sue type (*areola* = small open space). Because of its loose and fluid nature, areolar connective tissue provides a reservoir of water and salts for the surrounding tissues, and essentially all body cells obtain their nutrients from and release their wastes into this "tissue fluid." When a body region is inflamed, the areolar tissue in the area soaks up the excess fluid like a sponge, and the area swells and becomes puffy, a condition called **edema.** Many types of *phagocytes* wander through this tissue, scavenging for bacteria, dead cells, and other debris, which they destroy.

Adipose Tissue **Adipose** (ad′ĭ-pōs) **tissue** is commonly called *fat.* Basically, it is an areolar tissue in which fat cells predominate (Figure 3.19f). A glistening droplet of stored oil occupies most of a fat cell's volume and compresses the nucleus, displacing it to one side. Since the oil-containing region looks empty and the thin rim of cytoplasm containing the bulging nucleus looks like a ring with a seal, fat cells are sometimes called *signet ring cells.*

Adipose tissue forms the subcutaneous tissue beneath the skin, where it insulates the body and protects it from extremes of both heat and cold. Adipose tissue also protects some organs individually. For example, the kidneys are surrounded by a capsule of fat, and adipose tissue cushions the eyeballs in their sockets. There are also fat "depots" in the body, such as the hips and breasts, where fat is stored and available for fuel if needed.

Reticular Connective Tissue **Reticular connective tissue** consists of a delicate network of interwoven reticular fibers associated with *reticular cells,* which resemble fibroblasts (Figure 3.19g). Reticular tissue is limited to certain sites: it forms the **stroma** (literally, "bed" or "mattress"), or internal framework, which can support many free blood cells (largely lymphocytes) in lymphoid organs such as lymph nodes, the spleen, and bone marrow.

Blood

Blood, or *vascular tissue,* is considered a connective tissue because it consists of *blood cells,* surrounded by a nonliving, fluid matrix called *blood plasma* (Figure 3.19h). The "fibers" of blood are soluble protein molecules that become visible only during blood clotting. Still, we must recognize that blood is quite atypical as connective tissues go. Blood is the transport vehicle for the cardiovascular system, carrying nutrients, wastes, respiratory gases, and many other substances throughout the body. Blood is considered in detail in Chapter 10.

Muscle Tissue

Muscle tissues are highly specialized to *contract,* or *shorten,* to produce movement.

Types of Muscle Tissue

The three types of muscle tissue are illustrated in Figure 3.20. Notice their similarities and differences as you read through the descriptions that follow.

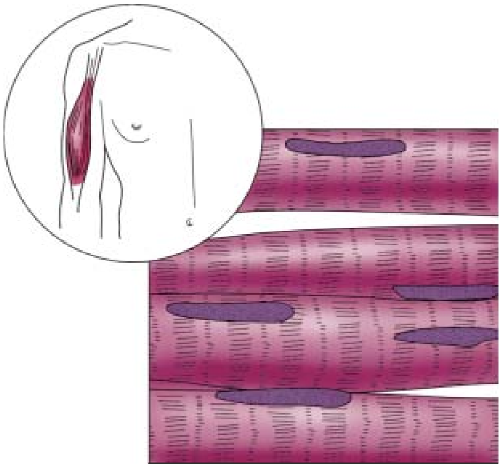
Skeletal Muscle

Skeletal muscle tissue is packaged by connective tissue sheets into organs called *skeletal muscles,* which are attached to the skeleton. These muscles, which can be controlled *voluntarily* (or consciously), form the flesh of the body, the so-called muscular system (see Chapter 6). When the skeletal muscles contract, they pull on bones or skin. The result of their action is gross body movements or changes in our facial expressions. The cells of skeletal muscle are long, cylindrical, multinucleate, and they have obvious *striations* (stripes). Because skeletal muscle cells are elongated to provide a long axis for contraction, they are often called *muscle fibers.*

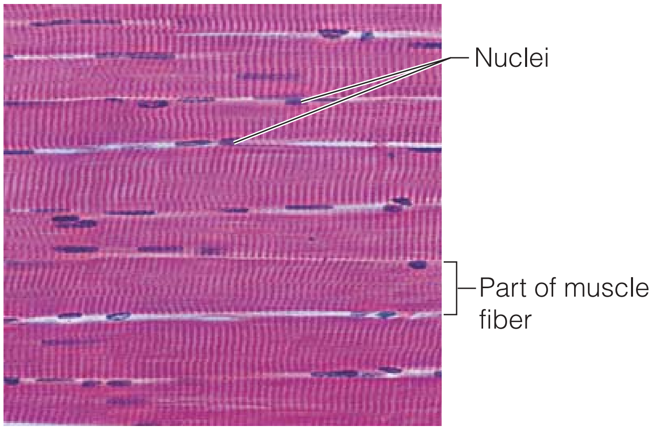
Cardiac Muscle

Cardiac muscle, covered in more detail in Chapter 11, is found only in the heart. As it contracts, the heart acts as a pump and propels blood through the blood vessels. Like skeletal muscle, cardiac muscle has striations, but cardiac cells are uninucleate, relatively short, branching cells that fit tightly together (like clasped fingers) at junctions called **intercalated disks.** These intercalated disks contain gap junctions that allow ions to pass freely from cell to cell, resulting in rapid conduction of the exciting electrical impulse across the heart. Cardiac muscle is under *involuntary control,* which means that we cannot consciously control

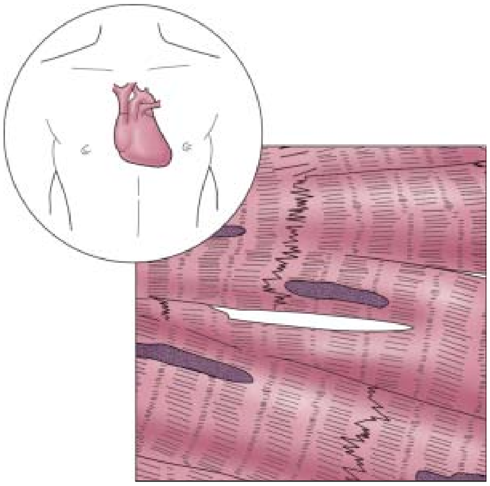
Q *Cell division typically yields two daughter cells, each with one nucleus. How is the multinuclear condition of skeletal muscle explained?*



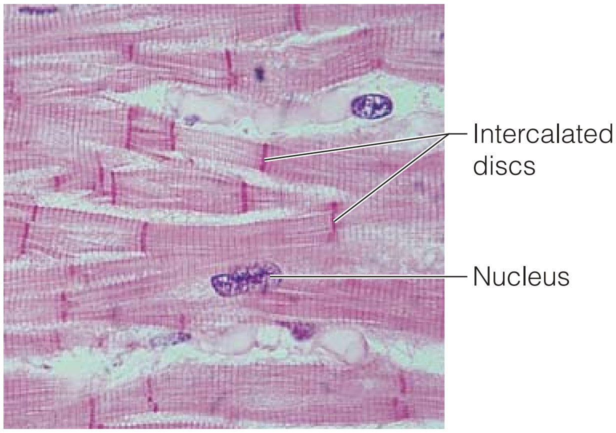
(a) Diagram: Skeletal muscle



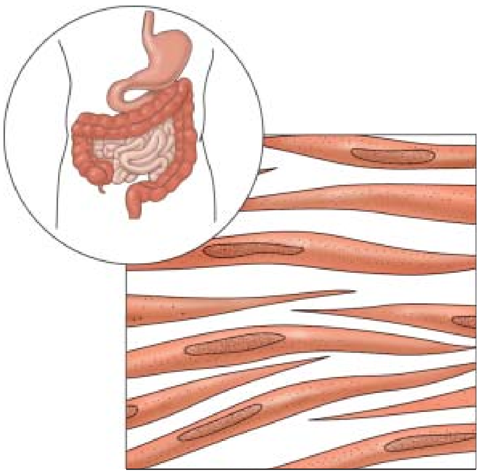
Photomicrograph: Skeletal muscle (approx. 300x).



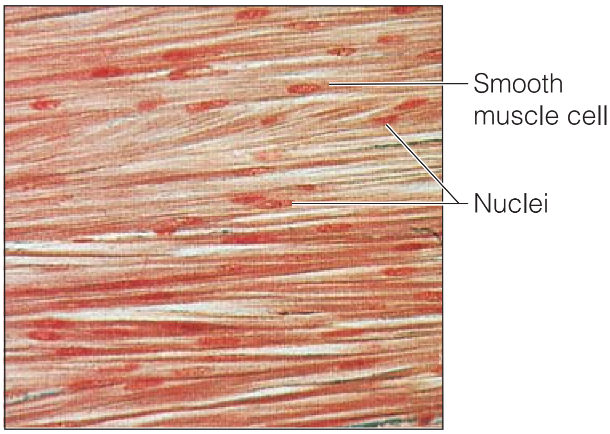
(b) Diagram: Cardiac muscle



Photomicrograph: Cardiac muscle (800x).



(c) Diagram: Smooth muscle



Photomicrograph: Sheet of smooth muscle (approx. 600x).

FIGURE 3.20 Types of muscle tissue and their common locations in the body.

A *Skeletal muscle cells repeatedly undergo mitosis unaccompanied by cytokinesis.*

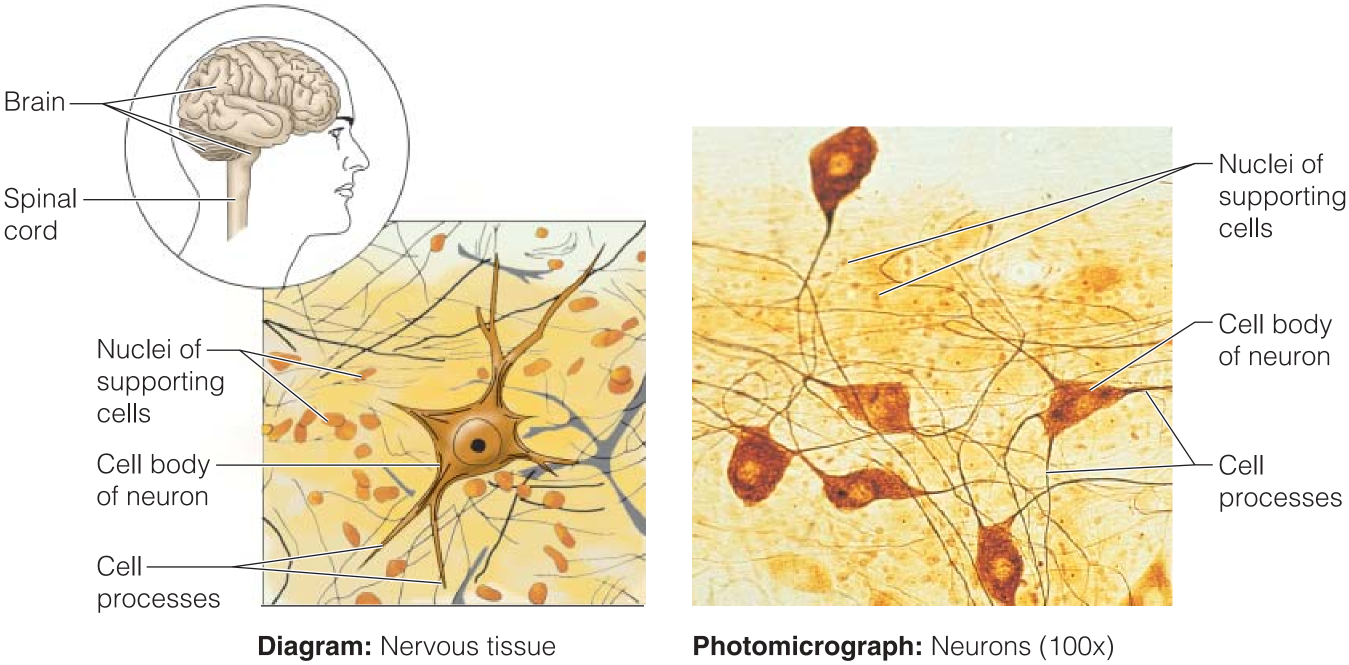


FIGURE 3.21 **Nervous tissue.** Neurons and supporting cells form the brain, spinal cord, and nerves.

the activity of the heart. (There are, however, rare individuals who claim they have such an ability.)

Smooth Muscle

Smooth, or **visceral, muscle** is so called because no striations are visible. The individual cells have a single nucleus and are spindle-shaped (pointed at each end). Smooth muscle is found in the walls of hollow organs such as the stomach, bladder, uterus, and blood vessels. As smooth muscle contracts, the cavity of an organ alternately becomes smaller (constricts on smooth muscle contraction) or enlarges (dilates on smooth muscle relaxation) so that substances are propelled through the organ along a specific pathway. Smooth muscle contracts much more slowly than the other two muscle types. *Peristalsis* (per″ĭ-stal′sis), a wavelike motion that keeps food moving through the small intestine, is typical of its activity.

Nervous Tissue

When we think of **nervous tissue,** we think of cells called **neurons.** All neurons receive and conduct electrochemical impulses from one part of the body to another; thus *irritability* and *conductivity* are their two major functional characteristics. The structure of neurons is unique (Figure 3.21). Their cytoplasm is drawn out into long processes (extensions), as much as 3 feet or more in the leg, which allows a single neuron to conduct an impulse over long distances in the body. Neurons, along with a special group of **supporting cells** that insulate, support, and protect the delicate neurons, make up the structures of the nervous system—the brain, spinal cord, and nerves.

Tissue Repair (Wound Healing)

The body has many techniques for protecting itself from uninvited guests or injury. Intact physical barriers such as the skin and mucous membranes, cilia, and the strong acid produced by stomach glands are just three examples of body defenses exerted at the local tissue level. When tissue injury does occur, it stimulates the body's inflammatory and immune responses, and the healing process begins almost immediately. Inflammation is a generalized (nonspecific) body response that attempts to prevent further injury. The immune response, on the other hand, is extremely specific and mounts a vigorous attack against recognized invaders (bacteria, viruses, toxins). These protective responses are considered in detail in Chapter 12. Here we will concentrate on the process of tissue repair itself.

Tissue repair, or wound healing, occurs in two major ways: by regeneration and by fibrosis. **Regeneration** is the replacement of destroyed tissue by the same kind of cells, whereas **fibrosis** involves repair by dense (fibrous) connective tissue, that is, by the formation of *scar tissue*. Which occurs depends on (1) the type of tissue damaged and (2) the severity of the injury. Generally speaking, clean cuts (incisions) heal much more successfully than ragged tears of the tissue.

Tissue injury sets a series of events into motion.

- **The capillaries become very permeable.** This allows fluid rich in clotting proteins and other substances to seep into the injured area from the bloodstream. Then leaked clotting proteins construct a clot, which stops the loss of blood, holds the edges of the wound together, and walls off the injured area, preventing bacteria or other harmful substances from spreading to surrounding tissues. Where the clot is exposed to air, it quickly dries and hardens, forming a scab.
- **Granulation tissue forms.** *Granulation tissue* is a delicate pink tissue composed largely of new capillaries that grow into the damaged area from undamaged blood vessels nearby. These capillaries are fragile and bleed freely, as when a scab is picked away from a skin wound. Granulation tissue also contains phagocytes that eventually dispose of the blood clot and connective tissue cells (fibroblasts) that synthesize the building blocks of collagen fibers (scar tissue) to permanently bridge the gap.
- **The surface epithelium regenerates.** As the surface epithelium begins to regenerate, it makes its way across the granulation tissue just beneath the scab. The scab soon detaches and the final result is a fully regenerated surface epithelium that covers an underlying area of fibrosis (the scar). The scar is either invisible or visible as a thin white line, depending on the severity of the wound.

The ability of the different tissue types to regenerate varies widely. Epithelial tissues such as the skin epidermis and mucous membranes regenerate beautifully. So, too, do most of the fibrous connective tissues and bone. Skeletal muscle regenerates poorly, if at all, and cardiac muscle and nervous tissue within the brain and spinal cord are replaced largely by scar tissue.

Homeostatic Imbalance

Scar tissue is strong, but it lacks the flexibility of most normal tissues. Perhaps even more important is its inability to perform the normal functions of the tissue it replaces. Thus, if scar tissue forms in the wall of the bladder, heart, or another muscular organ, it may severely hamper the functioning of that organ. ▲

PART III: DEVELOPMENTAL ASPECTS OF CELLS AND TISSUES

We all begin life as a single cell, which divides thousands of times to form our multicellular embryonic body. Very early in embryonic development, the cells begin to specialize to form the primary tissues, and by birth, most organs are well formed and functioning. The body continues to grow and enlarge by forming new tissue throughout childhood and adolescence.

Cell division is extremely important during the body's growth period. Most cells (except neurons) undergo mitosis until the end of puberty, when adult body size is reached and overall body growth ends. After this time, only certain cells routinely divide—for example, cells exposed to abrasion that continually wear away, such as skin and intestinal cells. Liver cells stop dividing; but they retain this ability should some of them die or become damaged and need to be replaced. Still other cell groups (for example, heart muscle and nervous tissue) almost completely lose their ability to divide when they are fully mature; that is, they become *amitotic* (am″ĭ-tot′ik). Amitotic tissues are severely handicapped by injury because the lost cells cannot be replaced by the same type