Outline

Objectives

AFTER YOU HAVE COMPLETED THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. List and discuss the generalized functions of the skeletal system.
2. Identify the major anatomical structures found in a typical long bone.
3. Discuss the microscopic structure of bone and cartilage, including the identification of specific cell types and structural features.
4. Explain how bones are formed, how they grow, and how they are remodeled.
5. Identify the two major subdivisions of the skeleton and list the bones found in each area.
6. List and compare the major types of joints in the body and give an example of each.

The primary organs of the skeletal system, bones, lie buried within the muscles and other soft tissues, providing a rigid framework and support structure for the whole body. In this respect the skeletal system functions like steel girders in a building; however, unlike steel girders, bones can be moved. Bones are also living organs. They can remodel themselves and help the body respond to a changing environment. This ability of bones to change allows our bodies to grow and adapt to new situations.

Our study of the skeletal system will begin with an overview of its function. We will then classify bones by their structure and describe the characteristics of a typical bone. After discussing the microscopic structure of skeletal tissues, we will briefly outline bone growth and formation. With this information, the study of specific bones and the way they are assembled in the skeleton will be more meaningful. The chapter will end with a discussion of skeletal functions and an overview of joints or **articulations** (ar-tick-yoo-LAY-shuns).

An understanding of how bones articulate with one another in joints and how they relate to other body structures provides a basis for understanding the functions of many other organ systems. Coordinated movement, for example, is possible only because of the way bones are joined to one another and because of the way muscles are attached to those bones. In addition, knowing where specific bones are in the body will assist you in locating other body structures that will be discussed later.

FUNCTIONS OF THE SKELETAL SYSTEM

Support

Bones form the body's supporting framework. All the softer tissues of the body literally hang from the skeletal framework.

Protection

Hard, bony "boxes" protect delicate structures enclosed within them. For example, the skull protects the brain. The breastbone and ribs protect vital organs (heart and lungs) and also a vital tissue (red bone marrow, the blood cell–forming tissue).

Movement

Muscles are anchored firmly to bones. As muscles contract and shorten, they pull on bones and thereby move them.

Storage

Bones play an important part in maintaining homeostasis of blood calcium, a vital substance required for normal nerve and muscle function. They serve as a safety-deposit box for calcium. When the amount of calcium in blood increases above normal, calcium moves out of the blood and into the bones for storage. Conversely, when blood calcium decreases below normal, calcium moves in the opposite direction. It comes out of storage in bones and enters the blood.

Hemopoiesis

The term ***hemopoiesis*** (hee-mo-poy-EE-sis) is used to describe the process of blood cell formation. It is a combination of two Greek words: *hemo* (HEE-mo) meaning "blood" and *poiesis* (poy-EE-sis) meaning "to make." Blood cell formation is a vital process carried on in **red bone marrow.** Red bone marrow is soft connective tissue inside the hard walls of some bones.

TYPES OF BONES

There are four types of bones. Their names suggest their shapes: *long* (for example, humerus or upper arm bone), *short* (for example, carpals or wrist bones), *flat* (for example, frontal or skull bone), and *irregular* (for example, vertebrae or spinal bones). Many important bones in the skeleton are classified as long bones, and all have several common characteristics. By studying a typical long bone, you can become familiar with the structural features of the entire group.

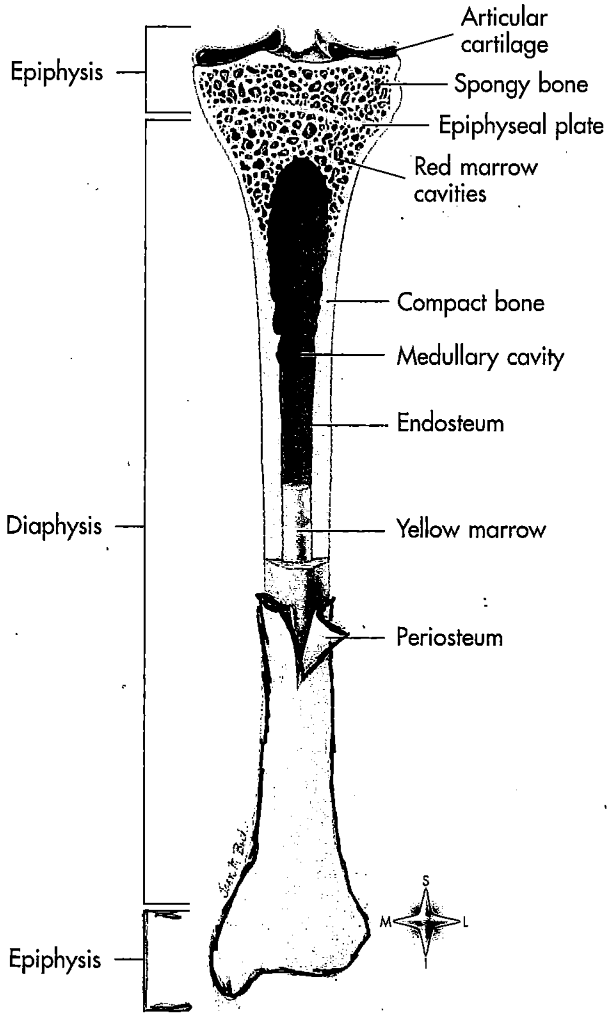
STRUCTURE OF LONG BONES

Figure 5-1 will help you learn the names of the main parts of a long bone. Identify each of the following:

1. **Diaphysis** (dye-AF-i-sis) or shaft—a hollow tube made of hard compact bone, hence a rigid and strong structure light enough in weight to permit easy movement
2. **Medullary cavity**—the hollow area inside the diaphysis of a bone; contains soft **yellow bone marrow,** an inactive, fatty form of marrow found in the adult skeleton
3. **Epiphyses** (e-PIF-i-sees) or the ends of the bone—red bone marrow fills in small spaces in the spongy bone composing the epiphyses
4. **Articular cartilage**—a thin layer of cartilage covering each epiphysis; functions like a

FIGURE 5-1

Longitudinal section of a long bone.



small rubber cushion would if it were placed over the ends of bones where they form a joint

5. **Periosteum**—a strong fibrous membrane covering a long bone except at joint surfaces, where it is covered by articular cartilage
6. **Endosteum**—a fibrous membrane that lines the medullary cavity

MICROSCOPIC STRUCTURE OF BONE AND CARTILAGE

The skeletal system contains two major types of connective tissue: **bone** and **cartilage.** Bone has different appearances and textures, depending on its location. In Figure 5-2, *A,* the outer layer of bone is hard and dense. Bone of this type is called **dense** or **compact bone.** The porous bone in the end of the long bone is called *spongy bone.* As the name implies, spongy bone contains many spaces that may be filled with marrow. Compact or dense bone appears solid to the naked eye. Figure 5-2, *B,* shows the microscopic appearance of spongy and compact bone. The needlelike threads of spongy bone that surround a network of spaces are called **trabeculae** (trah-BEK-yoo-lee).

As you can see in Figures 5-2 and 5-3, compact or dense bone does not contain a network of open spaces. Instead, the matrix is organized into numerous structural units called **osteons** or *Haversian systems.* Each circular and tubelike osteon is composed of calcified matrix arranged in multiple layers resembling the rings of an onion. Each ring is called a **concentric lamella** (lah-MEL-ah). The circular rings or lamellae surround the **central canal,** which contains a blood vessel.

Bones are not lifeless structures. Within their hard, seemingly lifeless matrix are many living bone cells called **osteocytes** (OS-tee-o-sites). Osteocytes lie between the hard layers of the lamellae in little spaces called **lacunae** (lah-KOO-nee). In Figures 5-2, *B,* and 5-3, note that tiny passageways or canals called **canaliculi** (kan-ah-LIK-yoo-lye) connect the lacunae with one other and with the central canal in each Haversian system. Nutrients pass from the blood vessel in the Haversian canal through the canaliculi to the osteocytes. Note also in Figure 5-2, *B,* that numerous blood vessels from the outer **periosteum** (pair-ee-OS-tee-um) enter the bone and eventually pass through the Haversian canals.

Cartilage both resembles and differs from bone. Like bone, it consists more of intercellular substance than of cells. Innumerable collagenous fibers reinforce the matrix of both tissues. However, in cartilage the fibers are embedded in

FIGURE 5-2

Microscopic structure of bone. A, Longitudinal section of a long bone shows the location of the microscopic section illustrated in **B.** Note that the compact bone forming the hard shell of the bone is constructed of cylindrical units called *osteons.* Spongy bone is constructed of bony projections called *trabeculae.*

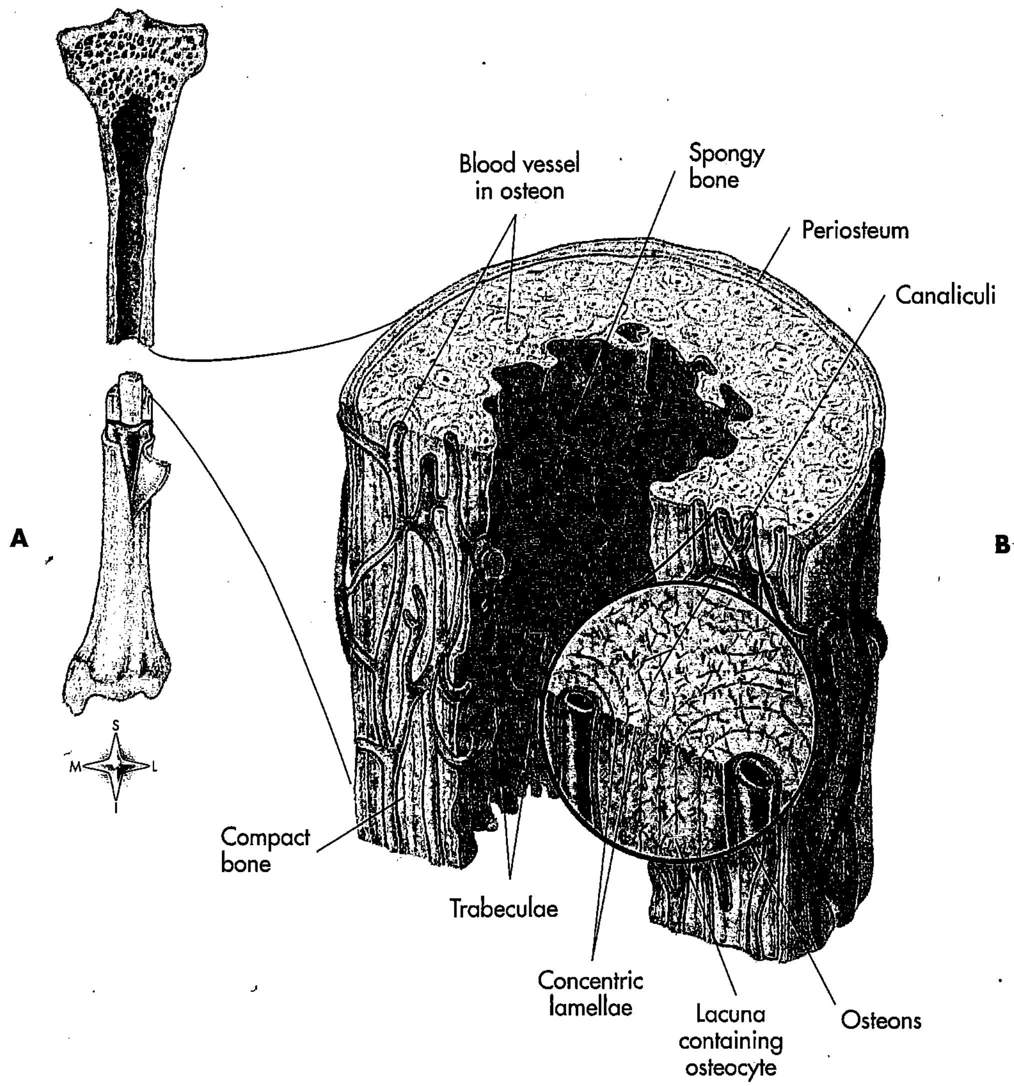


FIGURE 5-3

Compact bone. Photomicrograph shows osteon system of organization.

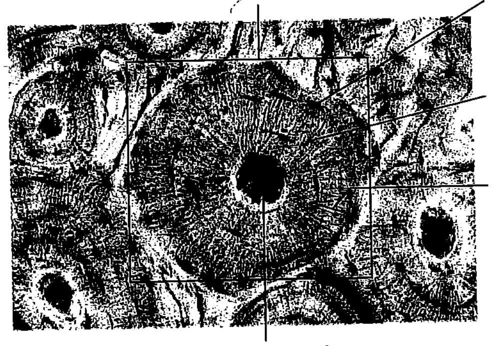
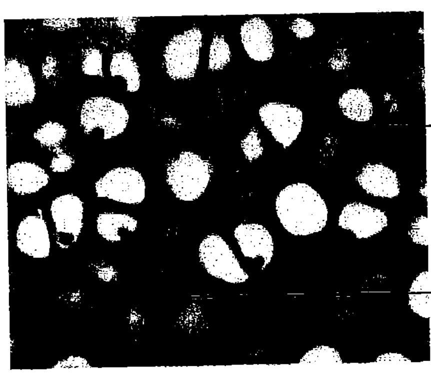


FIGURE 5-4

Cartilage tissue. Photomicrograph shows chondrocytes scattered around the tissue in spaces called *lacunae.*



a firm gel instead of in a calcified cement substance like they are in bone; hence cartilage has the flexibility of a firm plastic rather than the rigidity of bone. Note in Figure 5-4 that cartilage cells, called **chondrocytes** (kon-dro-sites), like the osteocytes of bone, are located in lacunae. In cartilage, lacunae are suspended in the cartilage matrix much like air bubbles in a block of firm gelatin. Because there are no blood vessels in cartilage, nutrients must diffuse through the matrix to reach the cells. Because of this lack of blood vessels, cartilage rebuilds itself very slowly after an injury.

BONE FORMATION AND GROWTH

When the skeleton begins to form in a baby before its birth, it consists not of bones but of cartilage and fibrous structures shaped like bones. Gradually these cartilage "models" become transformed into real bones when the cartilage is replaced with calcified bone matrix. This process of constantly "remodeling" a growing bone as it changes from a small cartilage model to the characteristic shape and proportion of the adult bone requires continuous activity by bone-forming cells called **osteoblasts** (OS-tee-o-blasts) and bone-resorbing cells called **osteoclasts** (OS-tee-o-clasts). The laying down of calcium salts in the gel-like matrix of the forming bones is an ongoing process. This calcification process is what makes bones as "hard as bone." The combined action of the osteoblasts and osteoclasts sculpts bones into their adult shapes (Figure 5-5). The process of "sculpting" by the bone-forming and bone-resorbing cells allows bones to respond to stress or injury by changing size, shape, and density. The stresses placed on certain bones during exercise increase the rate of bone deposition. For this reason, athletes or dancers may have denser, stronger bones than less active people.

Most bones of the body are formed from cartilage models as illustrated in Figures 5-5 and 5-6. This process is called **endochondral** (en-doe-KON-dral) **ossification** (os-i-fi-KAY-shun), meaning "formed in cartilage." A few flat bones, such as the skull bones illustrated in Figure 5-6, are formed by another process in connective tissue membranes.

As you can see in Figure 5-5, a long bone grows and ultimately becomes "ossified" from small centers located in both ends of the bone, called **epiphyses,** and from a larger center located in the shaft or the **diaphysis** of the bone. As long as any

FIGURE 5-5

Endochondral ossification. A, Bone formation begins with a cartilage model. **B** and **C,** Invasion of the diaphysis (shaft) by blood vessels and the combined action of osteoblast and osteoclast cells result in cavity formation, calcification, and the appearance of bone tissue. **D** and **E,** centers of ossification also appear in the epiphyses (ends) of the bone. **F,** Note the epiphyseal plate, indications that this bone is not yet mature and that additional growth is possible. **G,** In a mature bone, only a faint epiphyseal line marks where the cartilage has disappeared and the centers of ossification have fused together.

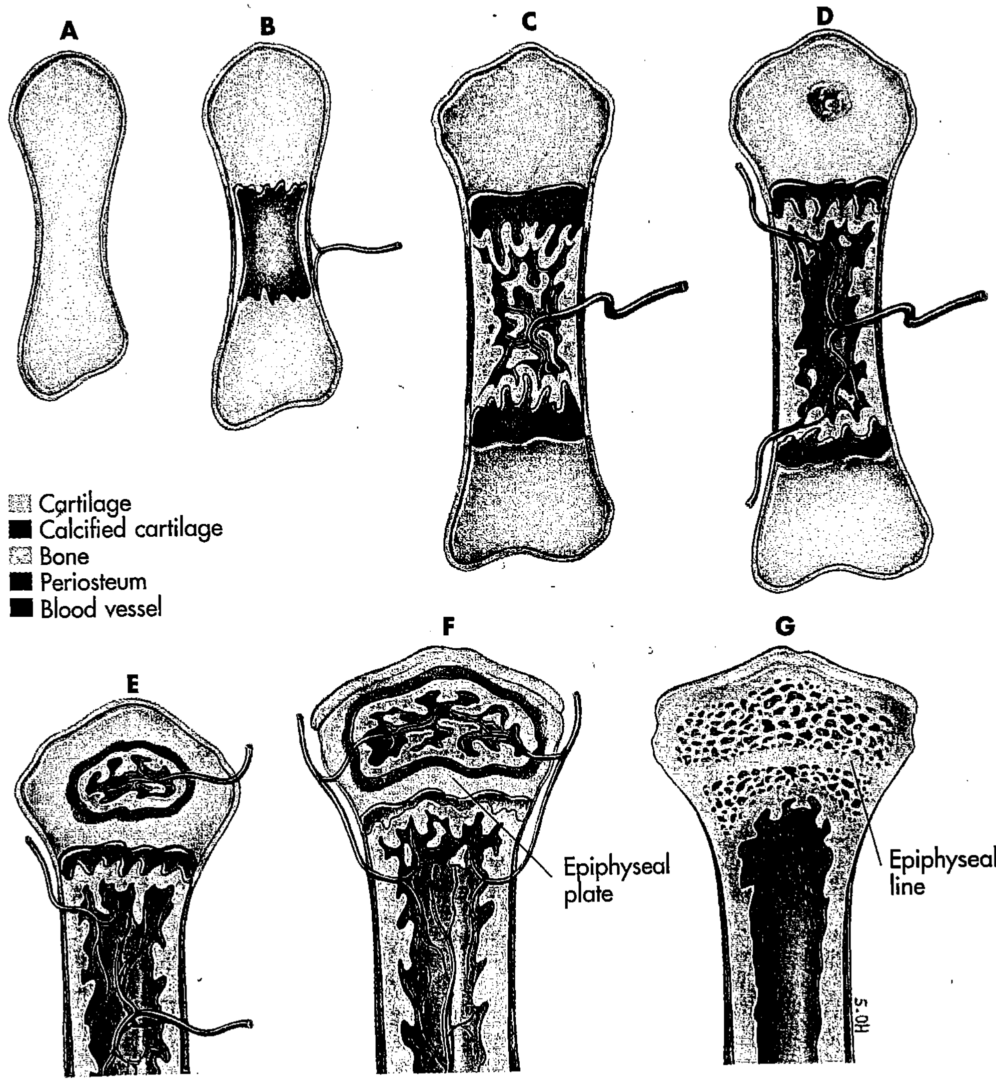
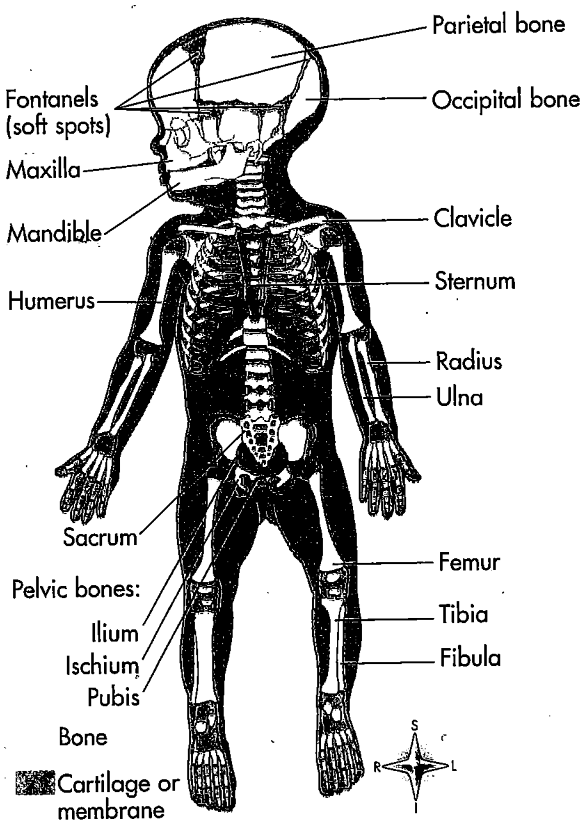


FIGURE 5-6

Bone development in a newborn. An infant's skeleton has many bones that are not yet completely ossified.



cartilage, called an **epiphyseal plate,** remains between the epiphyses and the diaphysis, growth continues. Growth ceases when all epiphyseal cartilage is transformed into bone. All that remains is an *epiphyseal line* that marks the location where the two centers of ossification have fused together. Physicians sometimes use this knowledge to determine whether a child is going to grow any more. They have an x-ray study performed on the child's wrist, and if it shows a layer of epiphyseal cartilage, they know that additional growth will occur. However, if it shows no epiphyseal cartilage, they know that growth has stopped and that the individual has attained adult height.

HEALTH & WELL-BEING

Osteoporosis

Osteoporosis (os-tee-o-po-RO-sis) is one of the most common and serious of all bone diseases. It is characterized by excessive loss of calcified matrix and collagenous fibers from bone. Osteoporosis occurs most frequently in elderly white females. Although white and black males are also susceptible, black women are seldom affected by it.

Because sex hormones play important roles in stimulating osteoblast activity after puberty, decreasing levels of these hormones in the blood of elderly persons reduces new bone growth and the maintenance of existing bone mass. Therefore some resorption of bone and subsequent loss of bone mass is an accepted consequence of advancing years. However, bone loss in osteoporosis goes far beyond the modest decrease normally seen in old age. The result is a dangerous pathological condition resulting in bone degeneration, increased susceptibility to "spontaneous fractures," and pathological curvature of the spine. Treatment may include sex hormone therapy and dietary supplements of calcium and vitamin D to replace deficiencies or to offset intestinal malabsorption.

Divisions of Skeleton

The human skeleton has two divisions: the **axial skeleton** and the **appendicular skeleton.** Bones of the center or axis of the body make up the axial skeleton. The bones of the skull, spine, and chest and the hyoid bone in the neck are all in the axial skeleton. The bones of the upper and lower extremities or appendages make up the appendicular skeleton. The appendicular skeleton consists of the bones of the upper extremities (shoulder, pectoral girdles, arms, wrists, and hands) and the lower extremities (hip, pelvic girdles, legs, ankles, and feet) (Table 5-1). Locate the various parts of the axial skeleton and the appendicular skeleton in Figure 5-7.