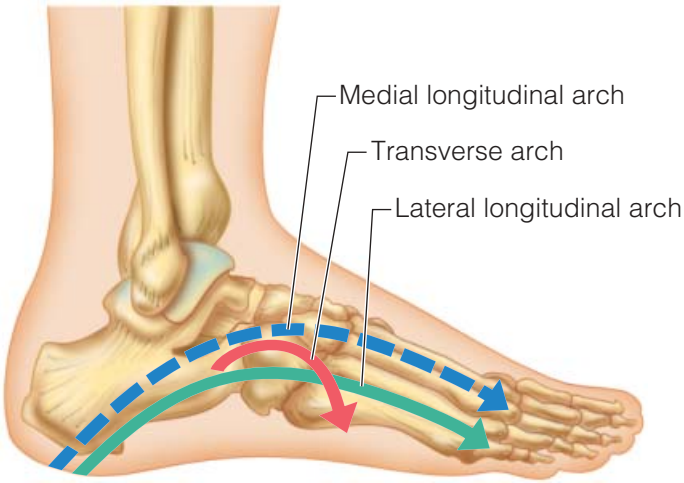


FIGURE 5.26 **Arches of the foot.**

Joints

With one exception (the hyoid bone of the neck), every bone in the body forms a joint with at least one other bone. **Joints,** also called **articulations,** have two functions: they hold the bones together securely but also give the rigid skeleton mobility.

The graceful movements of a ballet dancer and the rough-and-tumble grapplings of a football player illustrate the great variety of motion allowed by joints, the sites where two or more bones meet. With fewer joints, we would move like robots. Nevertheless, the bone-binding function of joints is just as important as their role in providing mobility. The immovable joints of the skull, for instance, form a snug enclosure for our vital brain.

Joints are classified in two ways—functionally and structurally. The functional classification focuses on the amount of movement allowed by the joint. On this basis, there are **synarthroses** (sin″ar thro′sēz) or immovable joints, **amphiarthroses** (am″fe ar thro′sēz) or slightly movable joints, and **diarthroses** (di″ar thro′sēz) or freely movable joints. Freely movable joints predominate in the limbs, where mobility is important. Immovable and slightly movable joints are restricted mainly to the axial skeleton, where firm attachments and protection of internal organs are priorities.

Structurally, there are *fibrous, cartilaginous,* and *synovial joints* based on whether fibrous tissue, cartilage, or a joint cavity separates the bony regions at the joint. As a general rule, fibrous joints are immovable and synovial joints are freely movable. Although cartilaginous joints have both immovable and slightly movable examples, most are amphiarthrotic. Since the structural classification is more clear-cut, we will focus on that classification scheme here. The joint types are shown in Figure 5.27 and described next.

Fibrous Joints

In **fibrous joints,** the bones are united by fibrous tissue. The best examples of this type of joint are the *sutures* of the skull (Figure 5.27a). In sutures, the irregular edges of the bones interlock and are bound tightly together by connective tissue fibers, allowing essentially no movement to occur. In **syndesmoses** (sin-dez-mo′sēz), the connecting fibers are longer than those of sutures; thus the joint has more "give." The joint connecting the distal ends of the tibia and fibula is a syndesmosis (Figure 5.27b).

Cartilaginous Joints

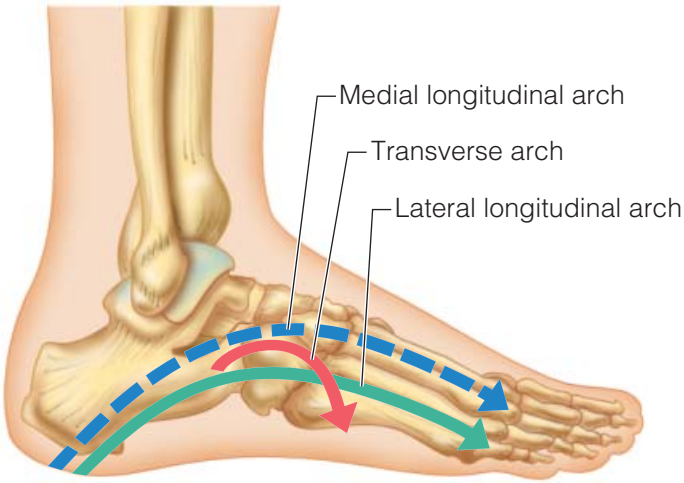
In **cartilaginous joints,** the bone ends are connected by cartilage. Examples of this joint type that are slightly movable (amphiarthrotic) are the *pubic symphysis* of the pelvis (Figure 5.27e) and *intervertebral joints* of the spinal column (Figure 5.27d), where the articulating bone surfaces are connected by pads (discs) of fibrocartilage. The hyaline-cartilage epiphyseal plates of growing long bones and the cartilaginous joints between the first ribs and the sternum are immovable (synarthrotic) cartilaginous joints (Figure 5.27c).

Synovial Joints

Synovial joints are those in which the articulating bone ends are separated by a joint cavity containing synovial fluid (see Figure 5.27f–h). They account for all joints of the limbs.

All synovial joints have four distinguishing features (Figure 5.28):

- **Articular cartilage.** Articular (hyaline) cartilage covers the ends of the bones forming the joint.
- **Fibrous articular capsule.** The joint surfaces are enclosed by a sleeve or capsule of fibrous connective tissue, and the capsule is lined with a smooth *synovial membrane* (the reason these joints are called synovial joints).
- **Joint cavity.** The articular capsule encloses a cavity, called the joint cavity, which contains lubricating synovial fluid.



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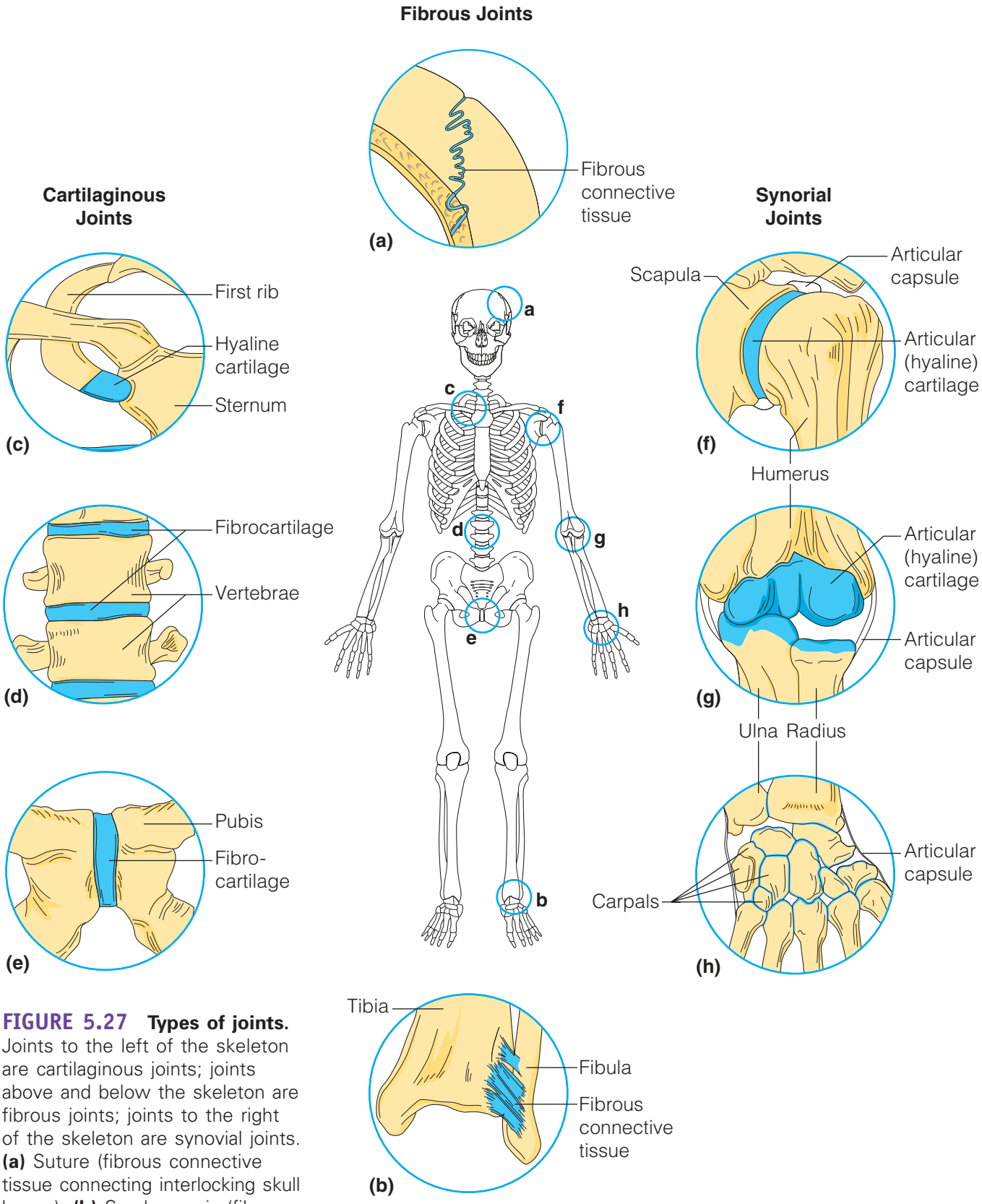

FIGURE 5.27 Types of joints. Joints to the left of the skeleton are cartilaginous joints; joints above and below the skeleton are fibrous joints; joints to the right of the skeleton are synovial joints. **(a)** Suture (fibrous connective tissue connecting interlocking skull bones). **(b)** Syndesmosis (fibrous connective tissue connecting the distal ends of the tibia and fibula). **(c)** Synchondrosis (joint between costal cartilage of rib 1 and the sternum). **(d)** Symphyses (intervertebral discs of fibrocartilage connecting adjacent vertebrae). **(e)** Symphysis (fibrocartilaginous pubic symphysis connecting the pubic bones anteriorly). **(f)** Synovial joint (multiaxial shoulder joint). **(g)** Synovial joint (uniaxial elbow joint). **(h)** Synovial joints (biaxial intercarpal joints of the hand).

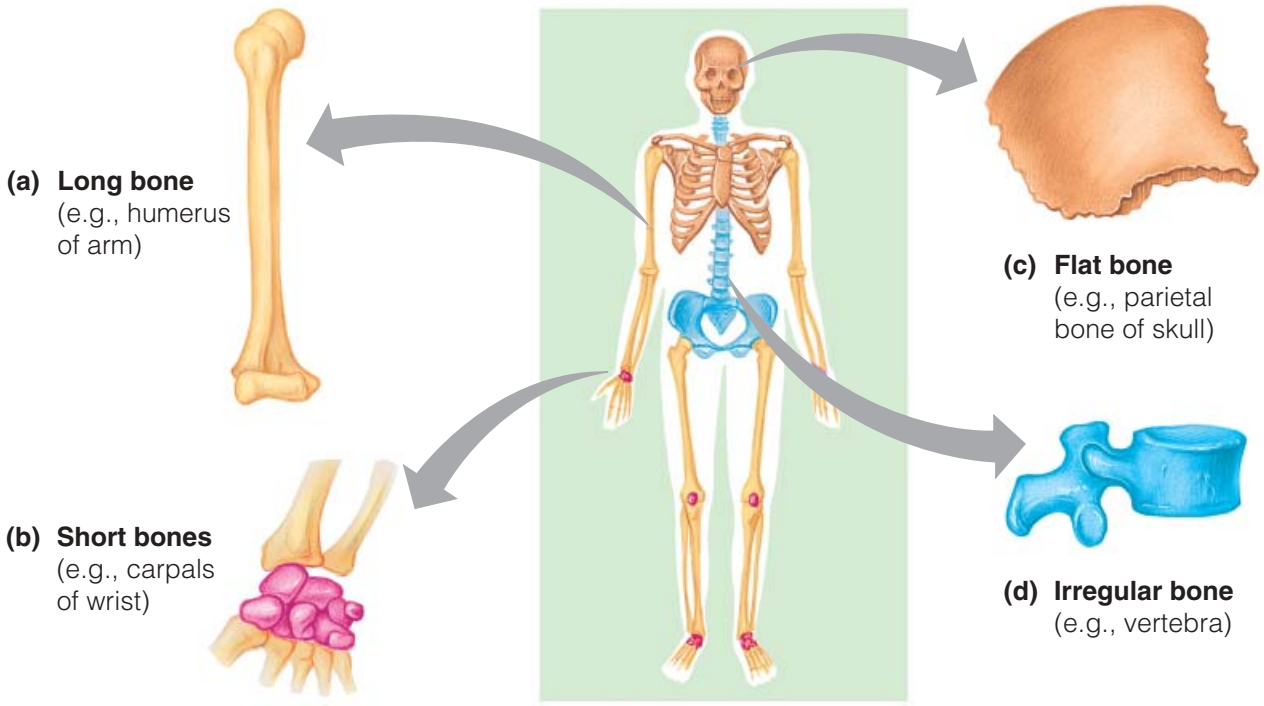

FIGURE 5.1 **Classification of bones on the basis of shape.**

provide a snug enclosure for the brain, allowing one to head a soccer ball without worrying about injuring the brain. The vertebrae surround the spinal cord, and the rib cage helps protect the vital organs of the thorax.

3. **Movement.** Skeletal muscles, attached to bones by tendons, use the bones as levers to move the body and its parts. As a result, we can walk, swim, throw a ball, and breathe. Before continuing, take a moment to imagine that your bones have turned to putty. What if you were running when this change took place? Now imagine your bones forming a rigid metal framework inside your body, somewhat like a system of plumbing pipes. What problems could you envision with this arrangement? These images should help you understand how well our skeletal system provides support and protection while allowing movement.
4. **Storage.** Fat is stored in the internal cavities of bones. Bone itself serves as a storehouse for minerals, the most important being calcium and phosphorus, although others are also stored. A small amount of calcium in its ion form (Ca^{2+}) must be present in the blood at all times for the nervous system to transmit messages, for muscles to contract, and for blood to clot. Because most of the body's calcium is deposited in the bones as calcium salts, the bones are a convenient place to get more calcium ions for the blood as they are used up. Problems occur not only when there is too little calcium in the blood, but also when there is too much. Hormones control the movement of calcium to and from the bones and blood according to the needs of the body. Indeed, "deposits" and "withdrawals" of calcium (and other minerals) to and from bones go on almost all the time.
5. **Blood cell formation.** Blood cell formation, or hematopoiesis (hem″ah-to-poi-e′sis), occurs within the marrow cavities of certain bones.

Classification of Bones

The adult skeleton is composed of 206 bones. There are two basic types of osseous, or bone, tissue: **Compact bone** is dense and looks smooth and homogeneous. **Spongy bone** is composed of small needlelike pieces of bone and lots of open space.

Bones come in many sizes and shapes (Figure 5.1). For example, the tiny pisiform bone of the

Q *How does this joint type differ structurally from cartilaginous and fibrous joints?*

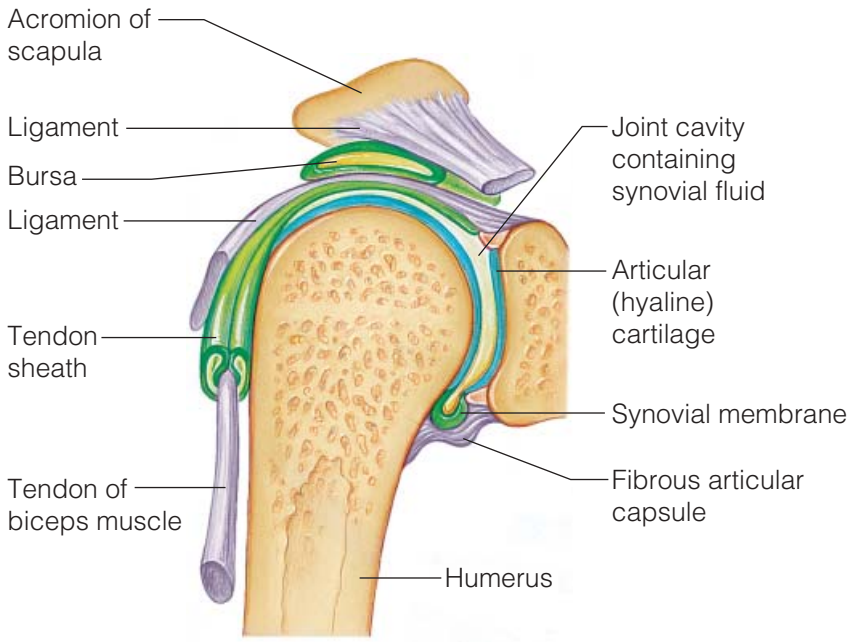

FIGURE 5.28 **General structure of a synovial joint.**

- **Reinforcing ligaments.** The fibrous capsule is usually reinforced with ligaments.

Bursae and tendon sheaths are not strictly part of synovial joints, but they are often found closely associated with them (Figure 5.28). Essentially bags of lubricant, they act like ball bearings to reduce friction between adjacent structures during joint activity. **Bursae** (ber′se; "purse") are flattened fibrous sacs lined with synovial membrane and containing a thin film of synovial fluid. They are common where ligaments, muscles, skin, tendons, or bones rub together. A **tendon sheath,** also shown in Figure 5.28, is essentially an elongated bursa that wraps completely around a tendon subjected to friction, like a bun around a hot dog.

Homeostatic Imbalance

A *dislocation* happens when a bone is forced out of its normal position in the joint cavity. The process of returning the bone to its proper position, called *reduction,* should be done only by a physician. Attempts by an untrained person to "snap the bone back into its socket" are usually more harmful than helpful.

A *It has a joint cavity instead of cartilage or fibrous tissue separating the articulating bones.*

Types of Synovial Joints Based on Shape

The shapes of the articulating bone surfaces determine what movements are allowed at a joint. Based on such shapes, our synovial joints can be classified as *plane, hinge, pivot, condyloid, saddle,* and *ball-and-socket joints* (Figure 5.29).

- In a **plane joint** (Figure 5.29a), the articular surfaces are essentially flat, and only short slipping or gliding movements are allowed. The movements of plane joints are *nonaxial;* that is, gliding does not involve rotation around any axis. The intercarpal joints of the wrist are the best examples of plane joints.
- In a **hinge joint** (Figure 5.29b), the cylindrical end of one bone fits into a trough-shaped surface on another bone. Angular movement is allowed in just one plane, like a mechanical hinge. Examples are the elbow joint, ankle joint, and the joints between the phalanges of the fingers. Hinge joints are classified as *uniaxial* (u″ne-aks′e-al; "one axis"); they allow movement around one axis only, as indicated by the single magenta arrow in Figure 5.29b.

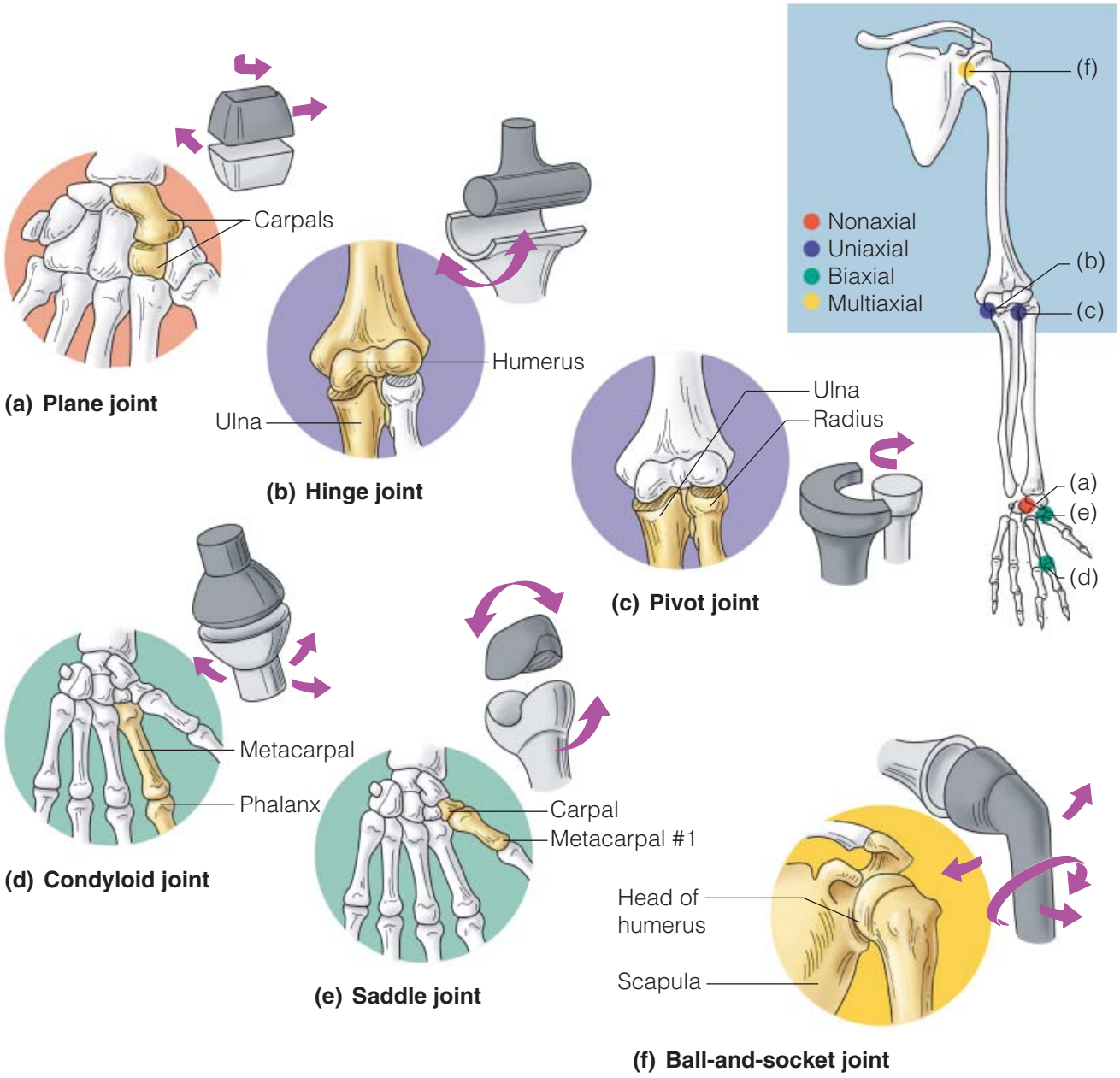

FIGURE 5.29 Types of synovial joints. (a) Plane joint (intercarpal and intertarsal joints). **(b)** Hinge joint (elbow and interphalangeal joints). **(c)** Pivot joint (proximal joint between the radius and the ulna). **(d)** Condyloid joint (knuckles). **(e)** Saddle joint (carpometacarpal joint of the thumb). **(f)** Ball-and-socket joint (shoulder and hip joints).

- In a **pivot joint** (Figure 5.29c), the rounded end of one bone fits into a sleeve or ring of bone (and possibly ligaments). Because the rotating bone can turn only around its long axis, pivot joints are also uniaxial joints (see the single arrow in Figure 5.29c). The proximal radioulnar joint and the joint between the atlas and the dens of the axis are examples.
- In a **condyloid joint** (kon′dĭ-loid; "knuckle-like"), the egg-shaped articular surface of one bone fits into an oval concavity in another (Figure 5.29d). Both of these articular surfaces are oval. Condyloid joints allow the moving bone to travel (1) from side to side and (2) back and forth, but the bone cannot rotate around its

long axis. Movement occurs around two axes, hence these joints are *biaxial* (*bi* = two), as in knuckle (metacarpophalangeal) joints.

- In **saddle joints,** each articular surface has both convex and concave areas, like a saddle (Figure 5.29e). These biaxial joints allow essentially the same movements as condyloid joints. The best examples of saddle joints are the carpometacarpal joints in the thumb, and the movements of these joints are clearly demonstrated by twiddling your thumbs.
- In a **ball-and-socket joint** (Figure 5.29f), the spherical head of one bone fits into a round socket in another. These *multiaxial* joints allow movement in all axes, including rotation (see the three arrows in Figure 5.29f), and are the most freely moving synovial joints. The shoulder and hip are examples.

The various types of movements that occur at synovial joints are discussed in detail in the next chapter, because they relate to muscle activity.

Homeostatic Imbalance of Joints

Few of us pay attention to our joints unless something goes wrong with them. Joint pain and inflammation may be caused by many things. For example, falling on one's knee can cause a painful *bursitis,* called "water on the knee," due to inflammation of bursae or synovial membrane. Sprains and dislocations are other types of joint problems that result in swelling and pain. In a *sprain,* the ligaments or tendons reinforcing a joint are damaged by excessive stretching, or they are torn away from the bone. Since both tendons and ligaments are cords of dense fibrous connective tissue with a poor blood supply, sprains heal slowly and are extremely painful.

Few inflammatory joint disorders cause more pain and suffering than arthritis. The term **arthritis** (*arth* = joint; *itis* = inflammation) describes over 100 different inflammatory or degenerative diseases that damage the joints. In all its forms, arthritis is the most widespread, crippling disease in the United States. One out of seven Americans suffers its ravages. All forms of arthritis have the same initial symptoms: pain, stiffness, and swelling of the joint. Then, depending on the specific form, certain changes in the joint structure occur.

Acute forms of arthritis usually result from bacterial invasion and are treated with antibiotic drugs. The synovial membrane thickens and fluid production decreases, leading to increased friction and pain. Chronic forms of arthritis include osteoarthritis, rheumatoid arthritis, and gouty arthritis, which differ substantially in their later symptoms and consequences. We will focus on these forms here.

Osteoarthritis (OA), the most common form of arthritis, is a chronic degenerative condition that typically affects the aged. OA, also called "wear-and-tear arthritis," affects the articular cartilages. Over the years, there is a softening, fraying, and eventual breakdown of the cartilage. As the disease progresses, the exposed bone thickens and extra bone tissue, called *bone spurs,* grows around the margins of the eroded cartilage and restricts joint movement. Patients complain of stiffness on arising that lessens with activity, and the affected joints may make a crunching noise (*crepitus*) when moved. The joints most commonly affected are those of the fingers, the cervical and lumbar joints of the spine, and the large, weight-bearing joints of the lower limbs (knees and hips).

The course of osteoarthritis is usually slow and irreversible, but it is rarely crippling. In most cases, its symptoms are controllable with a mild analgesic such as aspirin, moderate activity to maintain joint mobility, and rest when the joint becomes very painful. Some people with OA claim that rubbing capsaicin (a hot pepper extract) on the skin over painful joints provides relief. Others swear to the pain-reducing ability of glucosamine sulfate, a nutritional supplement.

Rheumatoid (roo'mah-toid) **arthritis (RA)** is a chronic inflammatory disorder. Its onset is insidious and usually occurs between the ages of 40 and 50, but it may occur at any age. It affects three times as many women as men. Many joints, particularly those of the fingers, wrists, ankles, and feet, are affected at the same time and usually in a symmetrical manner. For example, if the right elbow is affected, most likely the left elbow will be affected also. The course of RA varies and is marked by remissions and flare-ups (*rheumat* = susceptible to change or flux).

RA is an autoimmune disease—a disorder in which the body's immune system attempts to destroy its own tissues. The initial trigger for this reaction is unknown, but some suspect that it results from certain bacterial or viral infections.

RA begins with inflammation of the synovial membranes. The membranes thicken and the joints swell as synovial fluid accumulates. Inflammatory cells (white blood cells and others) enter the joint cavity from the blood and release a deluge of inflammatory chemicals that destroy body tissues when released inappropriately as in RA. In time the inflammed synovial membrane