The skeletal system serves as a framework for the support of the body and for the protection of delicate organs such as the brain, spinal cord, heart, and lungs. Bones serve as levers and, with the muscular system, produce movement. The bones are also storage areas for minerals, especially calcium and phosphorus. Bone marrow is involved in blood cell production.

20C-1 Objectives

- Identify the major bones of the human body
- Describe the anatomy of a typical long bone
- Explain how bones grow in length and diameter

20C-1 Bone Anatomy and Physiology

The adult human skeleton consists of approximately 206 bones grouped in two principal divisions—the axial and the appendicular skeletons. The *axial skeleton* is based around the imaginary vertical centerline of the body (the axis). The axial skeleton includes the bones of the skull, the ribs, the sternum, and the vertebral column, which total 80 bones. The bones of the extremities (arms and legs) and the bones of the pectoral and pelvic girdles make up the *appendicular skeleton*. There are 126 bones in the appendicular skeleton.

The bones of an adult human can be classified according to shape. The bones of the arms and legs are long bones, while the bones of the wrists and ankles are short bones. Inside the skull are several irregularly shaped bones, and the ribs and top part of the skull are good examples of flat bones. Some anatomists recognize a fifth type of bone—*sesamoid* or round bones—that are usually somewhat rounded and embedded within the tendons located next to joints. The patella, or kneecap, is an example of a sesamoid bone.

diaphysis: dia- (Gk. DIA, through) + -physis (PHYSES, growth)

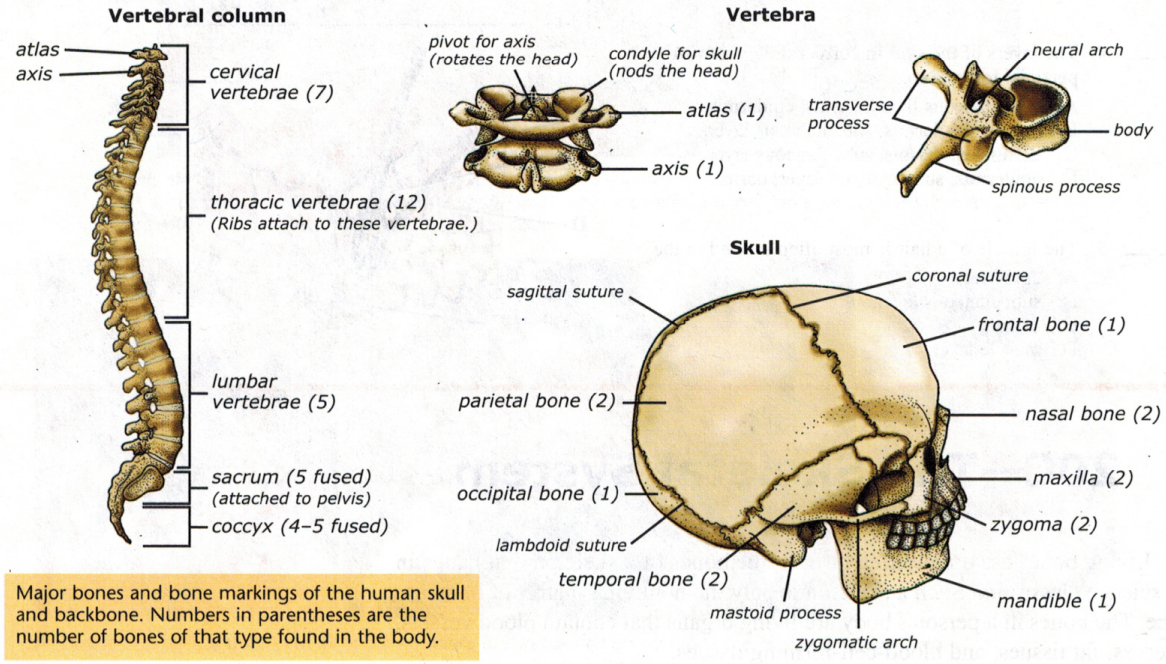
epiphysis: epi- (upon) + -physis (growth)

articular: (L. ARTICULUS, small joint)

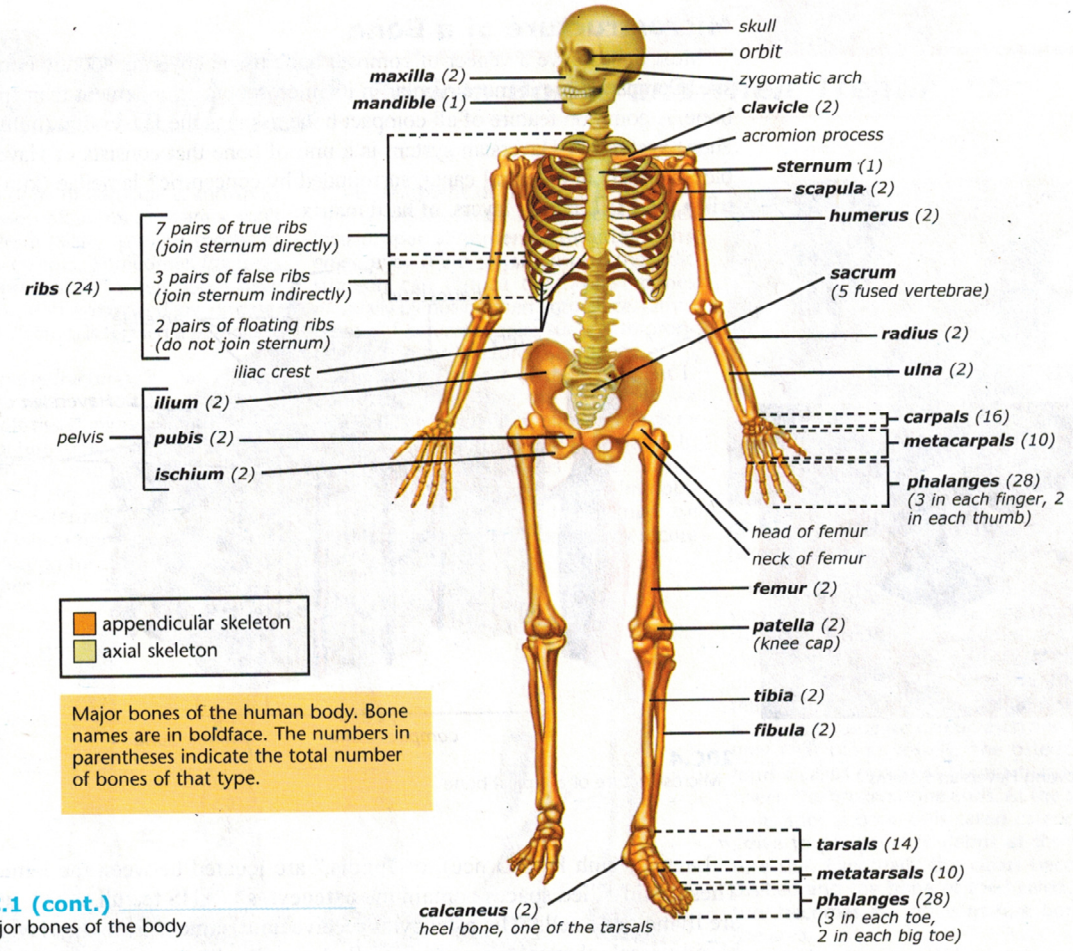
A long bone has two basic regions: the **diaphysis*** (die AF ih sis), or shaft, which is the long main portion, and the **epiphyses*** (ih PIF ih SEEZ), the ends of the bone. Between the diaphysis and each epiphysis is a thin internal layer of cartilage tissue called the **epiphyseal** (EP uh FIZ ee ul) **plate** or growth plate.

The surfaces of the epiphyses are covered with a thin layer of smooth bluish white **articular*** (ar TIK yuh lur) **cartilage**. This cartilage layer provides for smooth movement at the joints during activities such as swimming and for cushioning when one returns to the gym floor after a jump shot.

20C.1
Major bones of the body



Major bones and bone markings of the human skull and backbone. Numbers in parentheses are the number of bones of that type found in the body.



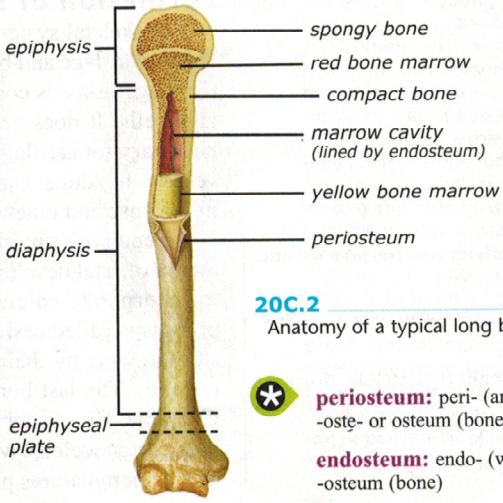
Major bones of the human body. Bone names are in boldface. The numbers in parentheses indicate the total number of bones of that type.

20C.1 (cont.)
Major bones of the body

The diaphysis of the bone is covered with a layer of dense white fibrous tissue called the **periosteum*** (pehr ee AHS tee um), which is responsible for muscle attachment and for bone growth and repair.

Fibers firmly anchor the periosteum to the bone. The diaphysis of the bone is made of compact bone that surrounds a hollow center called the marrow cavity. This cavity usually extends the entire length of the diaphysis. The lining of the marrow cavity is the **endosteum*** (en DAHS tee um) and, like the periosteum, is involved in bone growth and repair. In young people this cavity is filled mostly with **red bone marrow**, a soft tissue that produces red blood cells and certain other blood cells. **Yellow bone marrow** is fatty tissue that gradually replaces the red bone marrow as people grow older.

The ends of a long bone contain **spongy bone**. Spongy bone is sturdy but contains many small spaces that make it look like a sponge. These spaces are filled with red bone marrow and some fat. Red bone marrow in the ends of some long bones retains its blood-producing abilities throughout an individual's lifetime.

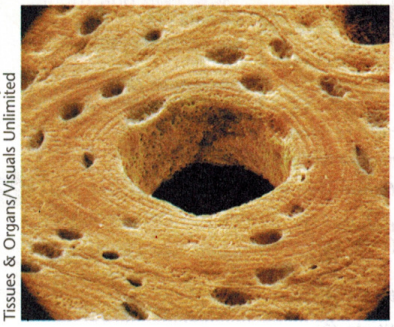


20C.2
Anatomy of a typical long bone

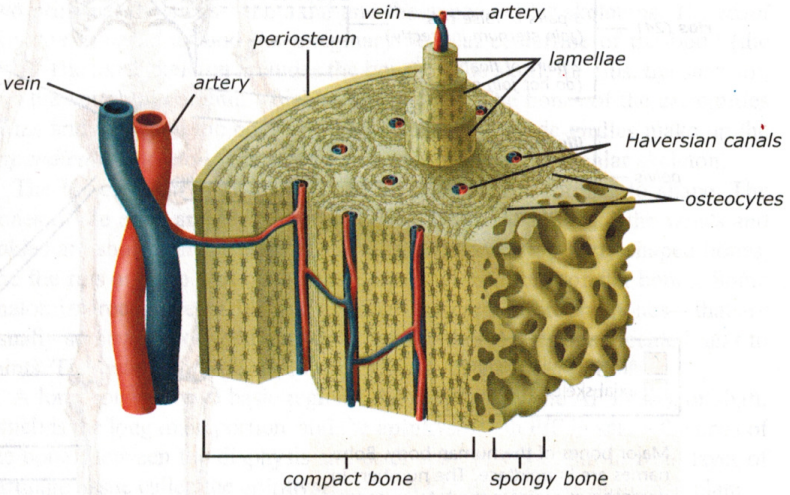
* **periosteum:** peri- (around) + -oste- or osteum (bone)
endosteum: endo- (within) + -osteum (bone)

Microstructure of a Bone

Most bones have a veneer of compact bone tissue covering spongy bone tissue. Compact bone is more regular in its microscopic arrangement than spongy bone. A common feature of all compact bone tissue is the **Haversian** (huh VUR zhun) **system**. A Haversian system is a unit of bone that consists of Haversian blood vessels in a central canal, surrounded by concentric* lamellae (kun SEN trik • luh MEL EE), or layers, of hard matrix.



20C.3
SEM showing Haversian systems



20C.4
Microstructure of a typical bone

Lacunae (luh KYOO nee), or "pools," are located between the lamellae. These fluid-filled spaces contain the **osteocytes*** (AHS tee uh SITES), which are living bone cells. The osteocytes receive nourishment from the Haversian blood vessels through tiny canals called *canaliculi** (KAN uh LIK yuh lye). Since several canaliculi open into each lacuna, the osteocytes are continually bathed with nutritive fluid from the Haversian blood vessels.

Formation of Bone Tissue

The skeletal system of an adult human consists of two types of connective tissue: cartilage and bone. Bone gives rigid support, while cartilage is flexible. Cartilage tissue is composed of a soft fibrous matrix that surrounds the cartilage cells. It does not usually contain blood vessels; however, the nutrients necessary for cartilage cells can diffuse through the matrix from nearby blood vessels. In adults, cartilage is found primarily on the ends of long bones and in the nose and outer ear. It also attaches the ribs to the sternum.

An embryo's tiny skeleton is composed mostly of cartilage. During the third month of fetal development, the osteocytes in the cartilaginous skeleton begin to incorporate calcium and other minerals into the cartilage matrix; this process is called **ossification*** (AHS uh fih KAY shun). Although most people stop growing by their late teens, ossification is not completed until the mid-twenties. The last bones to completely ossify are the sternum, clavicles, and vertebrae. Even after ossification is complete, the bone tissue is continually being "remodeled," which accounts for some of the change in facial features as a person matures physically.

concentric: con- (same) + -centric (center)

osteocytes: osteo- (bone) + -cytes (cell)

canaliculi: (L. CANALIS, channel)

ossification: ossi- (bone) + -fication or -fied (L. FICUS, a making or forming into)

Facets of Biology

Broken Bones and Their Treatment

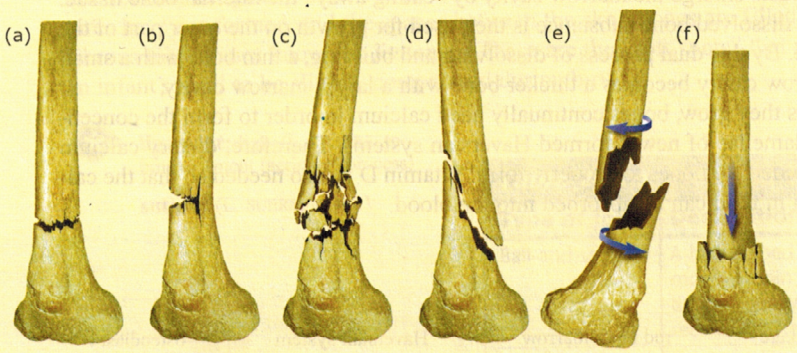
A broken bone or cartilage is known as a fracture. Most often fractures are a result of trauma from falling, playing sports, or vehicular accidents. Sometimes fractures occur "spontaneously" when bones have become brittle or weakened by disease. This type of fracture is termed a *pathologic fracture.*

When a bone fractures, it may also injure the surrounding soft tissues. Sometimes the soft tissue injury is more serious than the fracture itself, especially when an artery is torn or a lung is punctured. If the fractured bone segments stay within the soft tissue, it is termed a *closed* fracture. Fractures in which one or both segments protrude through the skin are called *compound* or *open.*

The treatment of fractures is twofold. First, the bone must be reduced, or set into proper alignment. Sometimes the emergency room physician or orthopedic surgeon can reduce the broken bones manually by pulling them into place. Other types of fractures require surgery to properly reduce the fractured segments.

The second aspect of the treatment is immobilization. Once the fragments are reduced, a cast made of plaster of Paris or fiberglass holds the bone fragments in place while healing takes place. Sometimes an operation is needed to immobilize the fracture. The surgeon may use small screws and plates to properly secure the bone ends.

Fracture immobilization can be internal (screws and plates) or external (casts).

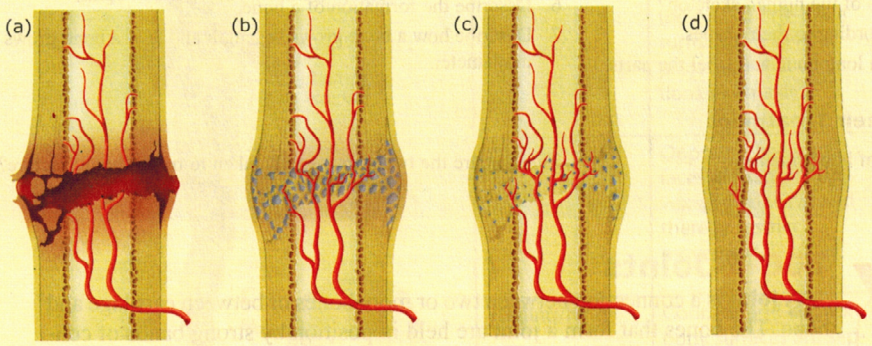


(a) A transverse *fracture is complete and often at 90° to the bone surface. (b) A* greenstick *fracture is incomplete, involving only one cortical plate. (c) A* comminuted *fracture is complete and has several fragments. (d) An* oblique *fracture occurs at an oblique angle to the bone surface. (e) A* spiral *fracture is the result of excessive twisting of a bone. (f) An* impacted *fracture is a complete fracture in which one fragment is driven into the other one.*

Immediately after a bone fractures, blood vessels rupture and bleed into the fracture site, forming a hematoma, or blood clot. Immature osteocytes called osteoblasts move from just under the periosteum into the hematoma (the periosteum is a source tissue for osteoblasts) and multiply near blood vessels. The osteoblasts form a callus (made of fibrocartilage) between the broken bone ends. At the same time, special bone cells called osteoclasts arrive to phagocytize debris at the fracture site. Eventually the callus becomes ossified and the bone of the healed fracture becomes like other mature bone in the area.

Some bones naturally heal more rapidly than others. The humerus (upper arm), for example, may heal in three months, while the tibia (lower leg), for a similar fracture, usually requires six months. Also, fractures heal faster in a young person. A broken bone in an elderly person sometimes takes years to heal. For this reason artificial bone sections are sometimes surgically substituted for broken bones in older people. This surgery is often done for fractured femurs, a common result of falls among the elderly, and it permits the person to walk in a few weeks.

Often it is unwise to immobilize a mending bone completely. A limited amount of use—but not enough to dislocate the bone piece—sometimes aids healing. Therefore, "walking casts" or other limited-use devices are often prescribed.



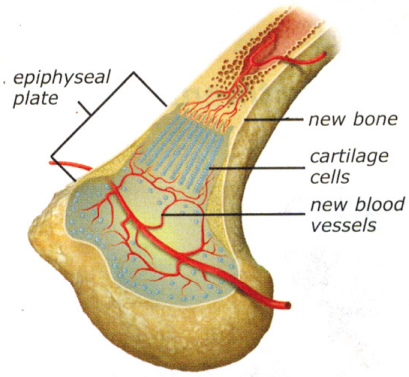
(a) A blood clot is formed at the fracture.

(b) The clot is replaced by connective tissue.

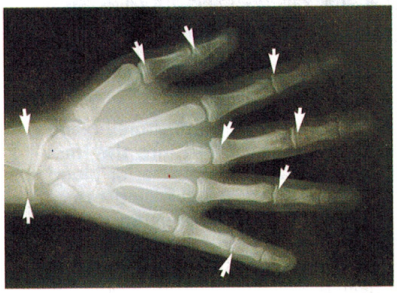
(c) The connective tissue is replaced by bone.

(d) Osteoclasts remove the excess bone, making the new bone like the original bone.

Stages of bone healing



20C.5
Epiphyseal plate anatomy



20C.6
Epiphyseal plates in a 12-year-old's hand

Bone Development

After birth, the bones continue to develop as the cartilage is replaced by mature bone. As the *long bones* in the legs lengthen, the person grows taller. Bones elongate by growing at the epiphyseal plates, which are the last cartilage tissue to ossify in the long bones.

The epiphyseal plate consists of a number of layers of cartilage cells lying between the epiphysis and the shaft. The layer of cartilage cells nearest the epiphysis divides to produce more cartilage cells and, thus, increases the length of the bone. Meanwhile, the layers of cartilage cells nearest the shaft slowly ossify. Once the cartilage in the epiphyseal plate has been replaced by bone, the elongation stops.

X-rays of the hand and wrist show many epiphyseal plates. Physicians can predict how tall a person will grow by measuring his epiphyseal plates during adolescence. Illnesses delay the ossification of the epiphyseal plates. In other words, whenever a person is ill, his growth rate slows.

As a person grows, the body requires an increasingly stronger skeletal system for support. Therefore, as bones increase in length, they must also increase in diameter. This increase in diameter occurs primarily beneath the periosteum, where new bone tissue is added. Specialized osteocytes called **osteoclasts** enlarge the marrow cavity by "eating away" the internal bone tissue. This dissolved bone substance is then used for growth on the outer part of the bone. By this dual process of dissolving and building, a thin bone with a small marrow cavity becomes a thicker bone with a larger marrow cavity.

As they grow, bones continually need calcium in order to form the concentric lamellae of newly formed Haversian systems. Therefore, dietary calcium is needed for bones to properly form. Vitamin D is also needed so that the calcium in food can be absorbed into the blood.

Key Terms 20C-1

diaphysis	articular cartilage	red bone marrow	Haversian system	osteoclast
epiphysis	periosteum	yellow bone marrow	osteocyte	
epiphyseal plate	endosteum	spongy bone	ossification	

Review Questions 20C-1

1. List the functions of the skeletal system.
2. What are the two main divisions of the human skeleton?
3. List the four types of bones according to their shapes.
4. Draw a longitudinal section of a long bone and label the parts.
5. Draw two Haversian systems side by side and label the parts.
6. Describe the formation of a bone.
7. Describe how a bone grows in length and how a bone grows in diameter.

Facet: Broken Bones and Their Treatment

1. List and describe several types of bone fractures.
2. What are the two steps usually taken to treat a bone fracture?

20C-2 Objectives

- List the major types of joints in the human body
- Describe the anatomy of a typical joint

20C-2 Joints

A **joint** is a connection between two or more bones or between cartilage and bone. The bones that form a joint are held in position by strong bands of connective tissue known as **ligaments**.* The fibers of the ligaments are actually extensions of the fibers of the periosteum. These continuous fibers secure the joint. Joints are essential in articulation, one of the most important functions of the skeletal system. *Articulation* refers to the smooth movement of one bone upon another.

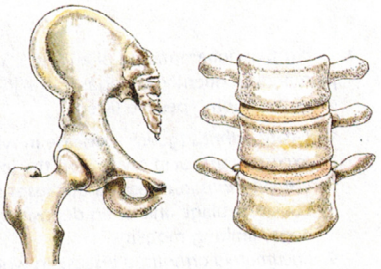
Classification of Joints

Joints are designed for specific functions and are classified into three groups according to the degree of movement.

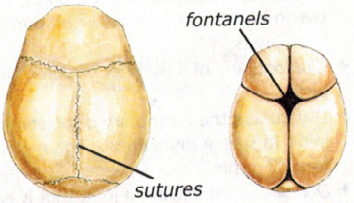
✦ *Freely movable joints.* Most joints in the skeletal system are freely movable. The ends of the bones at such joints are shaped to provide smooth articulation. Long bones bear most of the body's weight and, therefore, have large rounded ends. The bone that receives the rounded end usually has a depression that helps form a sturdy joint. The freely movable joints may be classified according to these ends of the bones that make up the joint and the kind of movement they permit.

✦ *Slightly movable joints.* In slightly movable joints a pad of cartilage between the bone ends permits limited movement. These joints connect the vertebrae. The ribs articulate with the sternum and allow for limited movement as a person inhales and exhales. The union between the pubic bones at the pubic symphysis is also classified as a slightly movable joint, even though there is movement only under severe stress, as in childbirth.

✦ *Immovable joints.* In some places where bones meet or where a bone attaches to cartilage, the joints must be rigid. The union of an epiphysis and diaphysis by the epiphyseal plate is an immovable joint. **Sutures,*** the interlocking margins of skull bones, are also immovable joints. At birth the sutures have not formed, and the spaces between the skull bones are filled with fibrous membranes known as *fontanels*. These are the "soft spots" that allow an infant's skull to be slightly compressed during birth.



20C.7
Freely movable joint (hip) (left) and Slightly movable joint (vertebral column) (right)



20C.8
Immovable joints (sutures) in adult cranium and fontanels in a young infant

* **ligament:** liga- (L. LIGARE, to bind) + -ment (action of process)

suture: (L. SUERE, to sew)

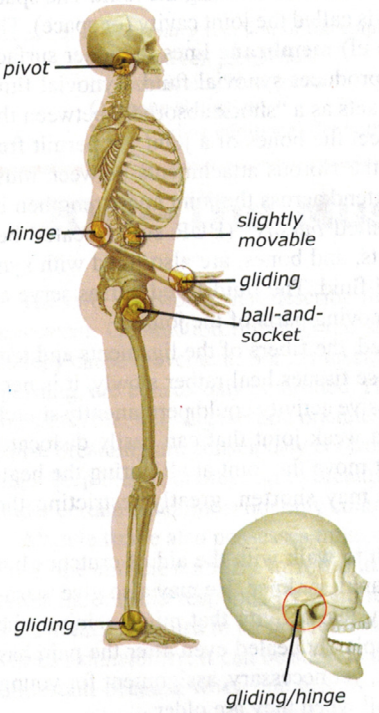


Table 20C-1 Movable Joints and Their Actions

Type of joint	Description	Action	Example
Ball-and-socket	A ball-shaped head moves within a socket that is "hollowed" to receive the head.	Free movement in all directions; rotation	Shoulder and hip
Hinge	Two cylindrical surfaces, one concave and the other convex, fit together to form the joint.	Bending only in one direction	Elbow, knee, and between phalanges (fingers and toes)
Pivot	A ringlike formation at the end of one bone surrounds a slender projection that functions as an axle.	Rotating and swiveling	Between atlas and axis in neck
Gliding	Opposing bone surfaces are slightly convex and concave and thereby restrict movement.	Limited movement sideways and up and down	Between carpals (wrist) and between tarsals (ankle)
Gliding/hinge	Concave and convex bony surfaces are separated by a disc of cartilage, forming two separate joint spaces.	Gliding movement in the upper joint space and hinge movement in the lower space	Temporomandibular (jaw) joint

Bone and Joint Diseases and Disorders

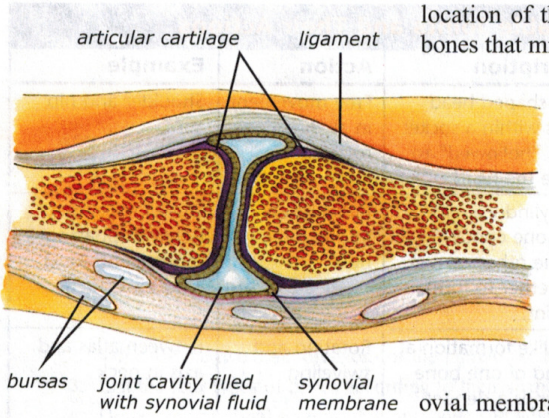
- *Arthritis:* an inflammation of a joint, usually accompanied by pain and, frequently, changes in the joint structure. The three most common types are listed.
  - *Gouty arthritis (gout):* a disease in which the body deposits excessive uric acid crystals on the joints.
  - *Osteoarthritis:* a disease that causes disintegration of the articular cartilage and often deposits bony spurs on the bone, limiting mobility.
  - *Rheumatoid arthritis:* a disease in which the fibrous tissue grows into the joint cavity. Later the joint may completely ossify.
- *Bunion:* an inflammation and thickening of the bursas of the joint of the great toe, usually resulting in enlargement of the joint and displacement of the toe.
- *Bursitis:* an inflammation of a bursa, especially one located between bones and muscles or tendons as in the shoulder and knee joints.
- *Clubfoot:* any of a number of deformities of the foot present at birth.
- *Dislocation:* the temporary displacement of a bone from its joint. In severe dislocations, ligaments and tendons may be torn. "Popping your knuckles" is a minor dislocation.
- *Double-jointed:* having a joint that is easily dislocated because the ligaments are abnormally long.
- *Flatfoot:* an abnormal flatness of sole and arch of foot often caused by stretching the ligaments of the joints of the tarsals.
- *Osteoporosis:* a bone condition in which calcium is removed more rapidly than it is replaced; common in the elderly; may be caused by several factors including lack of exercise and low intake of calcium, vitamin D, and proteins.
- *Rheumatism:* a general term for various conditions including arthritis; characterized by soreness and stiffness of muscles and pain in joints.
- *Rickets:* a disorder in infants caused by a deficiency of vitamin D. The bones become soft, and legs may become bowed.
- *Ruptured disc:* a disorder in which the central portion of the cartilaginous disc becomes flattened and protrudes outward; commonly called "slipped disc."
- *Spinal deformity:* an abnormal spinal curvature such as the "humpback" condition and lateral curvature of the back; may be caused by poor posture, injury, genetic disorders, or disease.
- *Sprain:* an injury of ligaments and tendons that causes pain and disability. In severe sprains, the ligaments may be completely torn.
- *Trick knee:* a temporary dislocation of the patella usually due to a previous injury.
- *Water on the knee:* a swelling of the knee in response to torn tissues. Fluid from the blood moves into the joint cavity to dilute toxins and limit movement so that healing can progress.

Anatomy of a Typical Joint

The joints that allow for free movement are often complicated structures. The location of the ligaments and muscle attachments and the presence of other bones that might restrict movement govern the amount of movement at a joint.

A connective tissue sheath called the **joint capsule** covers the proximal and distal bone ends forming the joint. The space within the joint capsule is called the joint cavity (or space). The **synovial** (sih NOH vee ul) **membrane** lines the inner surface of the joint cavity and produces synovial fluid. Synovial fluid lubricates the joint and acts as a "shock absorber" between the bones. Ligaments connect the bones of a joint yet permit free movement. **Tendons**,* the fibrous attachments between muscles and bones, often extend across the joint and strengthen it.

Saclike structures called *bursas** (BUR suz), located between tendons, ligaments, and bones, are also lined with synovial membranes that produce synovial fluid. The fluid-filled bursas serve as cushions and reduce friction between moving parts of the joints.



20C.9
Anatomy of a typical joint

When joints are sprained or dislocated, the fibers of the ligaments and tendons stretch and usually tear. Since these tissues heal rather slowly, it is necessary to restrict their movement. Excessive activity could permanently stretch the ligaments or tendons, resulting in a weak joint that can easily dislocate. However, if the injured person does not move the joint at all during the healing process, the ligaments or tendons may shorten, greatly restricting the movement of the joint.

Often the doctor will advise a person to walk with the aid of crutches but still "put some weight" on the sprained ankle or knee. He may also give warnings not to engage in any strenuous physical activity that might reinjure the weakened joint since it may not be completely healed even after the pain has subsided. These warnings are a difficult, yet necessary, assignment for young athletes if they expect to be athletes at all when they are older.

* **tendon:** (L. TENDERE, to stretch)
bursas: (L. BURSA, bag or purse)

The Skeletal System

1. List the four types of bones according to their shape.
2. What is another name for the growth plate in a bone?
3. What are the two functions of articular cartilage?
4. Draw a longitudinal section of a long bone (like the one on page 639) and label its parts.
5. Describe the difference between compact bone and spongy bone.
6. What happens in a bone to make it grow longer?
7. What happens in a bone to make it grow larger in diameter?
8. List the three major classifications of joints.
9. List the five types of movable joints and an example of each.