36–1 The Skeletal System

To retain their shapes, all organisms need some type of structural support. Unicellular organisms have a cytoskeleton that provides structural support. In multicellular animals, support is provided by some form of skeleton, including the external exoskeletons of arthropods and the internal endoskeletons of vertebrates. The human skeleton is composed of a type of connective tissue called bone. Bones and other connective tissues, such as cartilage and ligaments, form the skeletal system.

Scientists can infer a lot about the behavior of extinct species by studying fossil bones and reconstructing skeletons. The human skeleton also contains important clues. The shape of your hip bones shows that you walk upright on two legs. The structure of the bones in your hands, especially your opposable thumbs, indicates that you have the ability to grasp objects. The size and shape of your skull is a clue that you have a well-developed brain.

Guide for Reading

Key Concepts

- What are the functions of the skeletal system?
- What is the structure of a typical bone?
- What are the three different kinds of joints?

Vocabulary

periosteum
Haversian canal
bone marrow
cartilage
ossification
joint
ligament

Reading Strategy: Asking Questions Before you read, rewrite the headings in this section as *how, why,* or *what* questions about the skeletal system. As you read, write brief answers to those heading questions.

The Skeleton

The skeletal system has many important functions. **The skeleton supports the body, protects internal organs, provides for movement, stores mineral reserves, and provides a site for blood cell formation.** The bones that make up the skeletal system support and shape the body much like an internal wooden frame supports a house. Just as a house could not stand without its wooden frame, the human body would collapse without its bony skeleton. Bones protect the delicate internal organs of the body. For example, the skull forms a protective shell around the brain, and the ribs form a basketlike cage that protects the heart and lungs.

Bones provide a system of levers on which muscles act to produce movement. Levers are rigid rods that can be moved about a fixed point. In addition, bones contain reserves of minerals, mainly calcium salts, that are important to many body processes. Finally, bones are the site of blood cell formation. Blood cells are produced in the soft marrow tissue that fills the internal cavities in some bones.

There are 206 bones in the adult human skeleton. As shown in **Figure 36–2** on page 922, these bones can be divided into two parts—the axial skeleton and the appendicular skeleton. The axial skeleton supports the central axis of the body. It consists of the skull, the vertebral column, and the rib cage. The bones of the arms and legs, along with the bones of the pelvis and shoulder area, form the appendicular skeleton.

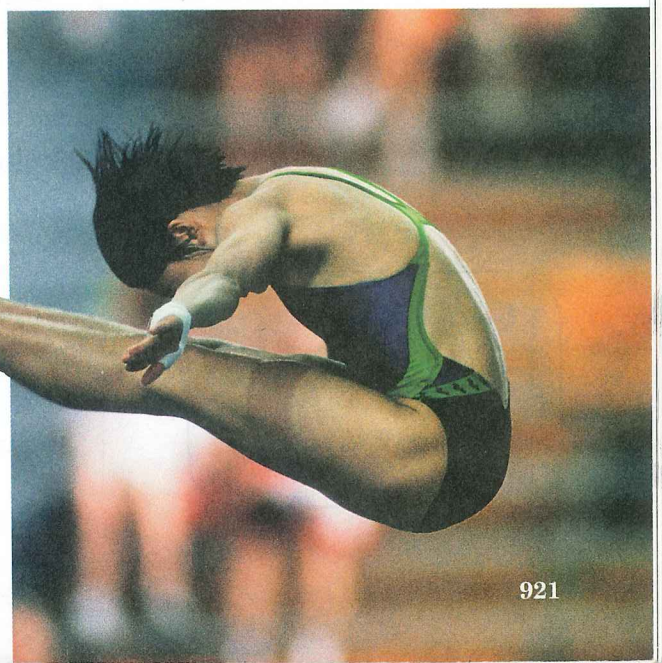
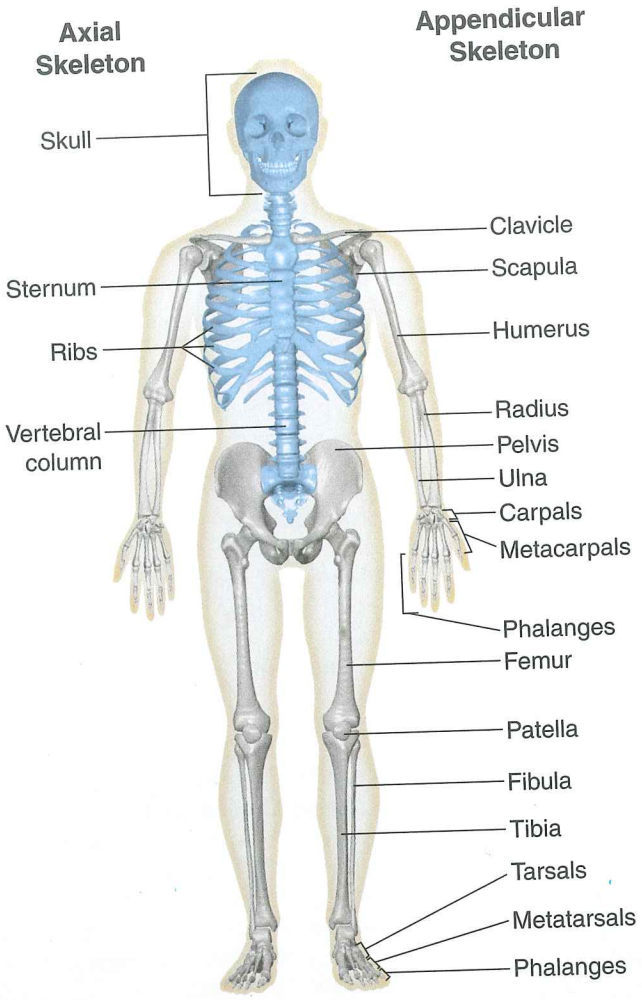


Figure 36–1 Bones provide a system of levers on which muscles act to produce movement. Without this coordination, movement would not be possible.



▲ **Figure 36–2** **The skeleton supports the body.** The human skeleton is divided into two parts: the axial skeleton and the appendicular skeleton.

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Structure of Bones

It is easy to think of bones as nonliving. After all, most of the mass of bone is mineral salts—mainly calcium and phosphorus. However, bones are living tissue. **Bones are a solid network of living cells and protein fibers that are surrounded by deposits of calcium salts.**

Figure 36–3 shows the structure of a typical bone. The bone is surrounded by a tough layer of connective tissue called the **periosteum** (pehr-ee-AHS-tee-um). Blood vessels that pass through the periosteum carry oxygen and nutrients to the bone. Beneath the periosteum is a thick layer of compact bone. Although compact bone is dense, it is far from being solid. Running through compact bone is a network of tubes called **Haversian** (huh-VUR-zhun) **canals** that contain blood vessels and nerves.

A less dense tissue known as spongy bone is found inside the outer layer of compact bone. It is found in the ends of long bones and in the middle part of short, flat bones. Despite its name, spongy bone is not soft and spongy; it is actually quite strong. Near the ends of bones where force is applied, spongy bone is organized into structures that resemble the supporting girders in a bridge. This latticework structure of spongy bone helps to add strength to bone without adding mass.

Osteocytes, which are mature bone cells, are embedded in the bone matrix. Two other kinds of bone cells—osteoclasts (AHS-tee-oh-klasts) and osteoblasts line the Haversian canals and the surfaces of compact and spongy bone. Osteoclasts break down bone. Osteoblasts produce bone. Although we stop growing in our late teens, our bones are continuously remodeled through the activity of osteoclasts and osteoblasts.

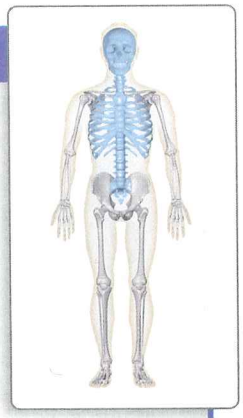
Within bones are cavities that contain a soft tissue called **bone marrow.** There are two types of bone marrow: yellow and red. Yellow marrow is made up primarily of fat cells. Red marrow produces red blood cells, some kinds of white blood cells, and cell fragments called platelets.

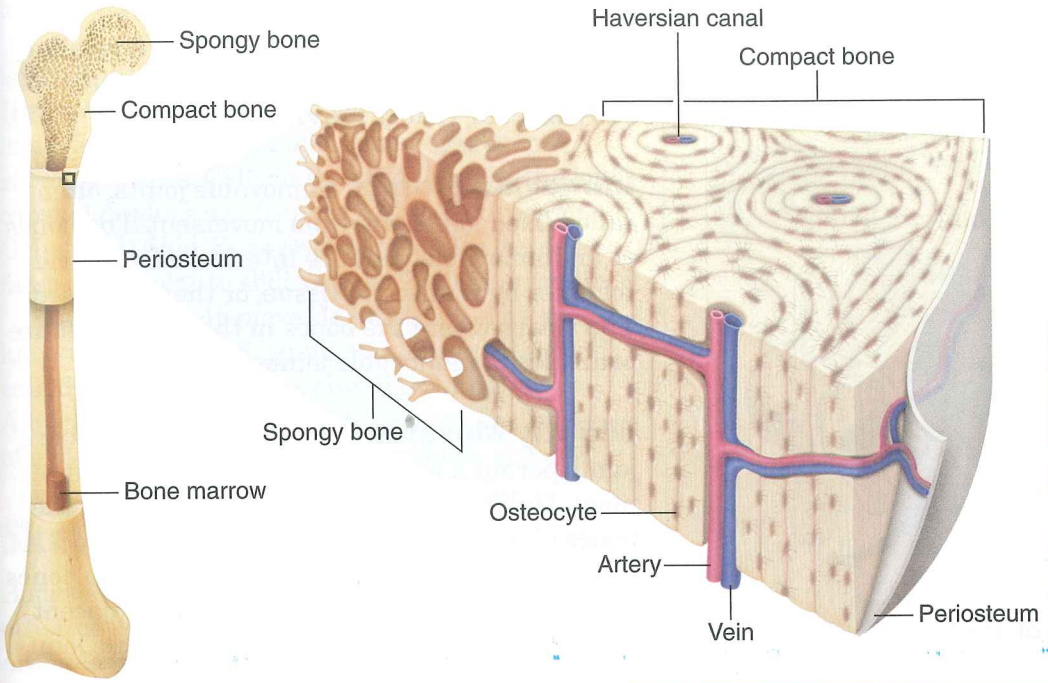
Development of Bones

The skeleton of an embryo is composed almost entirely of a type of connective tissue called **cartilage.** The cells that make up cartilage are scattered in a network of protein fibers including both tough collagen and flexible elastin.

FIGURE 36–3 STRUCTURE OF A BONE

Bones are a solid network of living cells and protein fibers that are supported by deposits of calcium salts. A typical long bone such as the femur contains spongy bone and compact bone. Within compact bone are Haversian canals, which contain blood vessels.





Haversian Canal
(magnification: 200×)

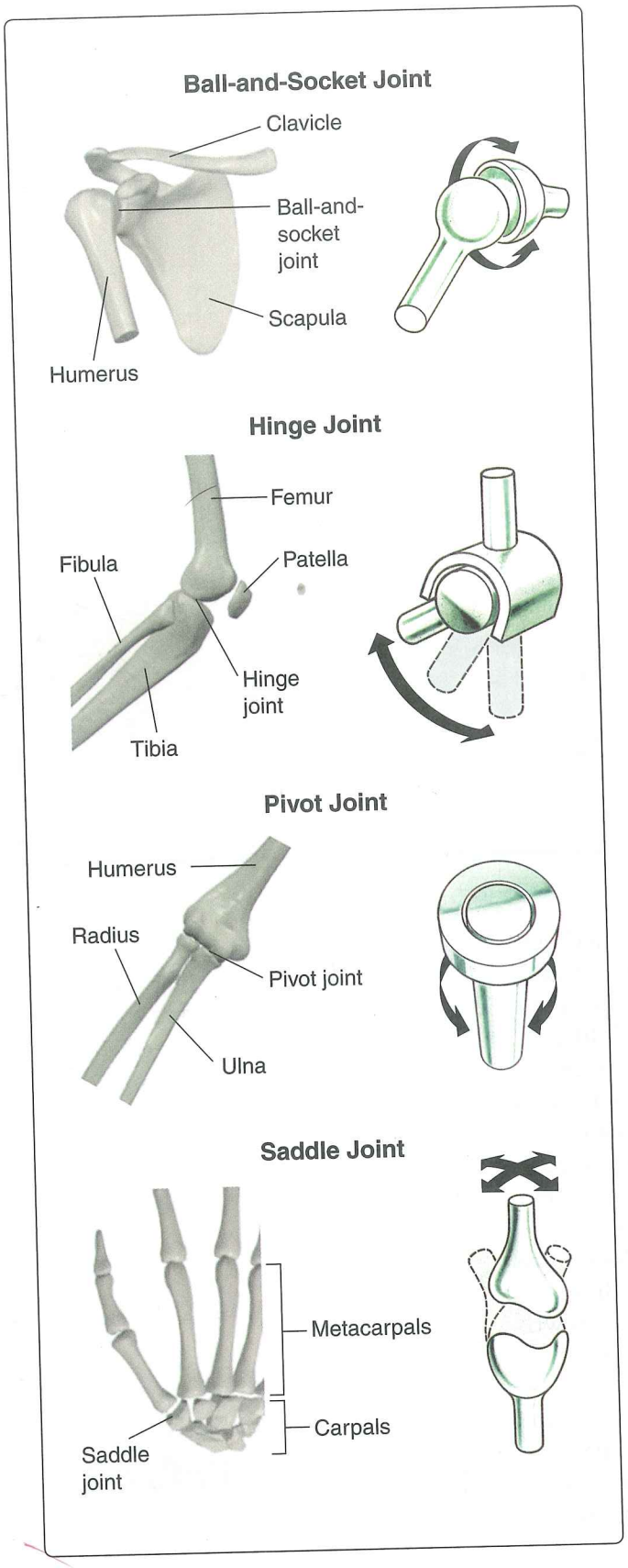
Unlike bone, cartilage does not contain blood vessels. Cartilage cells must rely on the diffusion of nutrients from the tiny blood vessels in surrounding tissues. Because cartilage is dense and fibrous, it can support weight, despite its extreme flexibility.

Cartilage is replaced by bone during the process of bone formation called **ossification** (ahs-uh-fih-KAY-shun). Ossification begins to take place up to seven months before birth. Bone tissue forms as osteoblasts secrete mineral deposits that replace the cartilage in developing bones. When the osteoblasts become surrounded by bone tissue, they mature into osteocytes.

Many long bones, including those of the arms and legs, have growth plates at either end. The growth of cartilage at these plates causes the bones to lengthen. Gradually, this new growth of cartilage is replaced by bone tissue, and the bones become larger and stronger. During late adolescence or early adulthood, the cartilage in the growth plates is replaced by bone, the bones become completely ossified, and the person "stops growing."

In adults, cartilage is found in those parts of the body that are flexible, such as the tip of the nose and the external ears. Cartilage also is found where the ribs are attached to the sternum, which allows the rib cage to move during breathing.

CHECKPOINT *What is ossification?*



▲ **Figure 36–4** **Freely movable joints are classified by the type of movement they permit.** The joints illustrated are in the shoulder, knee, elbow, and hand.

Types of Joints

A place where one bone attaches to another bone is called a **joint.** Joints permit bones to move without damaging each other. Some joints, such as those of the shoulder, allow extensive movement. Others, like the joints of the fully developed skull, allow no movement at all.

Depending on its type of movement, a joint is classified as immovable, slightly movable, or freely movable.

Immovable Joints Immovable joints, often called fixed joints, allow no movement. The bones at an immovable joint are interlocked and held together by connective tissue, or they are fused. The places where the bones in the skull meet are examples of immovable joints.

Slightly Movable Joints Slightly movable joints permit a small amount of restricted movement. Unlike the bones of immovable joints, the bones of slightly movable joints are separated from each other. The joints between the two bones of the lower leg and the joints between adjacent vertebrae are examples of slightly movable joints.

Freely Movable Joints Freely movable joints permit movement in one or more directions. Freely movable joints are grouped according to the shapes of the surfaces of the adjacent bones. The most common types of freely movable joints are shown in **Figure 36–4.**

Ball-and-socket joints permit movement in many directions. They allow the widest range of movement of any joint. Hinge joints permit back-and-forth motion, like the opening and closing of a door. Pivot joints allow one bone to rotate around another. Saddle joints permit one bone to slide in two directions.

CHECKPOINT *What are the four common types of freely movable joints?*

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Structure of Joints

In freely movable joints, cartilage covers the surfaces where two bones come together. This protects the bones as they move against each other. The joints are also surrounded by a fibrous joint capsule that helps hold the bones together while still allowing them to move.

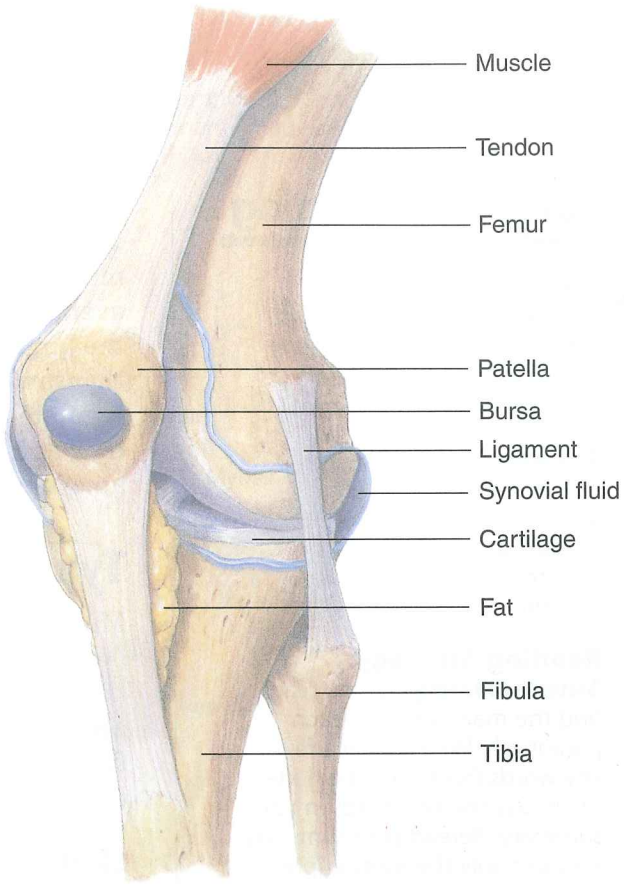
The joint capsule consists of two layers. One layer forms strips of tough connective tissue called **ligaments.** Ligaments, which hold bones together in a joint, are attached to the membranes that surround bones. Cells in the other layer of the joint capsule produce a substance called synovial (sin-OH-vee-ul) fluid. Synovial fluid enables the surfaces of the joint to slide over each other smoothly.

In some freely movable joints, such as the knee in **Figure 36–5,** small sacs of synovial fluid called bursae (BUR-see; singular: bursa) form. A bursa reduces the friction between the bones of a joint and also acts as a tiny shock absorber.

Skeletal System Disorders

Bones and joints can be damaged, just like any other tissue. Excessive strain on a joint may produce inflammation, a response in which excess fluid causes swelling, pain, heat, and redness. Inflammation of a bursa is called bursitis. A more serious disorder is arthritis, which involves inflammation of the joint itself.

In older people, especially women, loss of calcium in the bones can lead to a condition known as osteoporosis. Osteoporosis is a weakening of the bones that can cause serious fractures. Sound nutrition, including plenty of calcium in the diet, and weight-bearing exercise are among the best ways to prevent this serious problem.



▲ **Figure 36–5** The knee joint is protected by cartilage and bursae. The ligaments hold the bones composing the knee joint—femur, patella, tibia, and fibula—together. **Inferring** ***How do the cartilage and bursae help reduce friction?***

36–1 Section Assessment

1. **Key Concept** List the different functions of the skeletal system.
2. **Key Concept** Describe the structure of a typical bone.
3. **Key Concept** What is a joint? List the three types of joints.
4. How does compact bone differ from spongy bone?
5. **Critical Thinking Inferring** Why do you think the amount of cartilage decreases and the amount of bone increases as a person develops?

Writing in Science

Creative Writing

Use library or Internet resources to find out more about osteoporosis. Then, develop an advertising campaign for the dairy industry based on the relationship between milk and healthy bone development.