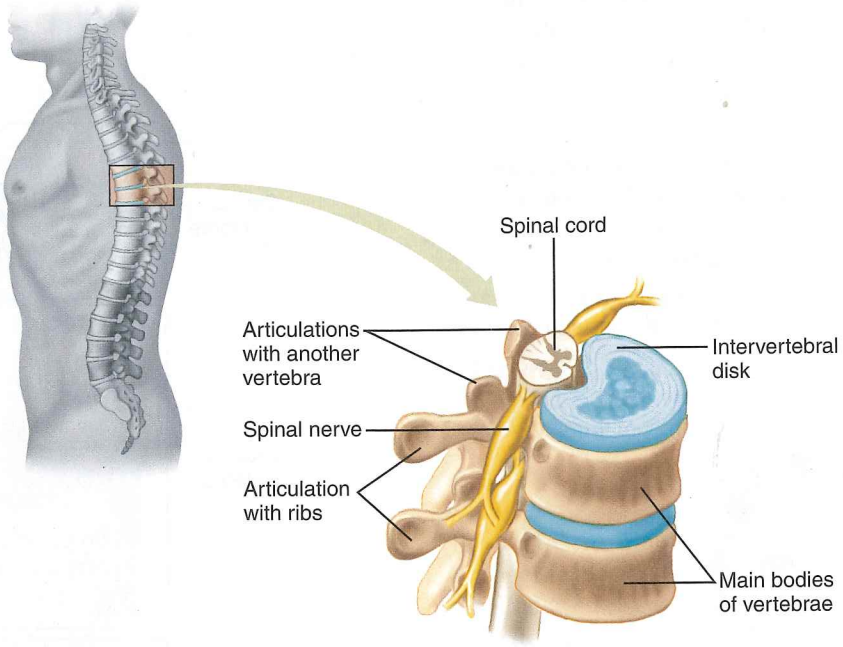
- Lumbar (the lower portion or "small" of the back, which forms the lumbar curve of the spine)—5 vertebrae.
- Sacral (in the sacrum or upper pelvic region)—In the course of evolution, the 5 sacral vertebrae have become fused.
- Coccygeal (the coccyx or tailbone)—4 fused vertebrae. The coccyx is all that remains of the tails of our ancient ancestors. It is an example of a *vestigial* structure, meaning one that no longer has any function.

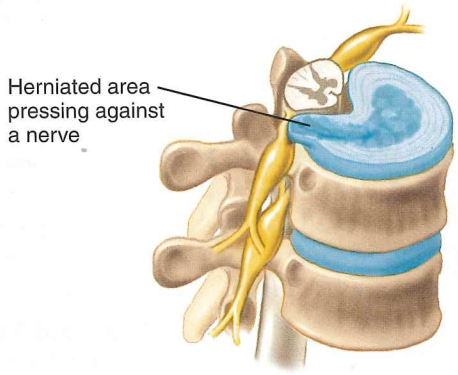
A closer look at vertebrae (Figure 5.9a) shows how they are stacked on each other and how they are joined. Vertebrae share two points of contact, called *articulations*, located behind their main body. There are also articulations with the ribs. The spinal cord passes through a hollow cavity between the articulations and the main body.

Neighboring vertebrae are separated from each other by a flat, elastic, compressible **intervertebral disk** composed of a soft gelatinous center and a tough outer layer of fibrocartilage. Intervertebral disks serve as shock absorbers, protecting the delicate vertebrae from the impact of walking, jumping, and other movements. In conjunction with the vertebral joints, vertebral disks also permit a limited degree of movement. This lends the vertebral column greater flexibility, allowing us to bend forward, lean backward, and rotate the upper body.

An especially strong impact or sudden movement can compress an intervertebral disk, forcing the softer center to balloon outward, press against spinal nerves, and cause intense back pain. This condition is referred to as a "herniated" or "slipped disk" (Figure 5.9b), and it occurs



a) Healthy disks.



b) A herniated disk.

Figure 5.9 Vertebrae.

most often in the lumbar vertebrae. Occasionally the disk may rupture, releasing its soft, pulpy contents. The pain that accompanies a herniated disk can be alleviated by surgery to remove the damaged disk, relieving the pressure against the nerve. However, surgical correction of a herniated disk reduces spinal flexibility somewhat because the two adjacent vertebrae must be fused together with bone grafts.

Generally the bony vertebral column does an effective job of shielding the softer spinal cord, which consists of nervous tissue that connects the brain to the rest of the body. However, injury to the vertebral column can damage the spinal cord or even sever it, resulting in partial or complete paralysis of the body below that point. Persons with suspected vertebral injuries should not be moved until a physician can assess the situation, because any twisting or bending could cause additional, perhaps permanent, damage to the spinal cord. You may have noticed that when athletes are injured on the field, they are instructed to lie absolutely still until a trainer and physician have examined them thoroughly.

The ribs and sternum: Protecting the chest cavity Humans have 12 pairs of **ribs** (Figure 5.10). One end of each rib branches from the thoracic region of the vertebral column. The other ends of the upper seven pairs attach via cartilage to the **sternum**, or breastbone, a flat blade-shaped bone composed of three separate bones that fuse during development. Rib pairs 8–10 are joined to the seventh rib by cartilage, and thus attach indirectly to the sternum. The bottom two pairs of ribs are called *floating ribs* because they do not attach to the sternum at all.

The ribs, sternum, and vertebral column form a protective *rib cage* that surrounds and shields the heart, lungs, and other organs of the chest (thoracic) cavity. The rib cage also helps us breathe, because muscles between the ribs lift them slightly during breathing, expanding the chest cavity and inflating the lungs. The base of the sternum is connected to the diaphragm, a muscle that is important to breathing.

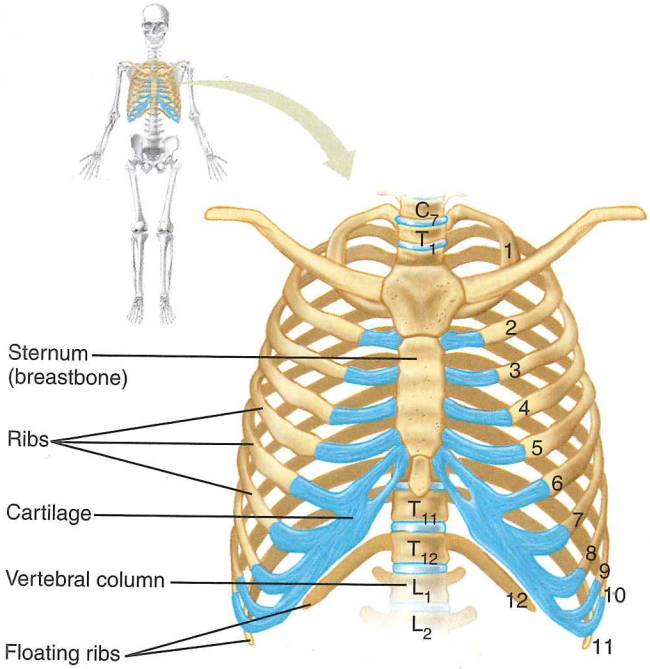


Figure 5.10 Ribs. The 12 pairs of ribs are numbered according to their attachment to the thoracic vertebrae. Only the first 7 pairs attach directly to the sternum.

☑ *What function do the ribs and sternum have that other parts of the skeleton do not have? How might this explain the fact that the ribs and sternum are connected by flexible cartilage rather than by bone?*

☑ **Quick Check** *Humans have more sacral vertebrae than most mammals do, and these sacral bones are fused into an unusually strong structure. Given what you know about the functions of the vertebral column, why do you think that is?* ■

The appendicular skeleton: Pectoral girdle, pelvic girdle, and limbs

Those parts of the body that attach to the axial skeleton are called *appendages*, from the Latin word meaning "to hang upon." The second division of the human skeleton, the **appendicular skeleton**, includes the arms, legs, and their attachments to the trunk, which are the pectoral and pelvic girdles.

The pectoral girdle lends flexibility to the upper limbs The **pectoral girdle**, a supportive frame for the upper limbs, consists of the right and left **clavicles** (collarbones) and right and left **scapulas** (shoulder blades) (Figure 5.11). The clavicles extend across the top of the chest and attach to the scapulas, the triangular bones in the upper back.

The arm and hand consist of 30 different bones. The upper end of the **humerus**, the long bone of the upper arm, fits into a socket in the scapula. The other end of the humerus meets with the **ulna** and **radius**, the two bones of the forearm, at the elbow. If you've ever hit your elbow and experienced a painful tingling, you know why this area is nicknamed the "funny bone"; you've just struck the ulnar nerve that travels along the elbow.

The lower ends of the ulna and radius meet the *carpal* bones, a group of eight small bones that make up the wrist. The five *metacarpal* bones form the palm of the hand, and they join with the 14 *phalanges*, which form the fingers and thumb.

The pectoral girdle and arms are particularly well adapted to permit a wide range of motion. They connect to the rest of the body via muscles and tendons—a relatively loose method of attachment. This structure gives the upper body of humans a degree of dexterity unsurpassed among large animals. We can rotate our upper arms almost 360 degrees—a greater range of movement than with any other joint in the body.

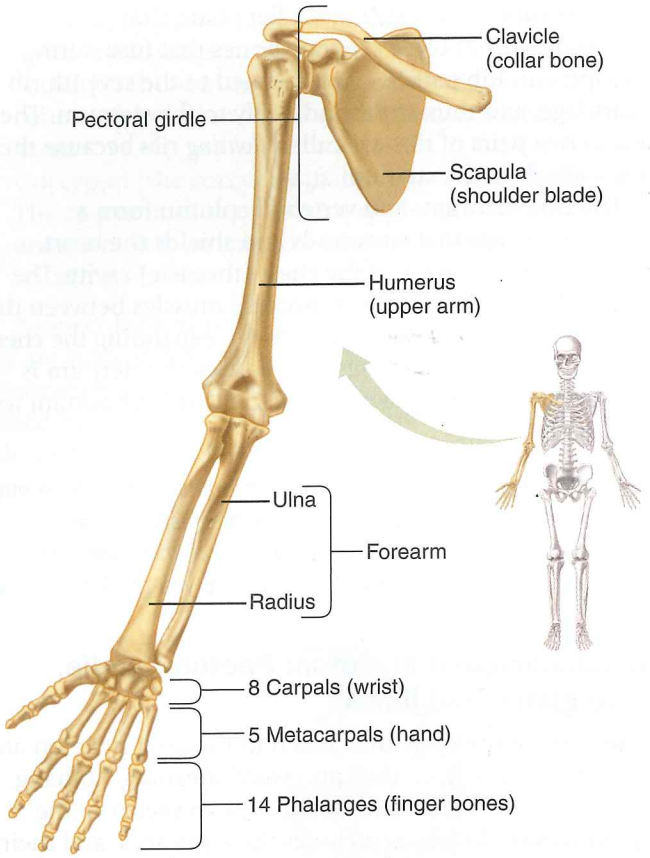


Figure 5.11 Bones of the right side of the pectoral girdle and the right arm and hand.

The upper arm can rotate in roughly a circle, the arm can bend in one dimension and rotate, and the wrist and fingers can all bend and rotate to varying degrees. We also have "opposable thumbs," meaning we can place them opposite our other fingers. The opposable thumb has played an important role in our evolutionary history, as it makes it easier to grasp and manipulate tools and other objects.

We pay a price for this flexibility, because freedom of movement also means relative instability. If you fall on your arm, for example, you might dislocate your shoulder joint or crack a clavicle. In fact, the clavicle is one of the most frequently broken bones in the body.

Although our upper limbs are well adapted to a wide range of movements, too much of one kind of motion can be harmful. Repetitive motions—performing the same task over and over—can lead to health problems called *repetitive stress syndromes*. Depending on the part of the body that is overused, these injuries can take many forms. A well-known repetitive stress syndrome is *carpal tunnel syndrome*, a condition often due to repetitive typing at a computer keyboard. The carpal bones of the wrist are held together by a sheath of connective tissue. The blood vessels, nerves, and tendons to the hand and fingers pass through the sheath via the "carpal tunnel." Overuse of the fingers and hands produces swelling and inflammation of the tendons, which causes them to press against the nerve supplying the hand. The result may be pain, tingling, or numbness in the wrist and hand. Mild episodes of carpal tunnel syndrome respond to rest and pain relievers. Severe cases can be treated with surgery to relieve the pressure.

The pelvic girdle supports the body The **pelvic girdle** consists of the two **coxal bones** and the sacrum and coccyx of the vertebral column (Figure 5.12). The coxal bones attach to

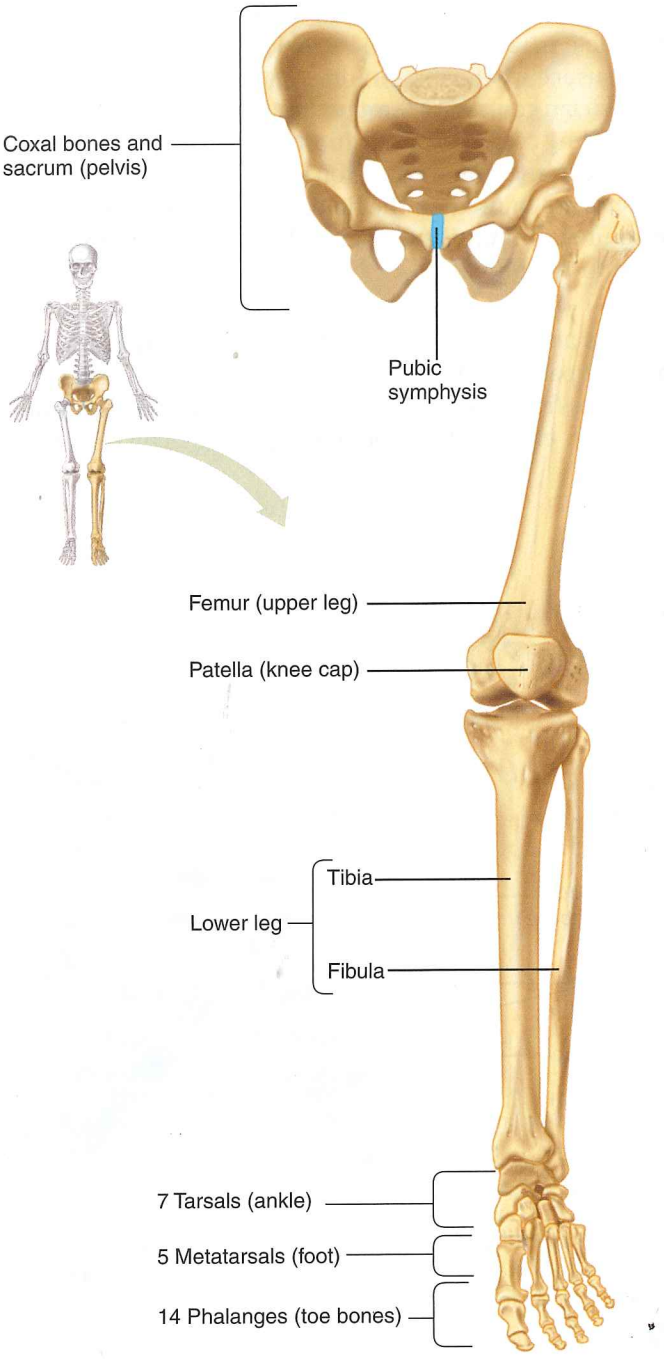


Figure 5.12 Bones of the pelvic girdle and the left leg and foot.

the sacral region of the vertebral column in back, then curve forward to meet in front at the *pubic symphysis*, where they are joined by cartilage. You can feel the upper curves of the coxal bones (the iliac region) as your hip bones. Together, these structures form the pelvis.

The primary function of the pelvic girdle is to support the weight of the upper body against the force of gravity. It also protects the organs inside the pelvic cavity and serves as a site of attachment for the legs. The structure of the pelvic girdle reflects a trade-off between dexterity and stability. Partly because the pelvic girdle and lower limbs are larger and more firmly connected to the rest of the body than the pectoral girdle and upper limbs, the lower limbs are less dexterous than the upper limbs.

The **femur** (thighbone) is the longest and strongest bone in the body. When you jog or jump, your femurs are exposed to forces of impact of several tons per square inch. The rounded upper end of each femur fits securely into a socket in a coxal bone, creating a stable joint that effectively supports the body while permitting movement. The lower end of the femur intersects at the knee joint with the larger of the two bones of the lower leg, the **tibia**, which in turn makes contact with the thinner **fibula**. The *patella*, or kneecap, is a triangle-shaped bone that protects and stabilizes the knee joint.

At the ankle, the tibia and fibula join with the seven *tarsal* bones that make up the ankle and heel. Five long bones, the *metatarsals*, form the foot. The 14 bones of the toes, like those of the fingers, are called *phalanges*.

In adult women the pelvic girdle is broader and shallower than it is in men, and the pelvic opening is wider (Figure 5.13). The wider pelvic opening allows for safe passage of a baby's head during labor and delivery. Differences in pelvic structures between men and women also account for the different degrees of hip sway between men and women as they walk. These characteristic differences appear during puberty when a woman's body begins to produce sex hormones. The sex hormones trigger a process of bone remodeling that shapes the female pelvic girdle to adapt for pregnancy and birth.

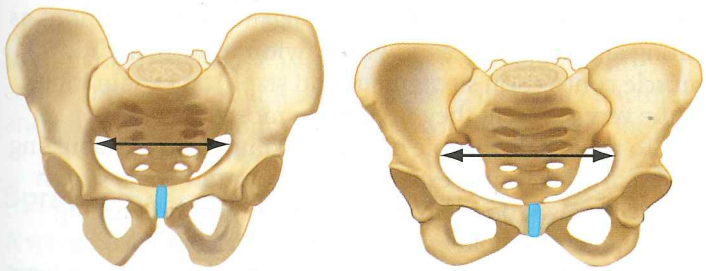


Figure 5.13 The pelvis. Note the wider pelvic opening (arrows) in the female.

Recap **The skull and vertebral column protect the brain and spinal cord, the rib cage protects the organs of the chest cavity, and the pelvic girdle supports the body's weight and protects the pelvic organs. The upper limbs are capable of a wide range of motions (dexterous movement). The lower limbs are stronger but less dexterous than the upper limbs.** ■

5.5 Joints form connections between bones

We now turn to the structures and tissues that hold the skeleton together while still permitting us to move about freely: joints, ligaments, and tendons. **Joints**, also called articulations, are the points of contact between bones. Ligaments and tendons are connective tissues that stabilize many joints.

Joints vary from immovable to freely movable

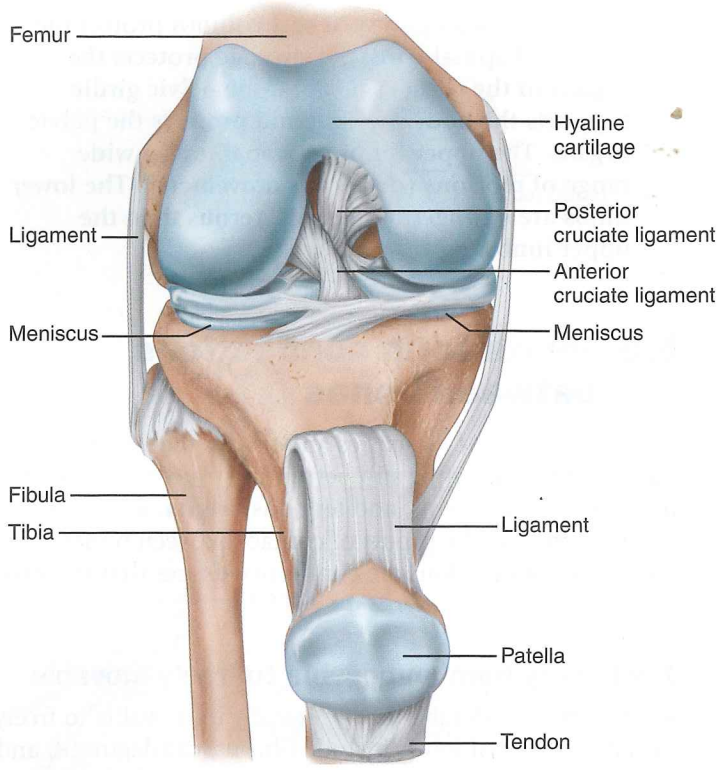
Joints vary considerably from basically immovable to freely movable. Types of joints include fibrous, cartilaginous, and synovial joints.

Fibrous joints are immovable. At birth, the flat bones in a baby's skull are separated by relatively large spaces filled with fibrous connective tissue. These "soft spots," called *fontanels*, enable the baby's head to change shape slightly so that it can squeeze safely through the mother's pelvic opening during childbirth. The presence of joints also allows for brain growth and development after birth. During childhood these fibrous joints gradually harden. By the time we reach adulthood, the joints have become thin lines, or sutures, between skull bones. These immovable joints firmly connect the bones that protect and stabilize the skull and brain.

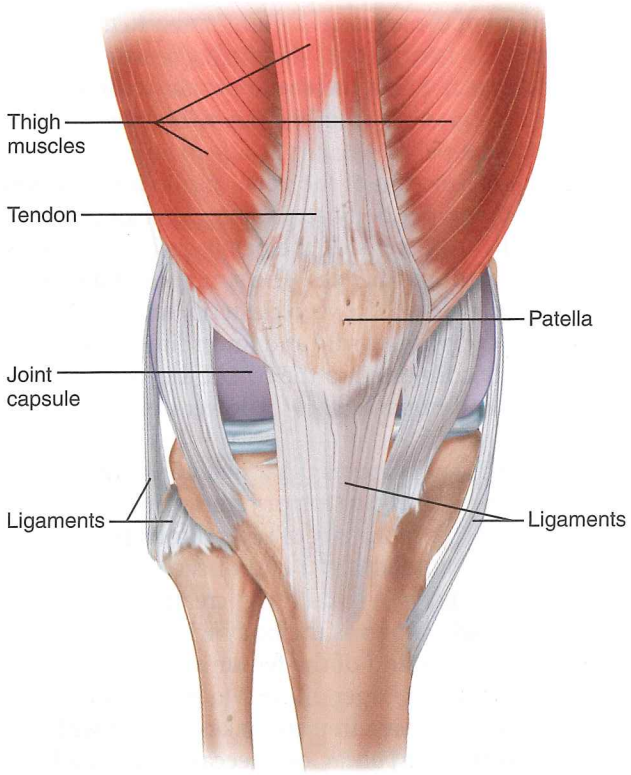
Cartilaginous joints, in which the bones are connected by hyaline cartilage, are slightly movable, allowing for some degree of flexibility. Examples include the cartilaginous joints that connect the vertebrae in the backbone, and those that attach the lower ribs to the sternum.

The most freely movable joints are **synovial joints**, in which the bones are separated by a thin fluid-filled cavity. The two bones of a synovial joint are fastened together and stabilized by ligaments. The interior of the cavity is lined with a *synovial membrane*, which secretes *synovial fluid* to lubricate and cushion the joint. To reduce friction even further, the articulating surfaces of the two bones are covered with a tough but smooth layer of hyaline cartilage. Together, the synovial membrane and the surrounding hyaline cartilage constitute the *joint capsule*.

Different types of synovial joints permit different kinds of movements. A *hinge joint*, such as the knee and elbow, gets its name because it allows movement in one plane like the hinges on a door. Figure 5.14 illustrates a human knee



a) A cutaway anterior view of the right knee with muscles, tendons, and the joint capsule removed and the bones pulled slightly apart so that the two menisci are visible.



b) A view of the knee with muscles, tendons, and ligaments in their normal position surrounding the intact joint capsule. The combination of ligaments, tendons, and muscles holds the knee tightly together.

Figure 5.14 The knee joint is a hinged synovial joint.

What is the difference between a ligament and a tendon? Hint: Find all the ligaments and tendons in this figure and notice what they are attached to.

joint. The knee joint is strong enough to withstand hundreds of pounds of force, yet it is flexible enough to swing freely in one direction. To reduce friction, there are small disks of cartilage on either side of the knee called *menisci* (singular: meniscus). The knee joint also includes 13 small sacs of fluid, called *bursae* (singular: bursa), for additional cushioning. The entire joint is wrapped in strong ligaments that attach bone to bone and tendons that attach bone to muscle. Note the two *cruciate ligaments* (posterior and anterior) that join the tibia to the femur bone. The anterior cruciate ligament is sometimes injured when the knee is hit with great force from the side.

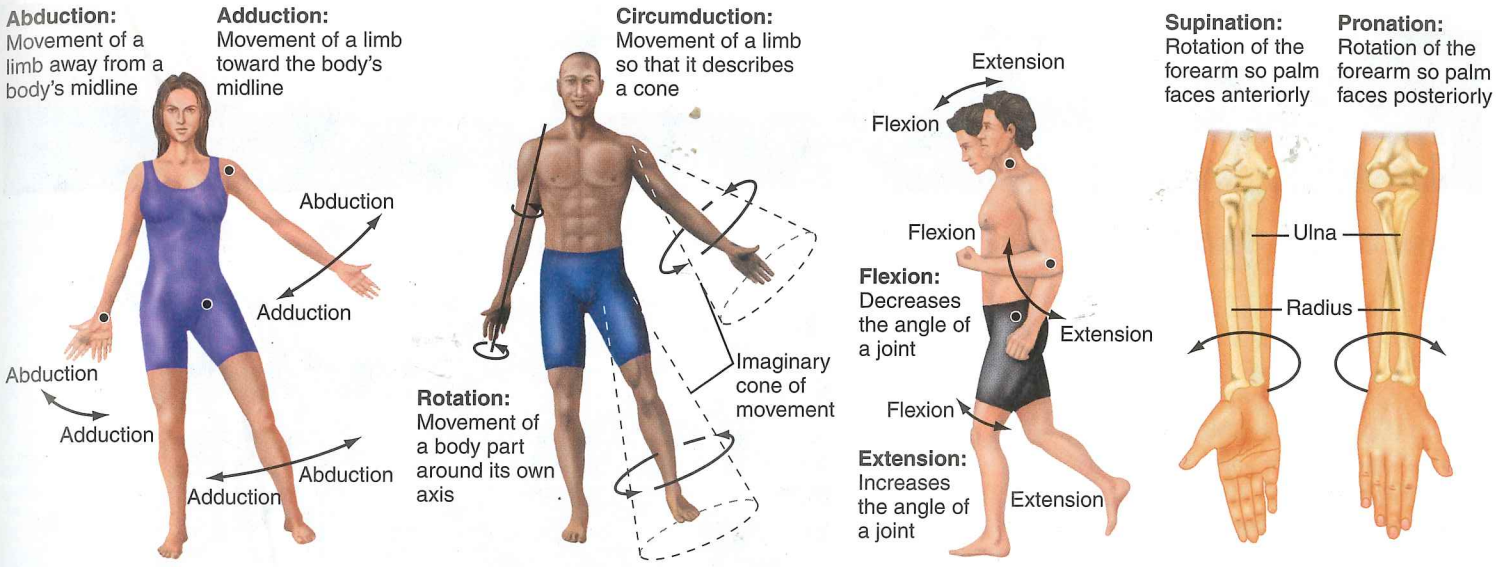
A second type of synovial joint, a *ball-and-socket joint*, permits an even wider range of movement. Examples include the joint between the femur and the coxal bone (see Figure 5.12), and between the humerus and the pectoral girdle (see Figure 5.11). In both cases, the rounded head of the bone fits into a socket, allowing movement in all planes.

Figure 5.15 illustrates the different types of movements made possible by hinge and ball-and-socket joints. Note that you can rotate your arm and your leg because the shoulder and hip are ball-and-socket joints, but you cannot rotate the hinge joint in your knee.

Ligaments, tendons, and muscles strengthen and stabilize joints

Thanks to its design, a synovial joint can withstand tremendous pounding day after day, year after year without wearing out. But where does it get its strength? For that we turn to ligaments, tendons, and muscles. As we have seen, the bones of a synovial joint are held tightly together by ligaments. They are stabilized even more by **tendons**, another type of tough connective tissue, which join the bones to muscles. Ligaments and tendons contain collagen arranged in parallel fibers, making ligaments and tendons as strong and as flexible as a twisted nylon rope. In addition, muscle contraction strengthens and stabilizes certain joints at the very moment they need it the most.

To appreciate the role of muscle contraction in stabilizing a joint, try this simple experiment. Sit in a low chair, stretch your leg straight out in front of you with your heel resting on the floor, and relax your muscles. Move your kneecap (patella) from side to side gently with your hand. Notice how easily you can shift it out of position. Now, without changing position, tense the muscle of your thigh and again try to move your kneecap with your hand. See the difference? The patella is attached to the tibia by a ligament and to the muscles of



a) Abduction and adduction. b) Rotation and circumduction. c) Flexion and extension d) Supination and pronation.

Figure 5.15 Types of movements made possible by synovial joints.

Which of these types of movement can be produced by a hinge joint, a ball-and-socket joint, or a fibrous joint?

the thigh by a tendon (review Figure 5.14b). Contraction of the thigh muscle (as when you take a step while walking) puts tension on the tendon and the ligament. The increased tension holds the patella and the rest of the joint firmly in place. If you move your hand to just below the kneecap, you can feel the tightening of the patellar ligament as you alternately contract and relax your thigh muscle.

Recap **Joints are the points of contact between bones. Fibrous joints are immovable in adults, cartilaginous joints permit some movement, and synovial joints are highly movable. Synovial joints are held together by ligaments and lubricated by synovial fluid.** ■

5.6 Diseases and disorders of the skeletal system

In this chapter we have already discussed several health conditions related to the skeletal system, including fractures and carpal tunnel syndrome. Now we look at several more.

Sprains mean damage to ligaments

A sprain is due to stretched or torn ligaments. Often it is accompanied by internal bleeding with subsequent bruising, swelling, and pain. The most common example is a sprained ankle. Sprains take a long time to heal because the ligaments have few cells and a poor blood supply. Minor sprains, in which the ligaments are only stretched, usually mend themselves with time. If a large ligament is torn completely, it generally does not heal by itself, and surgery may be necessary to remove it. Sometimes the joint can be stabilized with a piece of tendon or by repositioning other ligaments. Torn ligaments in the knee are particularly troublesome because they often leave the knee joint permanently unstable and prone to future injuries.

Quick Check *Which is likely to heal faster—a broken bone or a sprained ligament? Why?* ■

Bursitis and tendinitis are caused by inflammation

Bursitis and tendinitis refer to inflammation of the bursae or tendons. (The suffix *-itis* denotes that the disease is characterized by inflammation; perhaps the best-known inflammatory disease is appendicitis.) Inflammation is a response to injury characterized by redness, warmth, swelling, and pain.

Causes of bursitis and tendinitis may include tearing injuries to tendons, physical damage caused by blows to the joint, and some bacterial infections. Like ligaments, tendons and the tissues lining the bursae are not well supplied with blood vessels, so they do not heal quickly. Treatment usually involves applying cold during the first 24 hours and heat after that, resting the injured area, and taking pain-relieving medications. "Tennis elbow" is a painful condition caused by either bursitis or tendinitis. Other common locations for pain include the knee, shoulder, and the Achilles tendon that pulls up the back of the heel.

Health & Wellness

Treating a Sprained Ankle

For a severe sprain, many physicians advise the frequent application of cold to the sprained area during the first 24 hours, followed by a switch to heat. Why the switch, and what is the logic behind the timing of cold versus heat?

The biggest immediate problem associated with a sprain is damage to small blood vessels and subsequent bleeding into the tissues. Most of the pain associated with a sprain is due to the bleeding and swelling, not damage to ligaments themselves. The immediate application of cold constricts blood vessels in the area and prevents most of the bleeding. The prescription is generally to cool the sprain for 30 minutes every hour or 45 minutes every hour and a half. In other words, keep the sprain cold for about half the time, for as long as you can stand it. The in-between periods ensure adequate blood flow for tissue metabolism. It's also a good idea to keep the ankle wrapped in an elastic bandage and elevated between cooling treatments, to prevent swelling. If you're having trouble remembering all this, remember the acronym "RICE"—Rest, Ice, Compression, Elevation.

Treat sprains first with cold, then later with heat.

The key to a quick recovery from a sprain is rapid application of the RICE method. Athletes who try to "work through the pain" by continuing to compete while injured generally pay the price in a longer recovery time.

After 24 hours there shouldn't be any more bleeding from small vessels. The damage has been minimized, so now the goal is to speed the healing process. Heat dilates the blood vessels, improves the supply of nutrients to the area, and attracts blood cells that begin the process of tissue repair. ■

BlogInFocus MB

Could stem cells be used to speed up the rate of healing of joint injuries? To learn more, visit MJ's blog in the Study Area in MasteringBiology and look under "Stem Cells and Joint Injuries."

Arthritis is inflammation of joints

By their nature, joints are exposed to high compressive forces and are prone to excessive wear caused by friction. "Arthritis" is a general term for joint inflammation. The most common type of arthritis is *osteoarthritis*, a degenerative ("wear-and-tear") condition that affects about 20 million Americans, most over age 45. In osteoarthritis the cartilage covering the ends of the bones wears out. With time the bone thickens and may form bony spurs, which further restrict joint movement. The result is increased friction between the bony surfaces, and the joint becomes inflamed and painful.

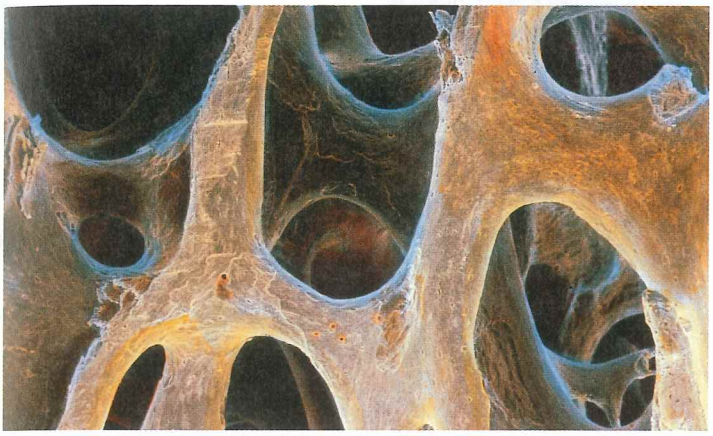
Over-the-counter medications can reduce the inflammation and pain, and surgical joint replacements for severe osteoarthritis are fairly routine today. Injections of hyaluronic acid, a component of hyaline cartilage, can also reduce arthritic knee pain. Many physicians advise people with osteoarthritis to exercise regularly, which helps preserve the joints' healthy range of motion. Several promising new treatments to reduce joint inflammation are still in the experimental stage.

Osteoarthritis should not be confused with *rheumatoid arthritis*. Rheumatoid arthritis also involves joint inflammation, but it is caused by the body's own immune system, which mistakenly attacks the joint tissues. We take a closer look at rheumatoid arthritis when we discuss the immune system.

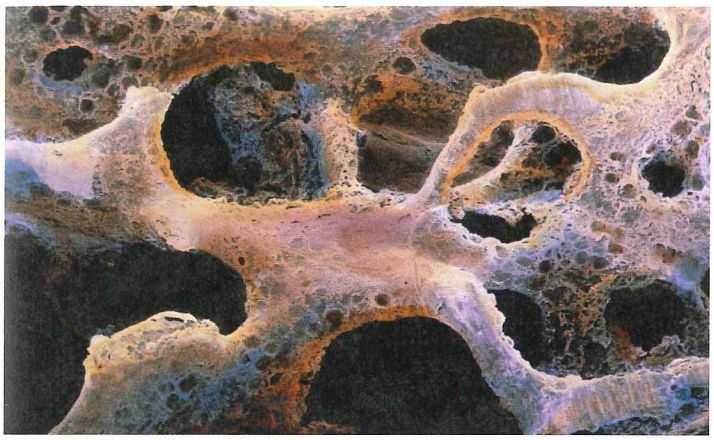
Quick Check *A medical researcher is trying to develop a new drug that will help patients with osteoarthritis. Which is likely to be most helpful: a drug that increases osteoclast activity, one that increases osteoblast activity, or one that increases chondroblast activity? Explain.* ■

Osteoporosis is caused by excessive bone loss

Osteoporosis is a condition caused by excessive bone loss over time (Figure 5.16), leading to brittle, easily broken bones. Symptoms include hunched posture (Figure 5.17), difficulty walking, and an increased likelihood of bone fractures, especially of the spine and hip. Osteoporosis is a major health problem in the United States. Over 10 million Americans have the condition, and it accounts for more than 1.5 million debilitating fractures every year.



a) A scanning electron micrograph (SEM) of normal bone.



b) SEM of a bone showing osteoporosis.

Figure 5.16 Bone loss in osteoporosis.

Figure 5.17 Osteoporosis. Osteoporosis can lead to repeated compression fractures of the spine and a permanent change in spine curvature.

A very slow progressive bone loss occurs in both men and women after age 35 because of a slight imbalance between the rates of bone breakdown by osteoclasts and new bone formation by osteoblasts. Overall, the rate of bone loss in men (and in women before menopause) is only about 0.4% per year. That means that on average, a man will lose only about 20% of his bone mass by age 85—not enough to cause disability in most cases.

For women it's a different story, because a decline in estrogen after menopause leads to a more rapid rate of bone loss in the decade immediately after menopause—as high as 2 to 3% per year. After that, the rate of loss begins to decline slowly toward 0.4% again. Nevertheless, women tend to lose considerably more bone mass over a lifetime than men, which is why women are more prone to osteoporosis. Other risk factors include smoking, a sedentary lifestyle, low calcium intake, and being underweight.

The good news is that osteoporosis can be prevented. Two important strategies: get enough calcium and vitamin D, and maintain a consistent exercise program throughout your life. Calcium is crucial for the formation of new bone tissue. Current recommendations call for a daily intake of about 1,000 to 1,500 mg per day for adults, but women who have gone through menopause may benefit from even higher intakes. Both men and women can benefit from weight-bearing exercise (such as walking) and strength training (such as lifting weights), because these activities increase bone mass. For women especially, estrogen replacement therapy after menopause can slow the rate of bone loss.

BlogInFocus MB

Should "pre-osteoporosis" (also known as osteopenia) be treated with drugs? For more on this controversial subject, visit MJ's blog in the Study Area in MasteringBiology and look under "Treating Pre-osteoporosis."

Several medications are available to treat osteoporosis. A class of drugs called biphosphonates (alendronate and risedronate) act by inhibiting the bone-resorbing function of osteoclasts. The FDA recently approved a new biphosphonate medication, Boniva Injection, which can be administered intravenously every three months. Teriparatide, a medication that is a fragment of the normal parathyroid hormone molecule, is the first osteoporosis medication that can actually stimulate the activity of the bone-forming osteoblasts.

Chapter Summary

The skeletal system consists of connective tissue *p. 102*

- Connective tissues of the skeletal system are bones, ligaments, and cartilage.
- Bone is a living tissue composed of cells and extracellular material.
- Ligaments, composed of dense fibrous connective tissue, attach bones to each other.
- Cartilage forms the intervertebral disks and lines the points of contact between bones.

Bone development begins in the embryo *p. 104*

- After about two months of fetal development, rudimentary models of bones have been formed from cartilage.
- Throughout the rest of fetal development and on into childhood, bone-forming cells called *osteoblasts* replace the cartilage model with bone.
- Growth in the length of long bones centers on growth plates in each epiphysis.

Mature bone undergoes remodeling and repair *p. 105*

- Bone undergoes replacement throughout life.
- Bones can change shape over time, depending on the forces to which they are exposed.
- The process of bone repair includes: (1) the formation of a hematoma, (2) the formation of a fibrocartilage callus that binds the broken ends together, and (3) the eventual replacement of the callus with new bone.

The skeleton protects, supports, and permits movement *p. 107*

- The axial skeleton is represented by the skull, the vertebral column, the sternum, and the ribs.
- In the vertebral column, intervertebral disks of fibrocartilage absorb shock and permit limited movement.
- The appendicular skeleton includes the pectoral girdle, the pelvic girdle, and the upper and lower limbs.

Joints form connections between bones *p. 113*

- Three types of joints connect bones: fibrous, cartilaginous, and synovial.
- Synovial joints are designed for movement without friction. They are lined with a synovial membrane and lubricated by synovial fluid.

Diseases and disorders of the skeletal system *p. 115*

- Sprains are the result of stretched or torn ligaments. Bursitis and tendinitis are caused by injuries to the bursae and tendons.
- "Arthritis" is a general term for joint inflammation.
- Osteoarthritis is a condition in which the cartilage covering the ends of the bones wears out and joint friction increases.
- Osteoporosis is a condition caused by progressive bone loss over time.

Terms You Should Know

appendicular skeleton, *111*
axial skeleton, *107*
bone, *102*
cartilage, *104*
central (Haversian) canal, *103*
chondroblast, *104*
compact bone, *102*
growth plate, *105*
intervertebral disk, *110*
joint, *113*
ligament, *104*
osteoblast, *105*
osteoclast, *105*
osteocyte, *102*
osteon, *103*
osteoporosis, *106*
spongy bone, *102*
tendon, *114*

Concept Review

Answers can be found in the Study Area in MasteringBiology.

1. List the five functions of bone.
2. Describe the functions of red and yellow bone marrow.
3. Explain how the two growth plates in a long bone account for the ability of a long bone to lengthen.
4. Explain what might cause a long bone to slowly change shape over many years.
5. Describe the process of bone remodeling and how it can reshape bones to make them stronger.
6. Name the three anatomical regions of the vertebral column that are above the *sacral* and *coccygeal* regions.
7. Explain why it is important not to move someone who may have suffered an injury to the vertebral column until a medical assessment can be made.
8. Describe the features of synovial joints that reduce friction and prevent the joint from wearing out prematurely.
9. Distinguish between *flexion* and *extension*.
10. Define the differences between *osteoarthritis* and *rheumatoid arthritis*.

Test Yourself

Answers can be found in Appendix A.

1. Which of the following might result from a parathyroid tumor that causes oversecretion of parathyroid hormone?
   a. joint inflammation leading to osteoarthritis
   b. bone loss due to stimulation of osteoclasts
   c. bone growth due to stimulation of osteoblasts
   d. conversion of cartilage to bone
2. Steps in the repair of a bone fracture include (1) bone deposition by osteoblasts, (2) bone and debris removal by osteoclasts, (3) hematoma, and (4) formation of a fibrocartilage callus. In what order do these steps occur?
   a. 1–2–3–4
   b. 3–4–1–2
   c. 3–4–2–1
   d. 4–3–2–1
3. All of the following bones form part of the eye socket except the:
   a. occipital bone
   b. lacrimal bone
   c. zygomatic bone
   d. ethmoid bone
4. All of the following bones of the skull are stationary except the:
   a. frontal bone
   b. mandible
   c. maxilla
   d. zygomatic bone

5. Which bones are found in both the hands and feet?
   a. carpals
   b. metacarpals
   c. tarsals
   d. phalanges
6. The movement of the thumb to trace a circle might best be described as:
   a. abduction
   b. rotation
   c. circumduction
   d. pronation
7. Synovial joints may include cartilage, ligaments, tendons, and synovial fluid. Which of these attach bones to other bones within the joint?
   a. synovial membrane
   b. ligaments
   c. tendons
   d. cartilage
8. Which of the following is an example of a cartilaginous joint?
   a. knee joint
   b. skull sutures
   c. pubic symphysis
   d. hip joint
9. All of the following are bones of the axial skeleton except:
   a. vertebrae
   b. ribs
   c. skull
   d. clavicle
10. Which of the following would be likely to prevent or slow the bone loss of osteoporosis?
    a. stimulate the activity of fibroblasts
    b. stimulate the activity of osteoblasts
    c. inhibit the activity of osteoclasts
    d. both (b) and (c)
11. Which of the following contains the richest population of the stem-cell precursors for red and white blood cells?
    a. red bone marrow
    b. yellow bone marrow
    c. osteoid
    d. hydroxyapatite
12. In the formation and development of bones within the fetus, which of these cell types functions earliest?
    a. osteocyte
    b. osteoblasts
    c. osteoclasts
    d. chondroblasts
13. Which of the following might be most helpful in determining whether an adolescent is no longer growing?
    a. measuring the length of the femur and hummers
    b. examining the growth plates near the ends of long bones
    c. examining bone density
    d. examining the fontanels in the skull
14. All of the following processes continue in the skeletal system throughout the life span except:
    a. bones continue to lengthen
    b. stem cells continue to form new blood cells
    c. bones continue to be remodeled
    d. bones continue to store minerals (calcium and phosphorus)
15. Which kind of joint is essentially immovable?
    a. hinge joint
    b. fibrous joint
    c. cartilaginous joint
    d. ball and socket joint

Apply What You Know

Answers can be found in the Study Area in MasteringBiology.

1. Compare and contrast swimming and running as forms of exercise training in terms of how they might affect muscle mass, bone mass, and the possibility of injuries to joints.
2. The administration of growth hormone is sometimes used clinically to stimulate growth in unusually short children who are deficient in growth hormone. However, growth hormone is ineffective in unusually short but otherwise normal adults. What accounts for the difference?
3. Although sports are getting more and more competitive at younger and younger ages, in baseball it is not recommended that children learn to throw curveballs at too young an age. What is the problem with throwing a curveball?
4. You and a friend decide to volunteer to help build houses with Habitat for Humanity over your spring break. Although you have only rarely used a hammer, you take on the task helping to construct the frame of the house. After your break is over and you have returned to campus, you notice a sharp pain in your elbow every time you bend your arm. You seek medical advice, and the doctor tells you that you have tendonitis. What is tendonitis? What might have caused your condition?
5. You just graduated and got your first job as a forensic investigator. Your first case is a skeleton that was discovered in the desert. The pathologist examines the bones and tells you that the skeleton belonged to an adult man. How can the pathologist be certain by examining only the bones? What else might the pathologist be able to tell you by examining the bones of this skeleton?
6. Obesity is a common problem in this country, even among children. What changes would you expect to see in the skeletal system of a person who has been obese for a long time?

BlogInFocus

Answers can be found in the Study Area in MasteringBiology.

1. Based on what you learned about synovial joints such as the knee, do you think runners are at increased risk of degenerative knee diseases such as osteoarthritis later in life, compared to non-runners? (To view a research paper on this issue, find MJ's blog in the Study Area in MasteringBiology and look under "Is Running Hard on Knees?")

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