TABLE 2-5
Stages of Cell Division

STAGE	CHARACTERISTICS
Prophase	The chromatin condenses into visible chromosomes Chromatids become attached at the centromere Spindle fibers appear The nucleolus and nuclear envelope disappear
Metaphase	Spindle fibers attach to each chromatid Chromosomes align across the center of the cell
Anaphase	Centromeres break apart Chromosomes move away from the center of the cell The cleavage furrow appears
Telophase	The nuclear envelope and both nuclei appear The cytoplasm and organelles divide equally The process of cell division is completed

Anaphase

As anaphase (AN-ah-faze) begins, the beadlike centromeres, which were holding the paired chromatids together, break apart. As a result, the individual chromatids, identified once again as chromosomes, move away from the center of the cell. Movement of chromosomes occurs along spindle fibers toward the centrioles. Note in Figure 2-7 that chromosomes are being pulled to opposite ends of the cell. A **cleavage furrow** that begins to divide the cell into two daughter cells can be seen for the first time at the end of anaphase.

Telophase

During telophase (TEL-o-faze) cell division is completed. Two nuclei appear, and chromosomes become less distinct and appear to break up. As the nuclear envelope forms around the chromatin, the cleavage furrow completely divides the cell into two parts. Before division is complete, each nucleus is surrounded by cytoplasm in which organelles have been equally distributed. By the end of telophase, two separate daughter cells, each having identical genetic characteristics, are formed. Each cell is fully functional and will perhaps itself undergo mitosis in the future.

Results of Cell Division

Mitosis results in the production of identical new cells. In the adult, mitosis replaces cells that have become less functional with age or have been damaged or destroyed by illness or injury. During periods of body growth, mitosis allows groups of similar cells to differentiate, or develop into different **tissues.**

If the body loses its ability to control mitosis, an abnormal mass of proliferating cells develops. This mass is a **neoplasm** (NEE-o-plazm). Neoplasms may be relatively harmless growths called *benign* (be-NINE) *tumors* or dangerous and *malignant* (mah-LIG-nant) cancerous growths. The stages of mitosis are listed in Table 2-5 with descriptions of changes that occur during each stage.

Tissues

The four main kinds of tissues that compose the body's many organs follow:

1. Epithelial tissue
2. Connective tissue
3. Muscle tissue
4. Nervous tissue

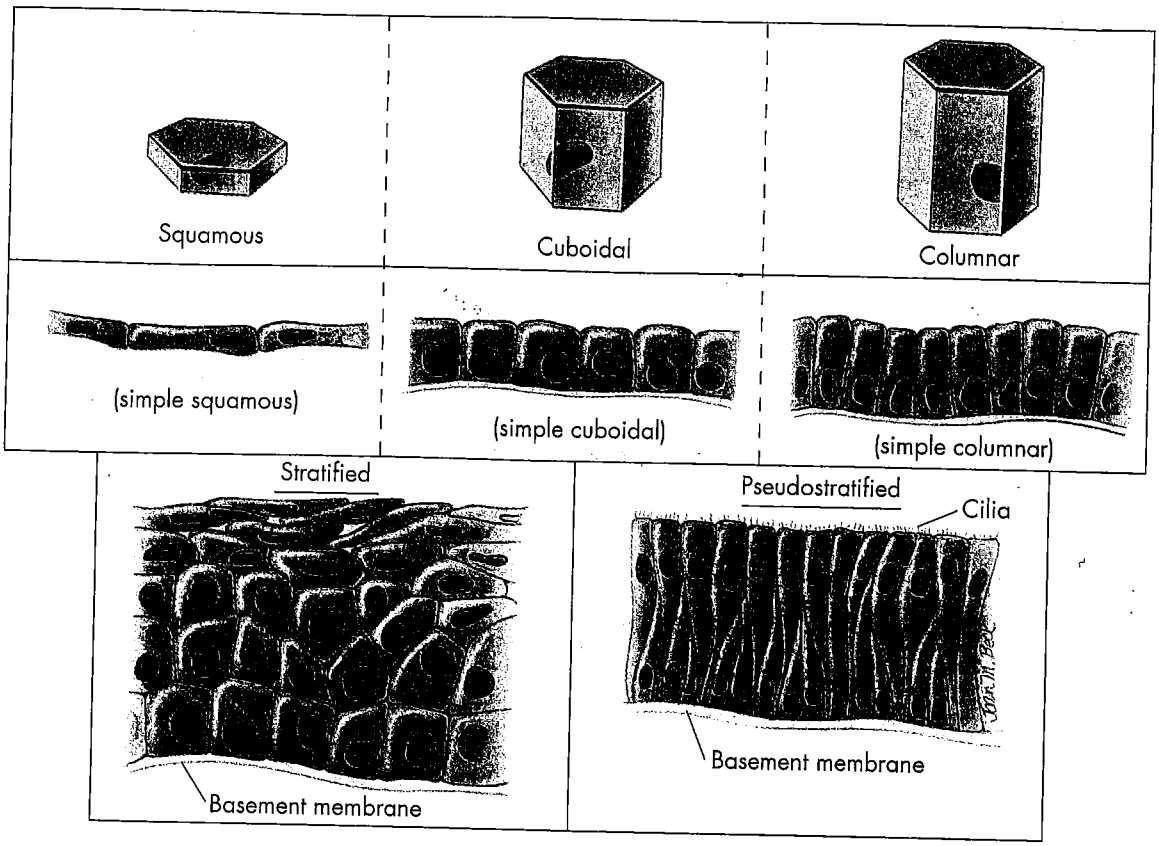
Tissues differ from each other in the size and shape of their cells, in the amount and kind of material between the cells, and in the special functions they perform to help maintain the body's survival. In Tables 2-6 through 2-8, you will find a listing of the four major tissues and the various subtypes of each. The tables also include the structure of each subtype along with examples of the location of the tissues and a primary function of each tissue type.

Epithelial Tissue

Epithelial (ep-i-THEE-lee-al) **tissue** covers the body and many of its parts. It also lines various parts of the body. Because epithelial cells are

FIGURE 2-8

Classification of epithelial tissues. The tissues are classified according to the shape and arrangement of cells.



packed close together with little or no intercellular material between them, they form continuous sheets that contain no blood vessels. Examine Figure 2-8. It illustrates how this large group of tissues can be subdivided according to the **shape** and **arrangement** of the cells found in each type.

Shape of Cells

If classified according to shape, epithelial cells are:

1. Squamous (flat and scalelike)
2. Cuboidal (cube shaped)
3. Columnar (higher than they are wide)
4. Transitional (varying shapes that can stretch)

Arrangement of Cells

If categorized according to arrangement of cells, epithelial tissue can be classified as the following:

1. Simple (a single layer of cells of the same shape)
2. Stratified (many layers of cells; named for the shape of cells in the outer layer)

Several types of epithelium are described in the paragraphs that follow and are illustrated in Figures 2-9 to 2-12.

Simple Squamous Epithelium

Simple squamous (SKWAY-mus) **epithelium** consists of a single layer of very thin and irregularly shaped cells. Because of its structure, substances can readily pass through simple squamous epithelial tissue, making transport its special function. Absorption of oxygen into the blood, for example, takes place through the simple squamous epithelium that forms the tiny air sacs in the lungs (Figure 2-9).

FIGURE 2-9

Simple squamous epithelium. A, Photomicrograph of lung tissue shows thin simple squamous epithelium lining the alveolar air sacs. **B,** Sketch of photomicrograph.

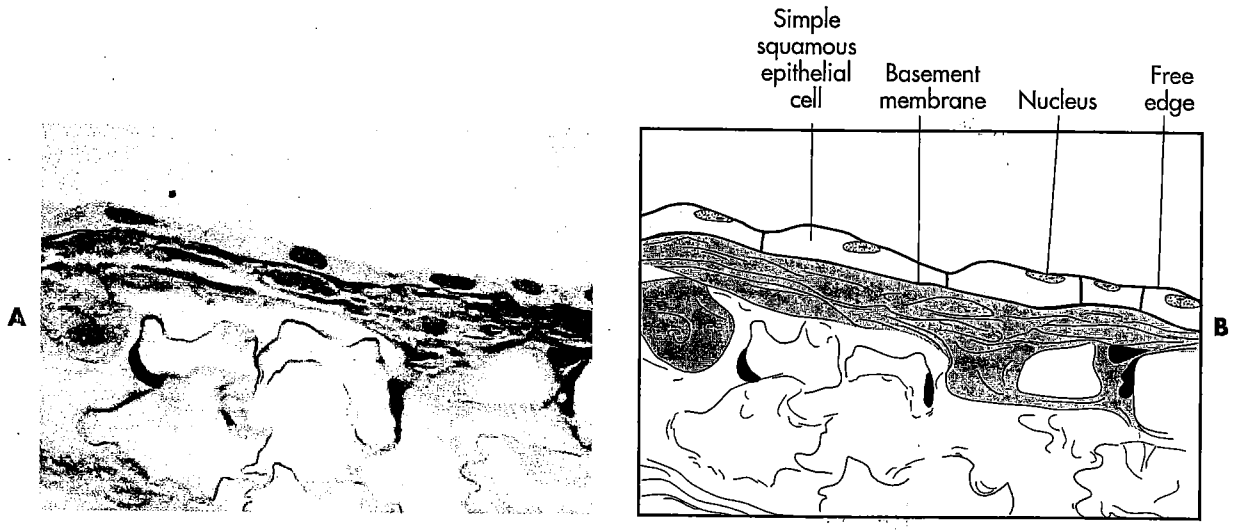
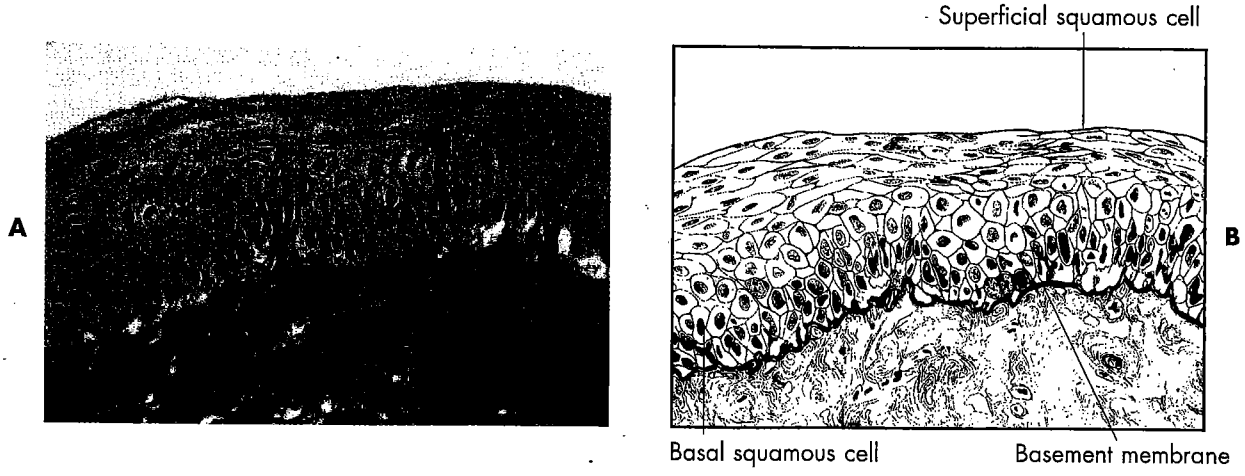


FIGURE 2-10

Stratified squamous epithelium. A, Photomicrograph. **B,** Sketch of the photomicrograph. Note the many layers of epithelial cells that have been stained yellow.



Stratified Squamous Epithelium

Stratified squamous epithelium (Figure 2-10) consists of several layers of closely packed cells, an arrangement that makes this tissue a specialist at protection. For instance, stratified squamous epithelial tissue protects the body against invasion by microorganisms. Most microbes cannot work their way through a barrier of stratified squamous tissue such as that which composes the surface of skin and of mucous membranes.

FIGURE 2-11

Simple columnar epithelium. A, Photomicrograph. **B,** Sketch of the photomicrograph. Note the goblet or mucus-producing cells that are present.

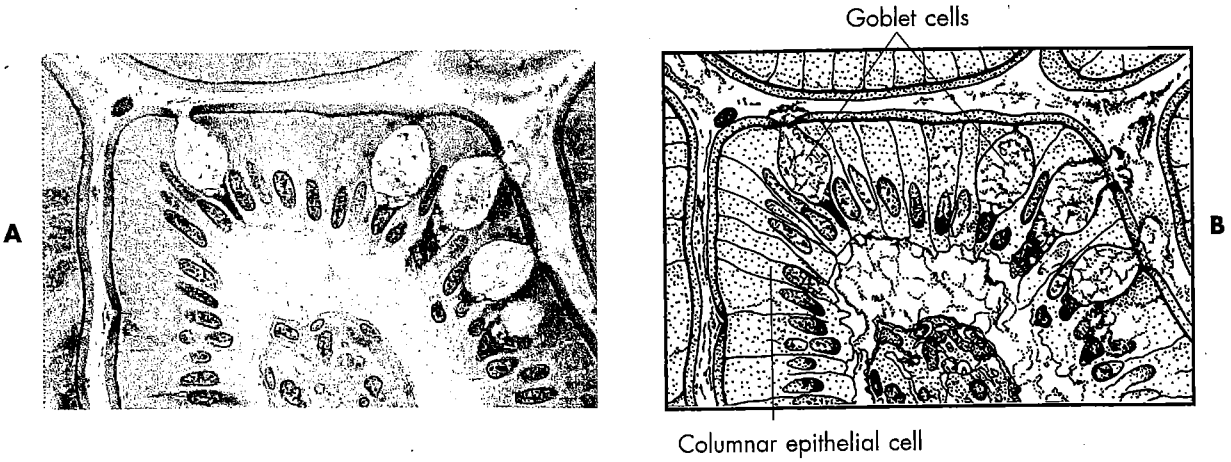
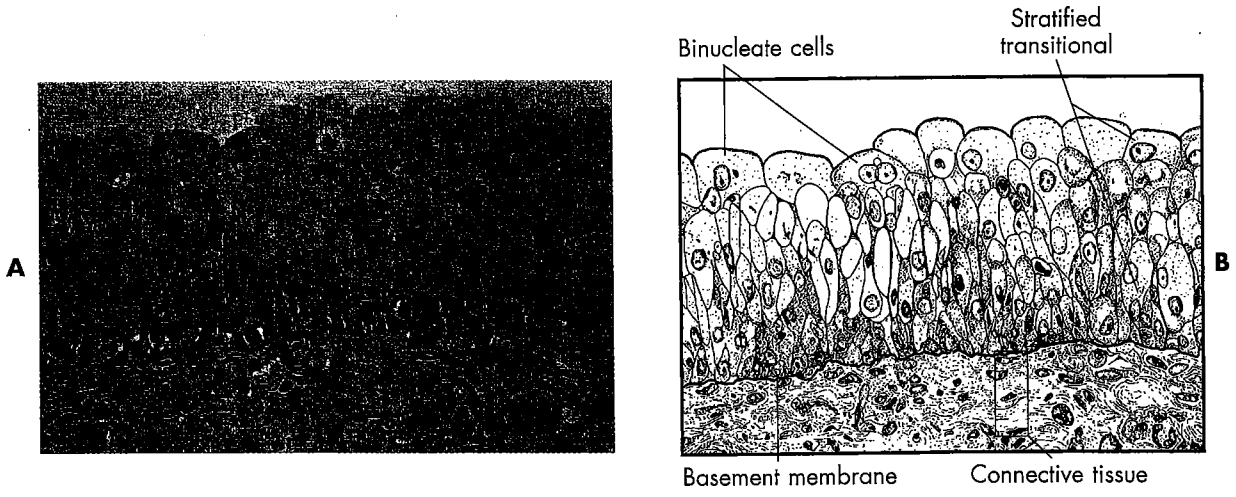


FIGURE 2-12

Stratified transitional epithelium. A, Photomicrograph of tissue lining the urinary bladder wall. **B,** Sketch of the photomicrograph. Note the many layers of epithelial cells of various shapes.



One way of preventing infections, therefore, is to take good care of your skin. Don't let it become cracked from chapping, and guard against cuts and scratches.

Simple Columnar Epithelium

Simple columnar epithelium can be found lining the inner surface of the stomach, intestines, and some areas of the respiratory and reproductive tracts. In Figure 2-11 the simple columnar cells are arranged in a single layer lining the inner surface of the colon or large intestine. These epithelial cells are higher than they are wide, and the nuclei are located toward the bottom of each cell. The "open spaces" among the cells are specialized **goblet cells** that produce mucus. The regular columnar-shaped cells specialize in absorption.

Stratified Transitional Epithelium

Stratified transitional epithelium is typically found in body areas subjected to stress and must be able to stretch; an example would be the wall of the urinary bladder. In many instances, up to 10 layers of differently-shaped cells of varying sizes are present in the absence of stretching. When stretching occurs, the epithelial sheet expands, the number of cell layers decreases, and cell shape changes from roughly cuboidal to nearly squamous (flat) in appearance. The fact that transitional epithelium has this ability keeps the bladder wall from tearing under the pressures of stretching. Stratified transitional epithelium is shown in Figures 2-8 and 2-12.

Pseudostratified Epithelium

Pseudostratified epithelium, illustrated in Figure 2-8, is typical of that which lines the trachea or windpipe. Look carefully at the illustration. Note that each cell actually touches the gluelike **basement membrane** that lies under all epithelial tissues. Although the epithelium in Figure 2-8 (pseudostratified) appears to be two cell layers thick, it is not. This is the reason it is called *pseudo* (or false) stratified epithelium. The cilia that extend from the cells are capable of moving in unison. In doing so, they move mucus along the lining surface of the trachea, thus affording protection against entry of dust or foreign particles into the lungs.

Cuboidal Epithelium

Simple cuboidal epithelium does not form protective coverings but instead forms tubules or other groupings specialized for secretory activity (Figure 2-13). Secretory cuboidal cells usually function in clusters or tubes of secretory cells commonly called glands. Glands of the body may be classified as exocrine if they release their secretion through a duct or as endocrine if they release their secretion directly into the bloodstream. Examples

FIGURE 2-13

Simple cuboidal epithelium. This scanning electron micrograph shows how a single layer of cuboidal cells can form glands. The secreting cells arrange themselves into single or branched tubules that open onto a surface—the lining of the stomach in this case.

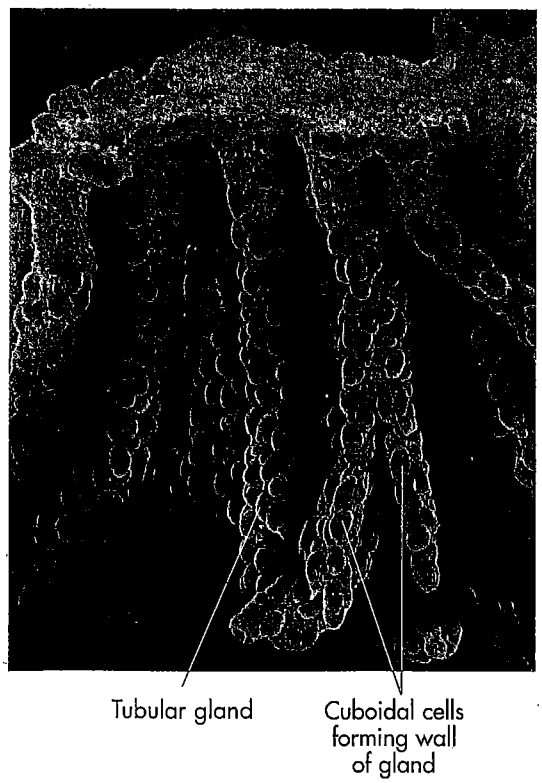


TABLE 2-6

Epithelial Tissues

TISSUE	STRUCTURE	LOCATION(S)	FUNCTION(S)
Simple squamous	Single layer of flattened cells	Alveoli of lungs	Diffusion of respiratory gases between alveolar air and blood
		Lining of blood and lymphatic vessels	Diffusion, filtration, and osmosis
Stratified squamous	Many layers; outermost layer(s) are flattened cells	Surface of lining of mouth and esophagus	Protection
		Surface of skin (epidermis)	Protection
Simple columnar	Single layer of tall, narrow cells	Surface layer of lining of stomach, intestines, parts of respiratory tract	Protection, secretion, transport (absorption)
Stratified transitional	Many layers of varying shapes, capable of stretching	Urinary bladder	Protection
Pseudostratified	Single layer of tall cells that wedge together to appear as if there are two or more layers	Surface of lining of trachea	Protection
Simple cuboidal	Single layer of cells that are as tall as they are wide	Glands, kidney tubules	Secretion, absorption

of glandular secretions include saliva produced by the salivary glands, digestive juices, sweat or perspiration, and hormones such as those secreted by the pituitary or thyroid glands. Simple cuboidal epithelium also forms the tubules that form urine in the kidneys.

Connective Tissue

Connective tissue is the most abundant and widely distributed tissue in the body. It also exists in more varied forms than any of the other tissue types. It is found in skin, membranes, muscles, bones, nerves, and all internal organs. Connective tissue exists as delicate, paper-thin webs that hold internal organs together and give them shape. It also exists as strong and tough cords, rigid bones, and even in the form of a fluid—blood.

The functions of connective tissue are as varied as its structure and appearance. It connects tissues to each other and forms a supporting framework for the body as a whole and for its individual organs. As blood, it transports substances throughout the body. Several other kinds of connective tissue function to defend us against microbes and other invaders.

Connective tissue differs from epithelial tissue in the arrangement and variety of its cells and in the amount and kinds of intercellular material, called matrix, found between its cells. In addition to the relatively few cells embedded in the matrix of most types of connective tissue, varying numbers and kinds of fibers are also present. The structural quality and appearance of the matrix and fibers determine the qualities of each type of connective tissue. The matrix of blood, for example, is a liquid, but other types of connective tissue, such as cartilage, have the consistency of firm rubber. The matrix of bone is hard and rigid, although the matrix of connective tissues such as tendons and ligaments is strong and flexible.

The following list identifies a number of the major types of connective tissue in the body. Photomicrographs of several are also shown.

1. Areolar connective tissue
2. Adipose or fat tissue
3. Fibrous connective tissue
4. Bone
5. Cartilage
6. Blood
7. Hemopoietic tissue

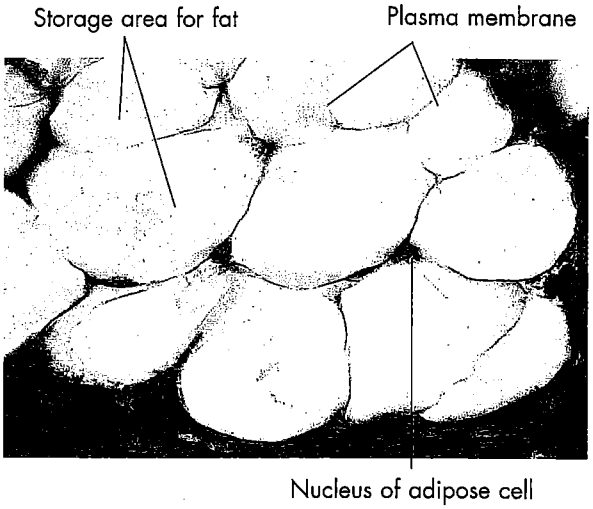
Areolar and Adipose Connective Tissue

Areolar (ah-REE-o-lar) **connective tissue** is the most widely distributed of all connective tissue types. It is the "glue" that gives form to the internal organs. It consists of delicate webs of fibers and of a variety of cells embedded in a loose matrix of soft, sticky gel.

Adipose (AD-i-pose) or **fat tissue** is specialized to store lipids. In Figure 2-14, numerous spaces have formed in the tissue so that large quantities of fat can accumulate inside cells.

FIGURE 2-14

Adipose tissue. Photomicrograph showing the large storage spaces for fat inside the adipose tissue cells.

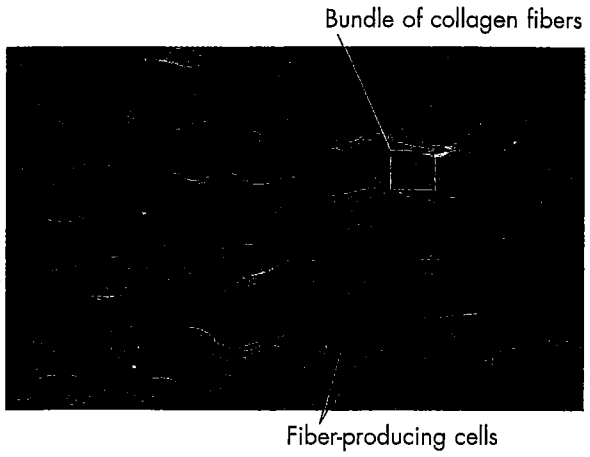


Fibrous Connective Tissue

Fibrous connective tissue (Figure 2-15) consists mainly of bundles of strong, white **collagen** fibers arranged in parallel rows. This type of connective tissue composes tendons. It provides great strength and flexibility but it does not stretch. Such characteristics are ideal for these structures that anchor our muscles to our bones.

FIGURE 2-15

Dense fibrous connective tissue. Photomicrograph of tissue in the tendon. Note the multiple bundles of collagenous fibers in a parallel arrangement.



Bone and Cartilage

Bone is one of the most highly specialized forms of connective tissue. The matrix of bone is hard and calcified. It forms numerous structural building blocks called **osteons** (AHS-tee-onz), or *Haversian* (ha-VER-shan) *systems*. When bone is viewed under a microscope, we can see these circular arrangements of calcified matrix and cells that give bone its characteristic appearance (Figure 2-16). Bones are a storage area for calcium and provide support and protection for the body.

Cartilage differs from bone in that its matrix is the consistency of a firm plastic or a gristlelike gel. Cartilage cells, which are called **chondrocytes** (KON-dro-sites), are located in many tiny spaces distributed throughout the matrix (Figure 2-17).

FIGURE 2-16

Bone tissue. Photomicrograph of dried, ground bone. Many wheel-like structural units of bone, known as osteons (Haversian systems), are apparent in this section.

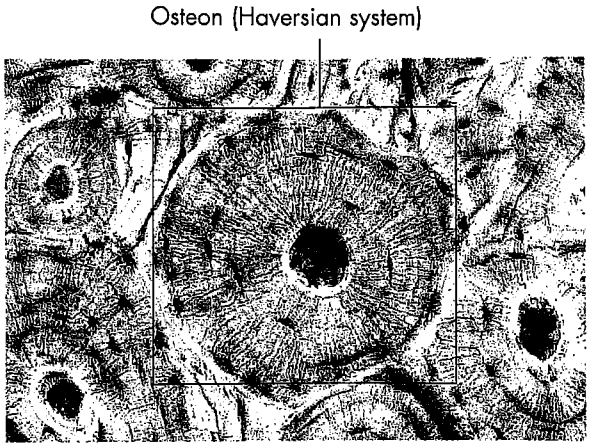
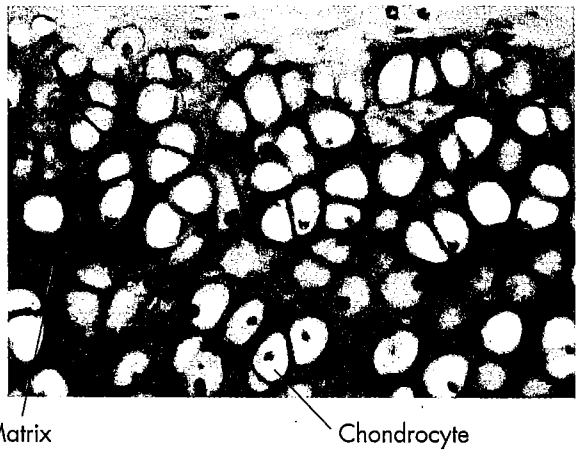


FIGURE 2-17

Cartilage. Photomicrograph showing the chondrocytes distributed throughout the gel-like matrix.

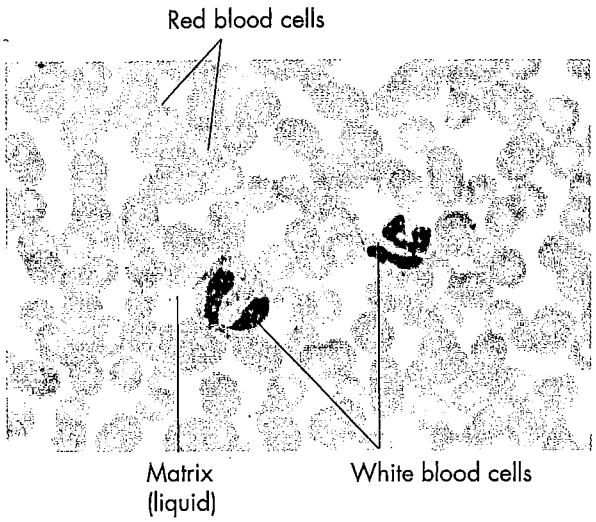


Blood and Hemopoietic Tissue

Because its matrix is liquid, **blood** is perhaps the most unusual form of connective tissue. It has transportational and protective functions in the body. Red and white blood cells are the cell types common to blood (Figure 2-18).

FIGURE 2-18

Blood. Photomicrograph of a human blood smear. This smear shows two white blood cells surrounded by a number of smaller red blood cells. The liquid matrix of this tissue is also called plasma.



Hemopoietic (hee-mo-poy-ET-ik) **tissue** is the bloodlike connective tissue found in the red marrow cavities of bones and in organs such as the spleen, tonsils, and lymph nodes. This type of tissue is responsible for the formation of blood cells and lymphatic system cells important in our defense against disease (Table 2-7).

Muscle Tissue

Muscle cells are the movement specialists of the body. They have a higher degree of contractility (ability to shorten or contract) than any other tissue cells. Unfortunately, injured muscle cells are often slow to heal and are frequently replaced by scar tissue if injured. There are three kinds of muscle tissue: **skeletal, cardiac,** and **smooth.**

Skeletal Muscle Tissue

Skeletal or striated muscle is called *voluntary* because willed or voluntary control of skeletal muscle contractions is possible. Note in Figure 2-19

TABLE 2-7

Connective Tissues

TISSUE	STRUCTURE	LOCATION(S)	FUNCTION(S)
Areolar	Loose arrangement of fibers and cells	Area between other tissues and organs	Connection
Adipose (fat)	Cells contain large fat compartments	Area under skin Padding at various points	Protection Insulation, support, nutrient reserve
Dense fibrous	Dense arrangement of collagen fiber bundles	Tendons, ligaments, fascia, scar tissue	Flexible but strong connection
Bone	Hard, calcified matrix arranged in osteons	Skeleton	Support, protection
Cartilage	Hard but flexible matrix with imbedded chondrocytes	Part of nasal septum, area covering articular surfaces of bones, larynx, rings in trachea and bronchi Disks between vertebrae External ear	Firm but flexible support Withstand pressure Flexible support
Blood	Liquid matrix with flowing red and white cells	Blood vessels	Transportation
Hemopoietic	Liquid matrix with dense arrangement of blood-cell–producing cells	Red bone marrow	Blood cell formation

that, when viewed under a microscope, skeletal muscle is characterized by many cross striations and many nuclei per cell. Individual cells are long and threadlike and are often called *fibers*. Skeletal muscles are attached to bones and when contracted produce voluntary and controlled body movements.

Cardiac Muscle Tissue

Cardiac muscle forms the walls of the heart, and the regular but involuntary contractions of cardiac muscle produce the heartbeat. Under the light microscope (Figure 2-20), cardiac muscle fibers have faint cross striations (like skeletal muscle) and thicker dark bands called *intercalated disks*. Cardiac muscle fibers branch and reform to produce an interlocking mass of contractile tissue.

Smooth Muscle Tissue

Smooth (visceral) muscle is said to be involuntary because it is not under conscious or willful control.

FIGURE 2-19

Skeletal muscle. Photomicrograph showing the striations of the muscle cell fibers in longitudinal section.

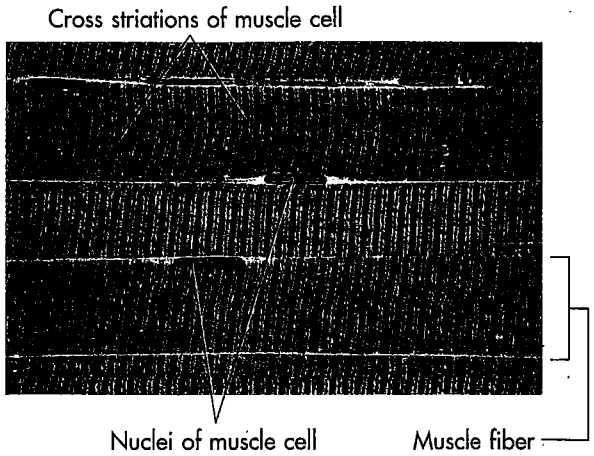
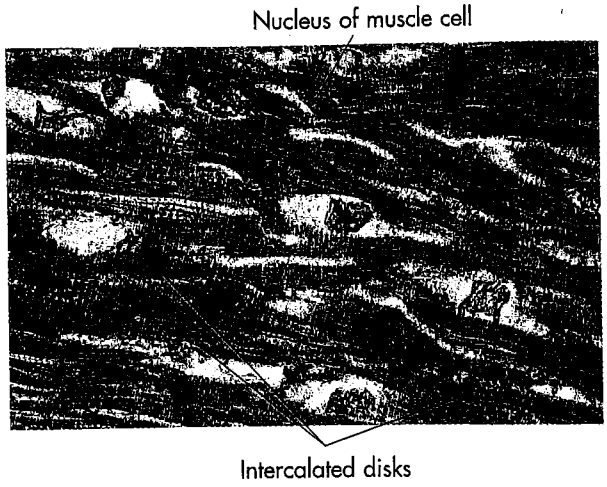


FIGURE 2-20

Cardiac muscle. Photomicrograph showing the branched, lightly striated fibers. The darker bands, called *intercalated disks*, which are characteristic of cardiac muscle, are easily identified in this tissue section.



Under a microscope (Figure 2-21), smooth muscle cells are seen as long, narrow fibers but not nearly as long as skeletal or striated fibers. Individual smooth muscle cells appear smooth (that is, without cross striations) and have only one nucleus per fiber. Smooth muscle helps form the walls of blood vessels and hollow organs such as the intestines and other tube-shaped structures in the body. Contractions of smooth (visceral) muscle propel food material through the digestive tract and help regulate the diameter of blood vessels.

HEALTH & WELL-BEING

Tissues and Fitness

Achieving and maintaining an ideal body weight is a health-conscious goal. However, a better indicator of health and fitness is **body composition.** Exercise physiologists assess body composition to identify the percentage of the body made of lean tissue and the percentage made of fat. Body-fat percentage is often determined by using calipers to measure the thickness of skin folds at certain places on the body. A person with low body weight may still have a high ratio of fat to muscle, an unhealthy condition. In this case the individual is "underweight" but "overfat." In other words, fitness depends more on the percentage and ratio of specific tissue types than the overall amount of tissue present.

Therefore one goal of a good fitness program is a desirable body-fat percentage. For men, the ideal is 12% to 18%, and for women, the ideal is 18% to 24%. Because fat contains stored energy (measured in calories), a low-fat percentage means a low-energy reserve. High body-fat percentages are associated with several life-threatening conditions, including cardiovascular disease and cancer. A balanced diet and an exercise program ensure that the ratio of fat to muscle tissue stays at a level appropriate for maintaining homeostasis.

Contraction of smooth muscle in the tubes of the respiratory system, such as the bronchioles in the lungs, can impair breathing and result in asthma attacks and labored respiration.

FIGURE 2-21

Smooth muscle. Photomicrograph, longitudinal section. Note the central placement of nuclei in the spindle-shaped smooth muscle fibers.

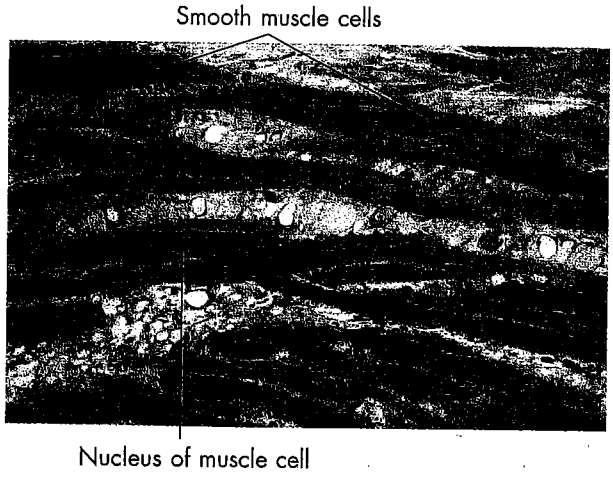
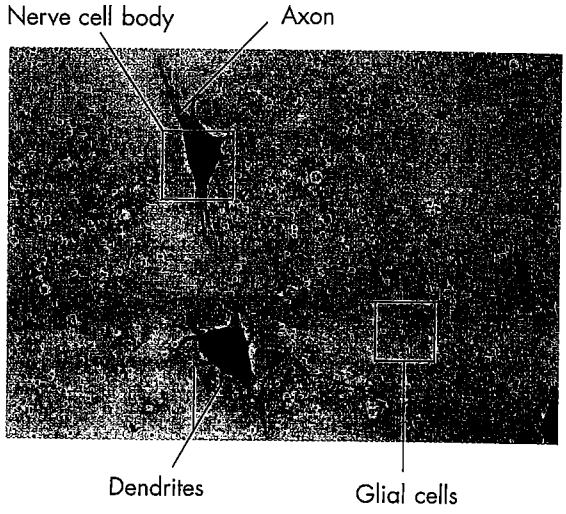


FIGURE 2-22

Nervous tissue. Photomicrograph of neurons in a smear of the spinal cord. Both neurons in this slide show characteristic cell bodies and multiple cell processes.



Nervous Tissue

The function of **nervous tissue** is rapid communication between body structures and control of body functions (Table 2-8). Nervous tissue consists of two kinds of cells: nerve cells, or **neurons** (NOO-rons), which are the functional or conducting units of the system, and special connecting and supporting cells called **glia** (GLEE-ah) or neuroglia.

All neurons are characterized by a **cell body** and two types of processes: one **axon,** which transmits a nerve impulse away from the cell body, and one or more **dendrites** (DEN-drites), which carry impulses toward the cell body. Both neurons in Figure 2-22 have many dendrites extending from the cell body.

TABLE 2-8

Muscle and Nervous Tissue

TISSUE	STRUCTURE	LOCATION(S)	FUNCTION(S)
MUSCLE			
Skeletal (striated (voluntary)	Long, threadlike cells with multiple nuclei and striations	Muscles that attach to bones	Maintenance of posture, movement of bones
		Eyeball muscles	Eye movements
		Upper third of esophagus	First part of swallowing
Cardiac (striated involuntary)	Branching, interconnected cylinders with faint striations	Wall of heart	Contraction of heart
Smooth (nonstriated involuntary or visceral)	Threadlike cells with single nuclei and no striations	Walls of tubular viscera of digestive, respiratory, and genitourinary tracts	Movement of substances along respective tracts
		Walls of blood vessels and large lymphatic vessels	Changing of diameter of vessels
		Ducts of glands	Movement of substances along ducts
		Intrinsic eye muscles (iris and ciliary body)	Changing of diameter of pupils and shape of lens
		Arrector muscles of hairs	Erection of hairs (goose pimples)
NERVOUS			
	Nerve cells with large cell bodies and thin fiber-like extensions; supportive glial cells also present	Brain, spinal cord, nerves	Irritability, conduction