.
Above: When body temperature rises above normal, the hypothalamus senses the change and causes blood vessels to dilate and sweat glands to secrete so that temperature returns to normal. *Below:* When body temperature falls below normal, the hypothalamus senses the change and causes blood vessels to constrict. In addition, shivering may occur to bring temperature back to normal. In this way, the original stimulus was removed.

Summarizing the Concepts

4.1 Types of Tissues

Human tissues are categorized into four groups:

Connective	Muscular	Nervous	Epithelial

4.2 Connective Tissue Connects and Supports

Connective tissues have cells separated by a matrix that contains ground substance and fibers (e.g., collagen fibers). The four types are

- loose fibrous connective tissue, including adipose tissue;
- dense fibrous connective tissue (tendons and ligaments);
- cartilage and bone (matrix for cartilage is solid, yet flexible; matrix for bone is extremely hard); and
- blood (matrix is a liquid called plasma).

4.3 Muscular Tissue Moves the Body

Muscular tissue is of three types: skeletal, smooth, and cardiac.

- Skeletal and cardiac muscle are striated.
- Cardiac and smooth muscle are involuntary.
- Skeletal muscle is found in muscles attached to bones.
- Smooth muscle is found in internal organs.
- Cardiac muscle makes up the heart.

4.4 Nervous Tissue Communicates

- Nervous tissue is composed of neurons and several types of neuroglia.
- Each neuron has dendrites, a cell body, and an axon. Axons conduct nerve impulses.

4.5 Epithelial Tissue Protects

Epithelial tissue covers the body and lines its cavities.

- Types of simple epithelia are squamous, cuboidal, and columnar.
- Certain of these tissues may have cilia or microvilli.
- Stratified epithelia have many layers of cells, with only the bottom layer touching the basement membrane.
- Glandular epithelia secretes a product either into ducts or into the blood.

4.6 Cell Junctions

Three types of junctions are common between epithelial cells:

- Tight junctions are zipperlike fastenings between cells.
- Adhesion junctions permit cells to stretch and bend.
- Gap junctions allow small molecules and signals to pass between cells.

4.7 Integumentary System

Skin and its accessory organs comprise the integumentary system. Skin has two regions:

- The epidermis contains stem cells, which produce new epithelial cells.
- The dermis contains epidermally derived glands and hair follicles, nerve endings, blood vessels, and sensory receptors.

A subcutaneous layer lies beneath the skin.

4.8 Organ Systems

Organs make up organ systems, which are summarized in the table below. Some organs are located in particular body cavities.

4.9 Homeostasis

Homeostasis is the relative constancy of the internal environment, which is tissue fluid and blood. All organ systems contribute to homeostasis.

- The cardiovascular, respiratory, digestive, and urinary systems directly regulate the amount of gases, nutrients, and wastes in the blood, keeping tissue fluid constant.
- The lymphatic system absorbs excess tissue fluid and functions in immunity.
- The nervous system and endocrine system regulate the other systems.

Negative Feedback

Negative feedback mechanisms keep the environment relatively stable. When a sensor detects a change above or below a set point, a control center brings about an effect that reverses the change and brings conditions back to normal again. Examples include

- regulation of blood glucose level by insulin,
- regulation of room temperature by a thermostat and furnace, and
- regulation of body temperature by the brain and sweat glands.

Positive Feedback

In contrast to negative feedback, a positive feedback mechanism brings about rapid change in the same direction as the stimulus and does not achieve relative stability. These mechanisms are useful under certain conditions, such as during birth.

Organ Systems

Transport Cardiovascular (hear and blood vessels) Lympatoc (lympahatic vessels)	***Integumentary*** Skin and accessory organs
Maintenance Digestive (e.g., stomach, intestines) Respiratory (tubes and lungs) Urninary (tubes and kidneys)	***Motor*** Skeletal (bones and cartilage) Muscular (muscles)
Control Nervous (brain, spinal cord, and nerves) Endocrine (glands)	***Reproduction*** Reproductive (tubes and testes in males; tubes and ovaries in females)

Understanding Key Terms

acne 73
adhesion junction 70
adipose tissue 62
basement membrane 68
blood 64
bone 63
carcinoma 62
cardiac muscle 65
cardiovascular system 74
cartilage 63
collagen fiber 62
columnar epithelium 68
compact bone 63
connective tissue 62
cuboidal epithelium 68
dense fibrous connective tissue 62
dermis 72
diaphragm 76
digestive system 74
elastic cartilage 63
elastic fiber 62
endocrine gland 69
endocrine system 75
epidermis 71
epithelial tissue 68
exocrine gland 69
fibroblast 62
fibrocartilage 63
gap junction 70
gland 69
hair follicle 73
homeostasis 78
hyaline cartilage 63
immune system 74
integumentary system 71
intercalated disks 65
lacuna 63
langerhans cell 72
ligament 62
loose fibrous connective tissue 62
lymph 64
lymphatic system 74
matrix 62
melanocyte 72
meninges 77
meningitis 77
mucous membrane 77
muscular system 75
muscular (contractile) tissue 65
nail 73
negative feedback 80
nerve 66
nervous system 75
nervous tissue 66
neuroglia 66
neuron 66
oil gland 73
organ 71
organ system 71
pathogen 64
peritonitis 77
platelet 64
pleura 77
positive feedback 81
pseudostratified columnar epithelium 68
red blood cell 64
reproductive system 75
respiratory system 74
reticular fiber 62
serous membrane 77
skeletal muscle 65
skeletal system 75
skin 71
smooth (visceral) muscle 65
spongy bone 63
squamous epithelium 68
striated 65
subcutaneous layer 71
sweat gland 73
synovial membrane 77
tendon 62
tight junction 70
tissue 62
tissue fluid 64
urinary system 74
vitamin D 72
white blood cell 64

Match the key terms to these definitions.

a. ________ Dense fibrous connective tissue that joins bone to bone at a joint.

b. ________ Outer region of the skin composed of keratinized stratified squamous epithelium.

c. ________ Cancer of epithelial tissue.

d. ________ Relative constancy of the body's internal environment.

e. ________ Porous bone found at the ends of long bones where blood cells are formed.

Testing Your Knowledge of the Concepts

1. What are the functions of the four major tissue types (page 62)
2. What features do all connective tissues have in common? (page 62)
3. Explain why you would have expected skeletal muscle to be voluntary but smooth muscle and cardiac muscle to be involuntary. (page 65)
4. What are the two types of cells found in nervous tissue? Briefly describe each type. (page 66)
5. How are epithelial tissues classified? Describe each major type, and give at least one location for each type. (pages 68–69)
6. Which of the three types of cell junctions permits communications between cells? Explain. (page 70)
7. Explain why the skin is sometimes referred to as the integumentary system. (page 71)
8. Referring Figure 4.12, list each organ system, the major organs, and major functions of each. (pages 74–75)
9. What organs of the body are found in the thoracic cavity? The abdominal cavity? (page 76)
10. List the types of membranes found in the body, their functions, and their locations. (page 77)
11. Why is homeostasis defined as the "*relative* constancy of the internal environment"? Does negative feedback or positive feedback tend to promote homeostasis? Explain. (pages 80–81)
12. Which of the following is not a type of fibrous connective tissue?
    a. hyaline cartilage
    b. areolar tissue
    c. tendons and ligaments
    d. adipose tissue
13. What type of cartilage is found in the rib cage and walls of the respiratory passages?
    a. fibrocartilage
    b. elastic cartilage
    c. ligamentous cartilage
    d. hyaline cartilage
14. Blood is a(n) ________ tissue because it has a ________.
    a. connective; gap junction
    b. muscular; ground substance
    c. epithelial; gap junction
    d. connective; ground substance
15. Skeletal muscle is
    a. striated.
    b. under voluntary control.
    c. multinucleated.
    d. All of these are correct.
16. Which is true of both cardiac and smooth muscle?
    a. striated
    b. multinucleated
    c. involuntary control
    d. spindle-shaped cells
17. Which of the following forms the myelin sheath around nerve fibers outside the brain and spinal cord?
    a. microglia
    b. neurons
    c. Schwann cells
    d. astrocytes

18. Which of these is NOT a type of epithelial tissue?
    a. simple cuboidal and stratified columnar
    b. bone and cartilage
    c. stratified squamouos and simple squamous
    d. pseudostratified and transitional
    e. All of these are epithelial tissues.

19. What type of epithelial tissue is found in the walls of the urinary bladder to provide it with the ability to distend?
    a. simple cuboidal epithelium
    b. transitional epithelium
    c. pseudostratified columnar epithelium
    d. stratified squamous epithelium

20. Tight junctions are associated with
    a. connective tissue.   c. cardiac muscle.
    b. adipose tissue.   d. epithelial tissue.

21. Without melanocytes, skin would
    a. be too thin.   c. lack color.
    b. lack nerves.   d. not be waterproof.

22. Which of the following is a function of skin?
    a. temperature regulation
    b. manufacture of vitamin D
    c. protection from invading pathogens
    d. All of these are correct.

23. Fluid balance is a primary goal of which system?
    a. endocrine   c. digestive
    b. lymphatic   d. integumentary

24. The skeletal system functions in
    a. blood cell production.   c. movement.
    b. mineral storage.   d. All of these are correct.

25. Which system helps control pH balance?
    a. digestive   c. respiratory
    b. urinary   d. Both b and c are correct.

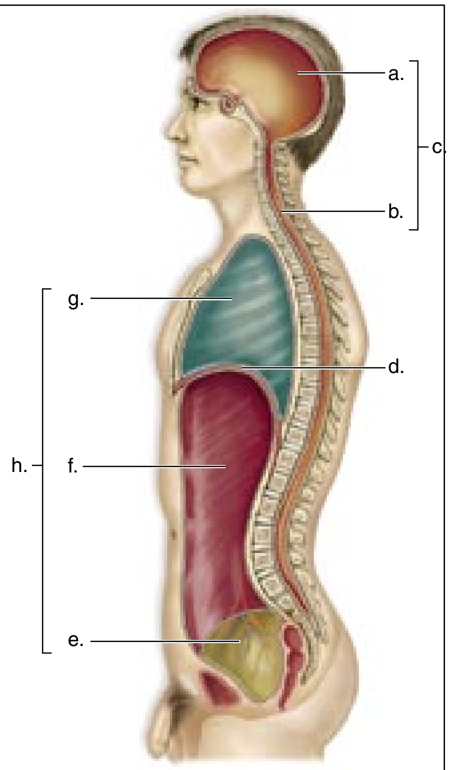
26. Which type of membrane is found lining systems that are open to the outside environment, such as the respiratory system?
    a. serous   c. synovial
    b. mucous   d. meningeal

27. The correct order for homeostatic processing is
    a. sensory detection, control center, effect brings about change in body.
    b. control center, sensory detection, effect brings about change in environment.
    c. sensory detection, control center, effect causes no change in environment.
    d. None of these is correct.

28. Which allows rapid change in one direction and does not achieve stability?
    a. homeostasis   c. negative feedback
    b. positive feedback   d. All of these are correct.

29. Which of the following is an example of negative feedback?
    a. Uterine contractions increase as labor progresses.
    b. Insulin decreases blood sugar levels after eating a meal.
    c. Sweating increases as body temperature drops.
    d. Platelets continue to plug an opening in a blood vessel until blood flow stops.

30. Label the body cavities plus the diaphragm in this diagram.



Thinking Critically About the Concepts

The need for transplant organs is very high and far outnumbers the organs available for donation. Recently, natural bladder cells were grown in the laboratory, creating an actual bladder. When the lab-grown bladder was attached to a damaged bladder, it performed as well as a bladder repaired by more conventional surgical methods. Hopefully, lab-grown organs will one day be widely available for transplant. A lab-grown organ that duplicates the structure and function of a natural organ should increase the success of the transplant, integration of the transplanted organ into its organ system, and the ability of the organ system to do its part in homeostasis.

1. Do you think Barbara's new "bladder" (formerly a section of her large intestine) will function just like the actual cancerous bladder that was removed? Why or why not?

2a. What two systems are especially important in coordinating the efforts of the various organ systems as they work to maintain homeostasis?

b. How do these two systems issue their "commands" to the other systems?

3a. What different tissues enable the trachea to perform its function of acting as an open tube for the passage of inhaled air?

b. The bladder has a layer of smooth muscle like other hollow organs, but it also contains transitional epithelium, found nowhere else in our body. Transitional epithelial cells are able to elongate themselves. Why would you expect to find this kind of tissue in the bladder based on its function?

4a. What specific proteins that make our body's reactions possible are affected by an increased body temperature?

b. What other homeostasis condition affects the function of these proteins?

c. What two systems are involved in maintaining the second condition that affects these specific proteins?

5. When you are cold, you may shiver.

a. How will shivering increase your body temperature?

b. Once body temperature is normal again, will shivering continue? Why or why not?