Appendicular Skeleton

PECTORAL (SHOULDER) GIRDLE

OBJECTIVE • Identify the bones of the pectoral (shoulder) girdle and their principal markings.

The ***pectoral girdles*** (PEK-tō-ral) or ***shoulder girdles*** attach the bones of the upper limbs to the axial skeleton (Figure 6.18). The right and left pectoral girdles each consist of two bones: a clavicle and a scapula. The clavicle, the anterior component, articulates with the sternum, and the scapula, the posterior component, articulates with the clavicle and the humerus. The pectoral girdles do not articulate with the vertebral column. The joints of the shoulder girdles are freely movable and thus allow movements in many directions.

Clavicle

Each ***clavicle*** (KLAV-i-kul = key) or collarbone is a long, slender S-shaped bone that is positioned horizontally above the first rib. The medial end of the clavicle articulates with the sternum, and the lateral end articulates with the acromion of the scapula (Figure 6.18). Because of its position, the clavicle transmits mechanical force from the upper limb to the trunk. If the force transmitted to the clavicle is excessive, as when you fall on your outstretched arm, a *fractured clavicle* may result.

Scapula

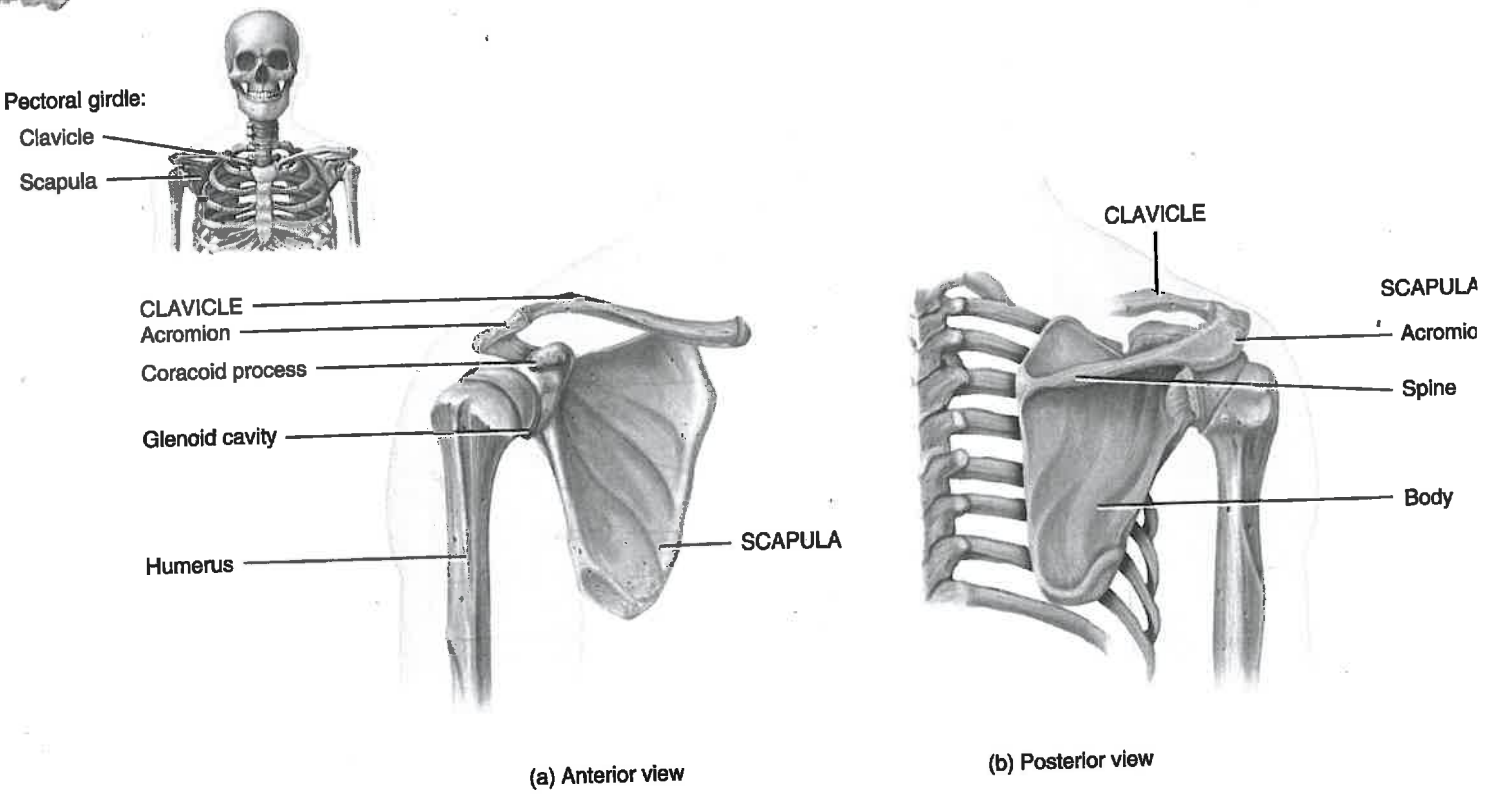
Each ***scapula*** (SCAP-yū-la), or ***shoulder blade***, is a large, flat, triangular bone situated in the posterior part of the thorax (Figure 6.18). A sharp ridge, the *spine*, runs diagonally across the posterior surface of the flattened, triangular *body* of the scapula. The lateral end of the spine, the *acromion* (a-KRŌ-mē-on; *acrom-* = topmost), is easily felt as the high point of the shoulder and is the site of articulation with the clavicle. Inferior to the acromion is a depression called the *glenoid cavity*. This cavity articulates with the head of the humerus (arm bone) to form the shoulder joint. Also present on the scapula is a projection called the *coracoid process* (KOR-a-koyd = like a crow's beak) to which muscles attach.

■ CHECKPOINT

21. What bones make up the pectoral girdle? What is the function of the pectoral girdle?

Figure 6.18 Right pectoral (shoulder) girdle.

The pectoral girdle attaches the bones of the upper limb to the axial skeleton.



Which bones make up a pectoral girdle?

UPPER LIMB

OBJECTIVE • Identify the bones of the upper limb and their principal markings.

Each ***upper limb*** consists of 30 bones. Each upper limb includes a humerus in the arm; ulna and radius in the forearm; and 8 carpals (wrist bones), 5 metacarpals (palm bones), and 14 phalanges (finger bones) in the hand (see Figure 6.6).

Humerus

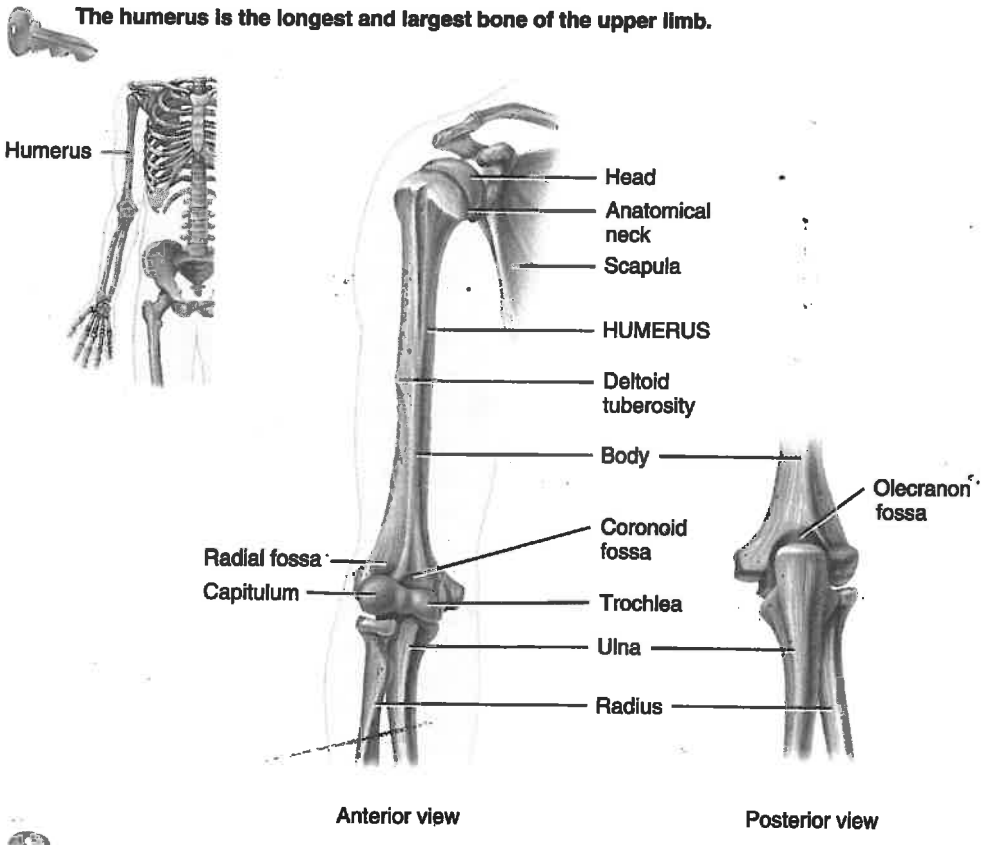
The ***humerus*** (HŪ-mer-us), or arm bone, is the longest and largest bone of the upper limb (Figure 6.19). At the shoulder it articulates with the scapula, and at the elbow it articulates with both the ulna and radius. The proximal end of the humerus consists of a *head* that articulates with the glenoid cavity of the scapula. It also has an *anatomical neck*, the former site of the epiphyseal plate, which is a groove just distal to the head. The *body* of the humerus contains a roughened, V-shaped area called the *deltoid tuberosity* where the deltoid muscle attaches. At the distal end of the humerus, the *capitulum* (ka-PIT-ū-lum = small head), is a rounded knob that articulates with the head of the radius. The *radial fossa* is a depression that receives the head of the radius when the forearm is flexed (bent). The *trochlea* (TRŌK-lē-a) is a spool-shaped surface that articulates with the ulna. The *coronoid fossa* (KOR-ō-noyd = crown-shaped) is a depression that receives part of the ulna when the forearm is flexed. The *olecranon fossa* (ō-LEK-ra-non) is a depression on the back of the bone that receives the olecranon of the ulna when the forearm is extended (straightened).

Ulna and Radius

The ***ulna*** is on the medial aspect (little-finger side) of the forearm and is longer than the radius (Figure 6.20). At the proximal end of the ulna is the *olecranon*, which forms the prominence of the elbow. The *coronoid process*, together with the olecranon, receives the trochlea of the humerus. The trochlea of the humerus also fits into the *trochlear notch*, a large curved area between the olecranon and the coronoid process. The *radial notch* is a depression for the head of the radius. A *styloid process* is at the distal end of the ulna.

The ***radius*** is located on the lateral aspect (thumb side) of the forearm. The proximal end of the radius has a disc-

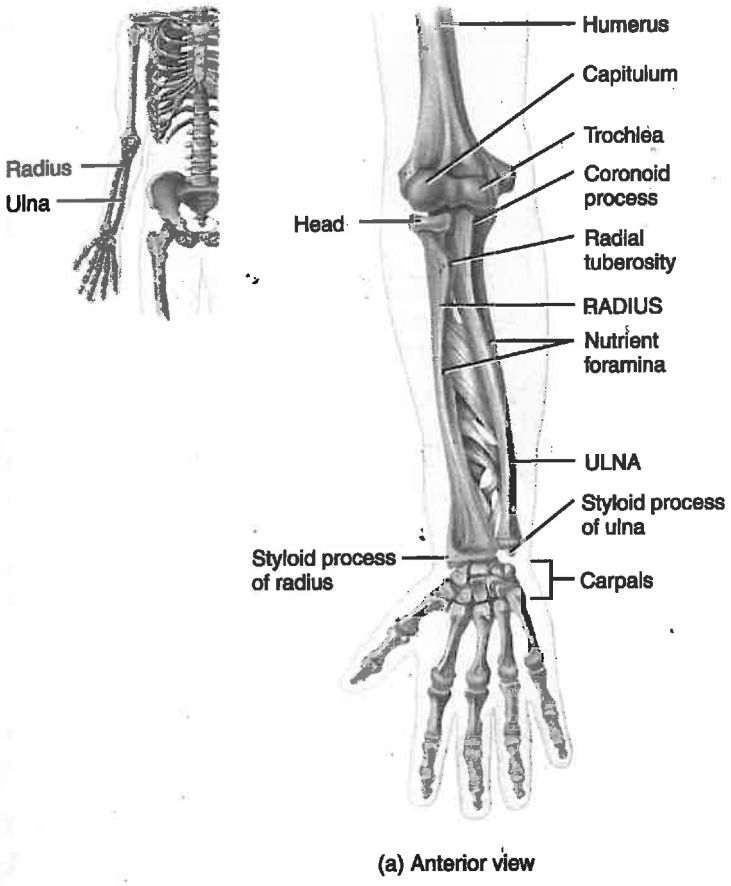
Figure 6.19 Right humerus in relation to the scapula, ulna, and radius.



With which part of the scapula does the humerus articulate?

Figure 6.20 Right ulna and radius in relation to the humerus and carpals.

In the forearm, the longer ulna is on the medial side, and the radius is on the lateral side.



What part of the ulna is called the elbow?

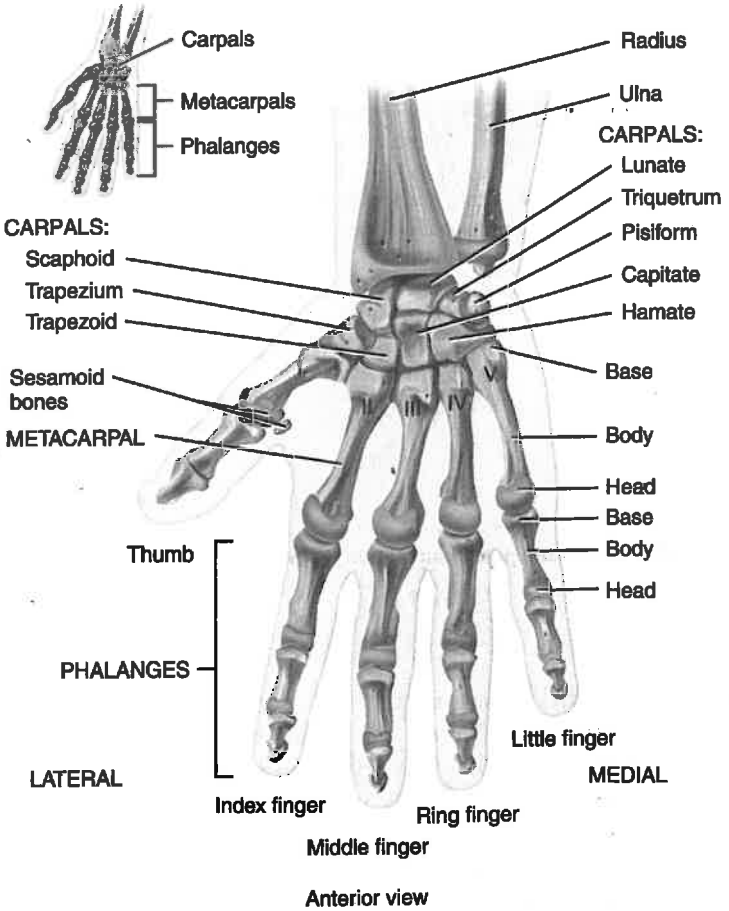
shaped *head* that articulates with the capitulum of the humerus and radial notch of the ulna. It has a raised, roughened area called the *radial tuberosity* that provides a point of attachment for the biceps brachii muscle. The distal end of the radius articulates with three carpal bones of the wrist. Also at the distal end is a *styloid process*. Fracture of the distal end of the radius is the most common fracture in adults older than 50 years.

Carpals, Metacarpals, and Phalanges

The *carpus (wrist)* of the hand contains eight small bones, the *carpals*, held together by ligaments (Figure 6.21). The carpals are arranged in two transverse rows, with four bones in each row, and they are named for their shapes. In the anatomical position, the carpals in the top row, from the

Figure 6.21 Right wrist and hand in relation to the ulna and radius.

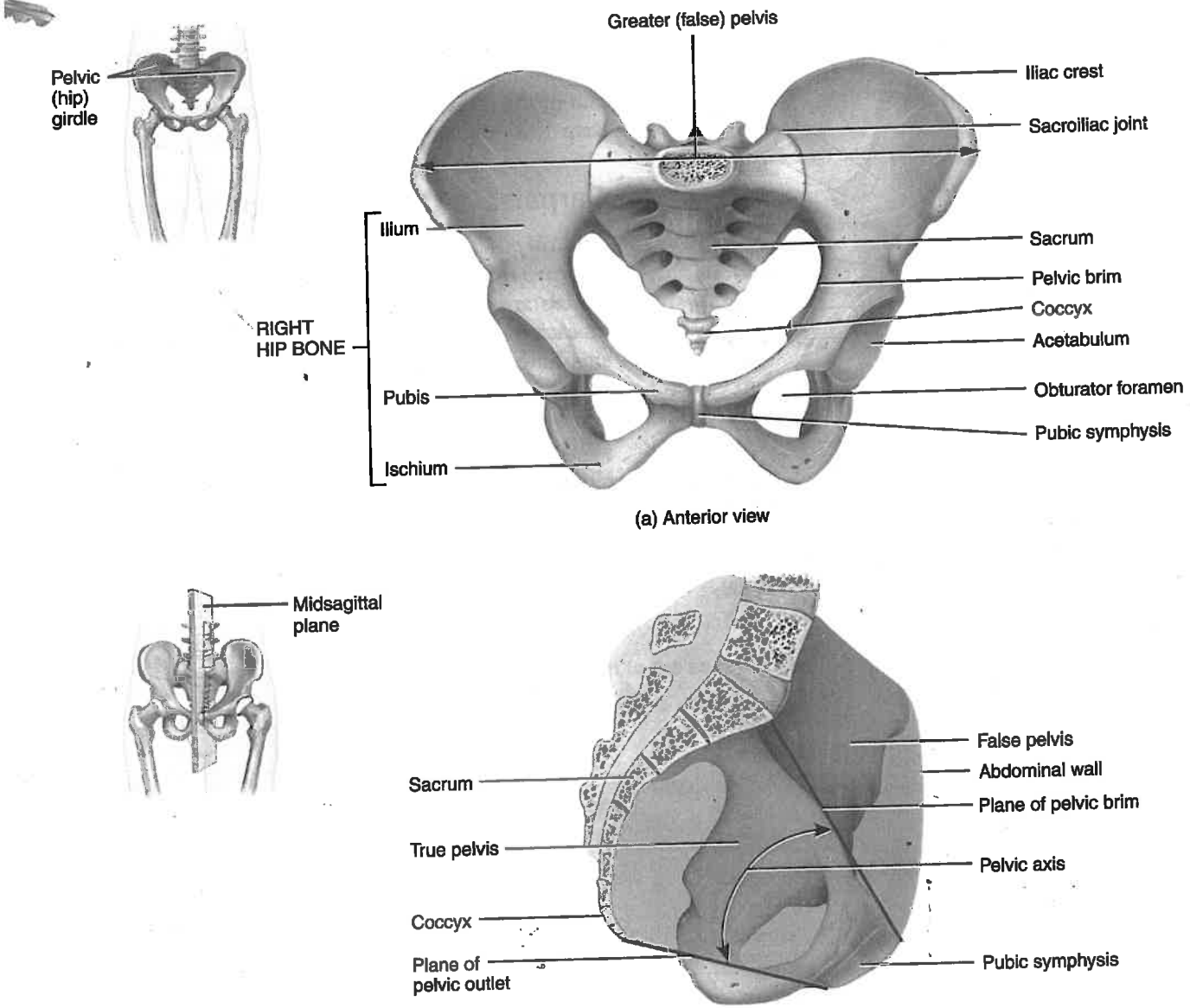
The skeleton of the hand consists of the carpals, metacarpals, and phalanges.



What part of which bones are commonly called the knuckles?

ure 6.22 Female pelvic (hip) girdle.

The hip bones are united in front at the pubic symphysis and in back at the sacrum.



What part of the pelvis surrounds the pelvic organs in the pelvic cavity?

lateral to medial position, are the ***scaphoid*** (SKAF-oid = boatlike), ***lunate*** (LOO-nāt = moon-shaped), ***triquetrum*** (trī-KWĒ-trum = three cornered), and ***pisiform*** (PĪ-si-form = pea-shaped). In about 70% of carpal fractures, only the scaphoid is broken because of the force transmitted through it to the radius. The carpals in the bottom row, from the lateral to medial position, are the ***trapezium*** (tra-PĒ-zē-um = four-sided figure with no two sides parallel), ***trapezoid*** (TRAP-e-zoid = four-sided figure with two sides parallel), ***capitate*** (KAP-i-tāt = head-shaped; the largest carpal bone, whose rounded projection, the head, articulates with the lunate), and ***hamate*** (HAM-āt = hooked; named for a large hook-shaped projection on its anterior surface). Together, the concavity formed by the pisiform and hamate (on the ulnar

side) and the scaphoid and trapezium (on the radial side) constitute a space called the ***carpal tunnel***. Through it pass the long flexor tendons of the digits and thumb and the median nerve.

Narrowing of the carpal tunnel gives rise to a condition called **carpal tunnel syndrome**, in which the median nerve is compressed. The nerve compression causes pain, numbness, tingling, and muscle weakness in the hand.

The ***metacarpus (palm)*** of the hand contains five bones called ***metacarpals*** (*meta-* = after or beyond). Each metacarpal bone consists of a proximal *base*, an intermediate *body*, and a distal *head*. The metacarpal bones are numbered I through V (or 1 to 5), starting with the lateral bone in the thumb. The heads of the metacarpals are commonly called the "knuckles" and are readily visible in a clenched fist.

The ***phalanges*** (fa-LAN-jēz = battle lines) are the bones of the fingers. They number 14 in each hand. Like the metacarpals, the phalanges are numbered I through V (or 1 to 5), beginning with the thumb. A single bone of a finger or toe is termed a *phalanx* (FĀ-lanks). Like the metacarpals, each phalanx consists of a proximal *base*, an intermediate *body*, and a distal *head*. There are two phalanges (proximal and distal) in the thumb and three phalanges (proximal, middle, and distal) in each of the other four digits. In order from the thumb, these other four digits are commonly referred to as the index finger, middle finger, ring finger, and little finger (Figure 6.21).

■ **CHECKPOINT**

22. What bones form the upper limb, from proximal to distal?

PELVIC (HIP) GIRDLE

OBJECTIVE • Identify the bones of the pelvic (hip) girdle and their principal markings.

The ***pelvic (hip) girdle*** consists of the two ***hip bones***, also called ***coxal bones*** (Figure 6.22 on page 142). The pelvic girdle provides a strong, stable support for the vertebral column, protects the pelvic viscera, and attaches the lower limbs to the axial skeleton. The hip bones are united to each other in front at a joint called the ***pubic symphysis*** (PŪ-bik SIM-fi-sis); posteriorly they unite with the sacrum at the sacroiliac joint.

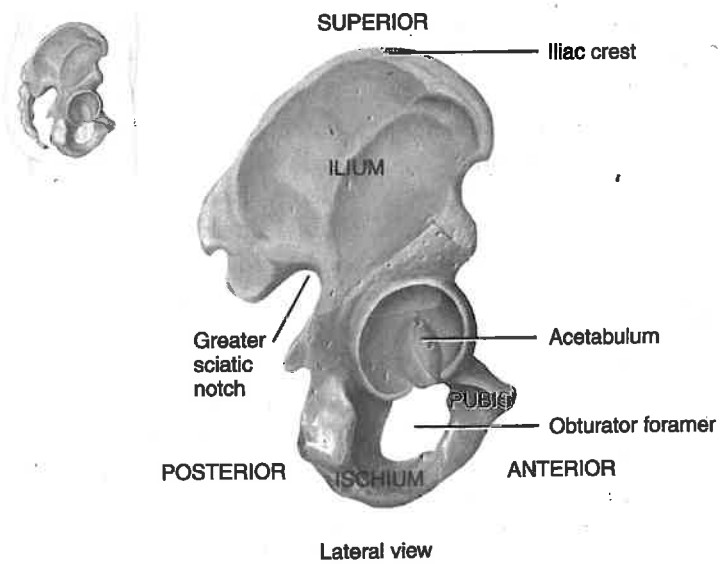
Together with the sacrum and coccyx, the two hip bones of the pelvic girdle form a basinlike structure called the ***pelvis*** (plural is *pelvises* or *pelves*). In turn, the bony pelvis is divided into upper and lower portions by a boundary called the ***pelvic brim*** (Figure 6.22). The part of the pelvis above the pelvic brim is called the ***false (greater) pelvis***. The false pelvis is actually part of the abdomen and does not contain any pelvic organs, except for the urinary bladder, when it is full, and the uterus during pregnancy. The part of the pelvis below the pelvic brim is called the ***true (lesser) pelvis***. The true pelvis surrounds the pelvic cavity (see Figure 1.8 on page 15). The upper opening of the true pelvis is called the ***pelvic inlet***, and the lower opening of the true pelvis is called the ***pelvic outlet***. The ***pelvic axis*** is an imaginary curved line passing through the true pelvis; it joins the central points of the planes of the pelvic inlet and outlet. During childbirth, the pelvic axis is the course taken by the baby's head as it descends through the pelvis.

Pelvimetry is the measurement of the size of the inlet and outlet of the birth canal, which may be done by ultrasonography or physical examination. Measurement of the pelvic outlet in pregnant females is important because it must become large enough for the fetus to pass through at birth.

Each of the two hip bones of a newborn is composed of three parts: the ilium, the pubis, and the ischium (Figure 6.23). The ***ilium*** (= flank) is the largest of the three subdivisions of the hip bone. Its upper border is the *iliac crest*. Or

Figure 6.23 Right hip bone. The lines of fusion of the ilium, ischium, and pubis are not always visible in an adult hip bone.

The two hip bones form the pelvic girdle, which attaches the lower limbs to the axial skeleton and supports the vertebral column and viscera.



Which bone fits into the socket formed by the acetabulum?

the lower surface is the *greater sciatic notch* (sī-AT-ik) through which the sciatic nerve, the longest nerve in the body, passes. The ***ischium*** (IS-kē-um = lip) is the lower, posterior part of the hipbone. The ***pubis*** (PŪ-bis = pubic hair) is the lower, anterior part of the hipbone. By age 23 years, the three separate bones have fused into one. The deep fossa (depression) where the three bones meet is the *acetabulum* (as-e-TAB-ū-lum = vinegar cup). It is the socket for the head of the femur. The ischium joins with the pubis, and together they surround the *obturator foramen* (OB-too-rā-ter), the largest foramen in the skeleton.

■ **CHECKPOINT**

23. What bones make up the pelvic girdle? What is the function of the pelvic girdle?

LOWER LIMB

OBJECTIVE • List the skeletal components of the lower limb and their principal markings.

Each ***lower limb*** is composed of 30 bones: the femur in the thigh; the patella (kneecap); the tibia and fibula in the leg (the part of the lower limb between the knee and the ankle); and 7 tarsals (ankle bones), 5 metatarsals, and 14 phalanges (toes) in the foot (see Figure 6.6).

Femur

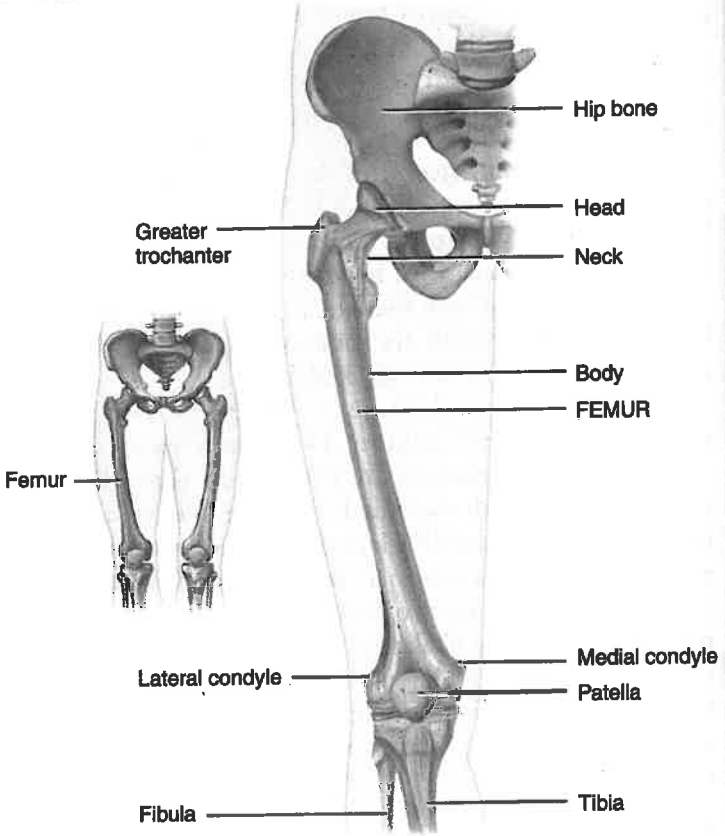
The ***femur*** (thigh bone) is the longest, heaviest, and strongest bone in the body (Figure 6.24). Its proximal end articulates with the hip bone, and its distal end articulates with the tibia and patella. The body of the femur bends medially, and as a result, the knee joints are brought nearer to the midline of the body. The bend is greater in females because the female pelvis is broader.

The ***head*** of the femur articulates with the acetabulum of the hip bone to form the ***hip joint***. The ***neck*** of the femur is a constricted region below the head. A fairly common fracture in the elderly occurs at the neck of the femur, which becomes so weak that it fails to support the weight of the body. Although it is actually the femur that is fractured, this condition is commonly known as a broken hip. The *greater trochanter* (trō-KAN-ter) is a projection felt and seen in front of the hollow on the side of the hip. It is where some of the thigh and buttock muscles attach and serves as a landmark for intramuscular injections in the thigh.

The distal end of the femur expands into the *medial condyle* and *lateral condyle*, projections which articulate with the tibia. The *patellar surface* is located on the anterior surface of the femur between the condyles.

Figure 6.24 Right femur in relation to the hip bone, patella, tibia, and fibula.

The head of the femur articulates with the acetabulum of the hip bone to form the hip joint.



Anterior view

With which bones does the distal end of the femur articulate?

Patella

The ***patella*** (= little dish), or kneecap, is a small, triangular bone in front of the joint between the femur and tibia, commonly known as the knee joint (Figure 6.24). The patella develops in the tendon of the quadriceps femoris muscle. Its functions are to increase the leverage of the tendon, maintain the position of the tendon when the knee is flexed, and protect the knee joint. During normal flexion and extension of the knee, the patella tracks (glides) up and down in the groove between the two femoral condyles.

In "runner's knee," or **patellofemoral stress syndrome**, normal tracking does not occur. Instead, the patella tracks laterally, and the increased pressure of abnormal tracking causes the associated pain. A common cause of runner's knee is constantly walking, running, or jogging on the same side of the road. Because roads are high in the middle and slope down on the sides, the slope stresses the knee that is closer to the center of the road.

Tibia and Fibula

The ***tibia***, or shin bone, is the larger, medial, weight-bearing bone of the leg (Figure 6.25). The tibia articulates at its proximal end with the femur and fibula, and at its distal end with the fibula and talus of the ankle. The proximal end of the tibia expands into a *lateral condyle* and a *medial condyle*, projections which articulate with the condyles of the femur to form the *knee joint*. The *tibial tuberosity* is on the anterior surface below the condyles and is a point of attachment for the patellar ligament. The medial surface of the distal end of the tibia forms the *medial malleolus* (ma-LĒ-ō-lus = little hammer), which articulates with the talus of the ankle and forms the prominence that can be felt on the medial surface of your ankle.

Shin splints is the name given to soreness or pain along the tibia. Probably caused by inflammation of the periosteum brought about by repeated tugging of the attached muscles and tendons, it is often the result of walking or running up and down hills.

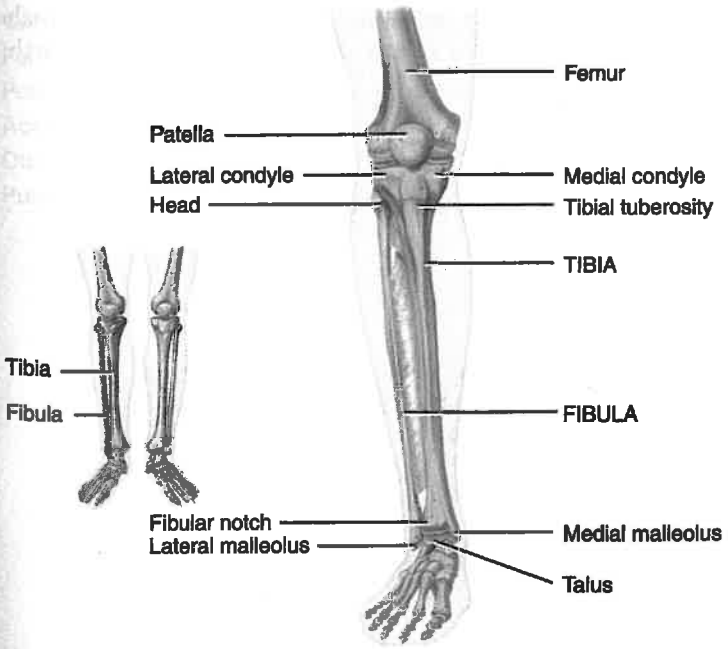
The ***fibula*** is parallel and lateral to the tibia (Figure 6.25) and is considerably smaller than the tibia. The *head* of the fibula articulates with the lateral condyle of the tibia below the knee joint. The distal end has a projection called the *lateral malleolus* that articulates with the talus of the ankle. This forms the prominence on the lateral surface of the ankle. As shown in Figure 6.25, the fibula also articulates with the tibia at the *fibular notch*.

Tarsals, Metatarsals, and Phalanges

The ***tarsus (ankle)*** of the foot contains seven bones, the ***tarsals***, held together by ligaments (Figure 6.26). Of these, the ***talus*** (TĀ-lus = ankle bone) and ***calcaneus*** (kal-KĀ-nē-us = heel bone) are located on the posterior part of the foot. The anterior part of the ankle contains the ***cuboid*** (KŪ-boyd), ***navicular*** (na-VIK-ū-lar), and three ***cuneiform bones*** (KŪ-nē-i-form) called the *first*, *second*, and *third cuneiforms*. The talus is the only bone of the foot that articulates with the fibula and tibia. It articulates medially with the medial malleolus of the tibia and laterally with the lateral malleolus of the fibula. During walking, the talus initially bears the entire weight of the body. About half the weight is then trans-

Figure 6.25 Right tibia and fibula in relation to the femur, patella, and talus.

The tibia articulates with the femur and fibula proximally and with the fibula and talus distally, while the fibula articulates proximally with the tibia below the knee joint and distally with the talus.

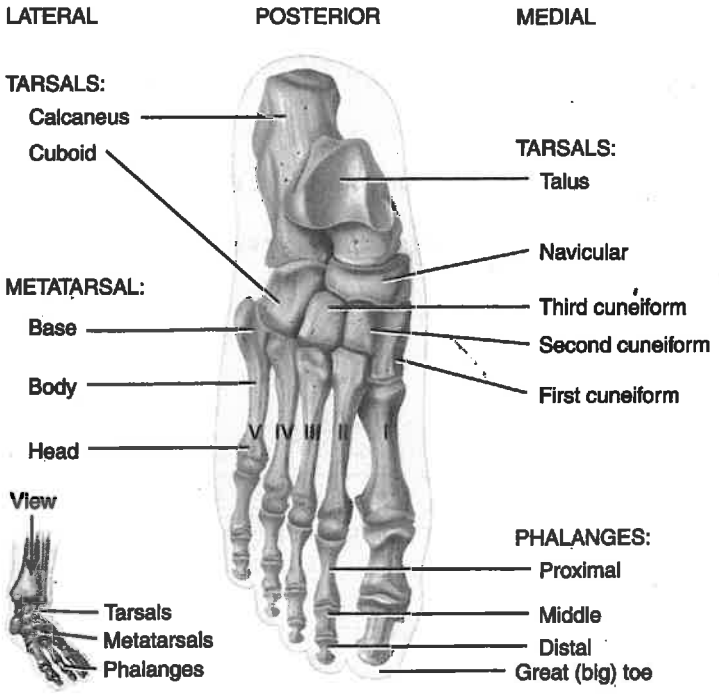


Anterior view

Which leg bone bears the weight of the body?

Figure 6.26 Right foot.

The skeleton of the foot consists of the tarsals, metatarsals, and phalanges.



Superior view

Which tarsal bone articulates with the tibia and fibula?

mitted to the calcaneus. The remainder is transmitted to the other tarsal bones. The calcaneus is the largest and strongest of the tarsals.

Five bones called ***metatarsals*** and numbered I to V (or 1 to 5) from the medial to lateral position form the skeleton of the *metatarsus*. Like the metacarpals of the palm, each metatarsal consists of a proximal *base*, an intermediate *body*, and a distal *head*. The first metatarsal, which is connected to the big toe, is thicker than the others because it bears more weight.

The ***phalanges*** of the foot resemble those of the hand both in number and arrangement. Each also consists of a proximal *base*, an intermediate *body*, and a distal *head*. The great or big toe (*hallux*) has two large, heavy phalanges—proximal and distal. The other four toes each have three phalanges—proximal, middle, and distal.

The bones of the foot are arranged in two ***arches*** (Figure 6.27). These arches enable the foot to support the weight of the body, provide an ideal distribution of body weight over the hard and soft tissues of the foot, and provide leverage while walking. The arches are not rigid—they yield as weight is applied and spring back when the weight is lifted, thus helping to absorb shocks. The *longitudinal arch* extends from the front to the back of the foot and has two parts, medial and lateral. The *transverse arch* is formed by the navicular, three cuneiforms, and the bases of the five metatarsals.

The bones composing the arches are held in position by ligaments and tendons. If these ligaments and tendons are weakened by excess weight, postural abnormalities, or genetic predisposition, the height of the medial longitudinal arch may decrease or "fall." The result is a condition called **flatfoot.**

■ CHECKPOINT

24. What bones form the lower limb, from proximal to distal?
25. What are the functions of the arches of the foot?

COMPARISON OF FEMALE AND MALE SKELETONS

OBJECTIVE • Identify the principal structural differences between female and male skeletons.

The bones of a male are generally larger and heavier than those of a female. The articular ends are thicker in relation to the shafts. In addition, because certain muscles of the male are larger than those of the female, the points of muscle attachment—tuberosities, lines, and ridges—are larger in the male skeleton.

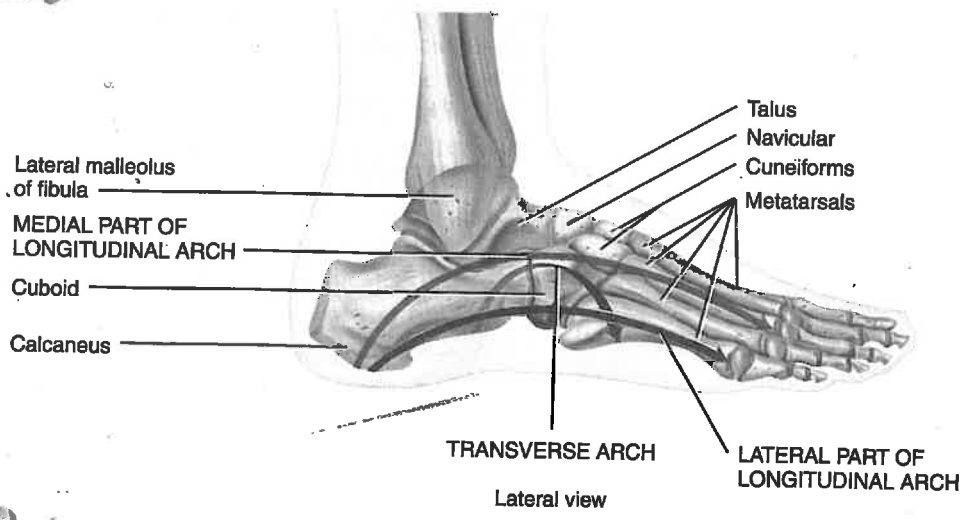
Many significant structural differences between the skeletons of females and males are related to pregnancy and childbirth. Because the female's pelvis is wider and shallower than the male's, there is more space in the true pelvis of the female, especially in the pelvic inlet and pelvic outlet, which accommodate the passage of the infant's head at birth. Several of the significant differences between the female and male pelves are shown in Table 6.4.

■ CHECKPOINT

26. Explain the major structural differences between female and male skeletons related to pregnancy and childbirth.

Figure 6.27 Arches of the right foot.

Arches help the foot support and distribute the weight of the body and provide leverage during walking.



What structural aspect of the arches allows them to absorb shocks?

AGING AND THE SKELETAL SYSTEM

OBJECTIVE • Describe the effects of aging on the skeletal system.

From birth through adolescence, more bone is produced than is lost during bone remodeling. In young adults, the rates of bone production and loss are about the same. As the levels of sex steroids diminish during middle age, especially in women after menopause, a decrease in bone mass occurs because bone destruction outpaces bone formation. Because women's bones generally are smaller than men's bones to begin with, loss of bone mass in old age typically causes greater problems in women. These factors contribute to a higher incidence of osteoporosis in women.

Aging has two main effects on the skeletal system: Bones become more brittle and lose mass. Bone brittleness results from a decrease in the rate of protein synthesis and in the production of human growth hormone, which diminishes the production of the collagen fibers that give bone its strength and flexibility. As a result, inorganic minerals gradually constitute a greater proportion of the bone extracellular matrix.

Loss of bone mass results from demineralization and usually begins after age 30 in females, accelerates greatly around age 45 as levels of estrogens decrease, and continues until as much as 30% of the calcium in bones is lost by age 70. Once bone loss begins in females, about 8% of bone mass is lost every 10 years. In males, calcium loss from bone typically does not begin until after age 60, and about 3% of bone mass is lost every 10 years. The loss of calcium from bones is one of the problems in osteoporosis (described on page 150). Loss of bone mass also leads to bone deformity, pain, stiffness, some loss of height, and loss of teeth.

■ CHECKPOINT

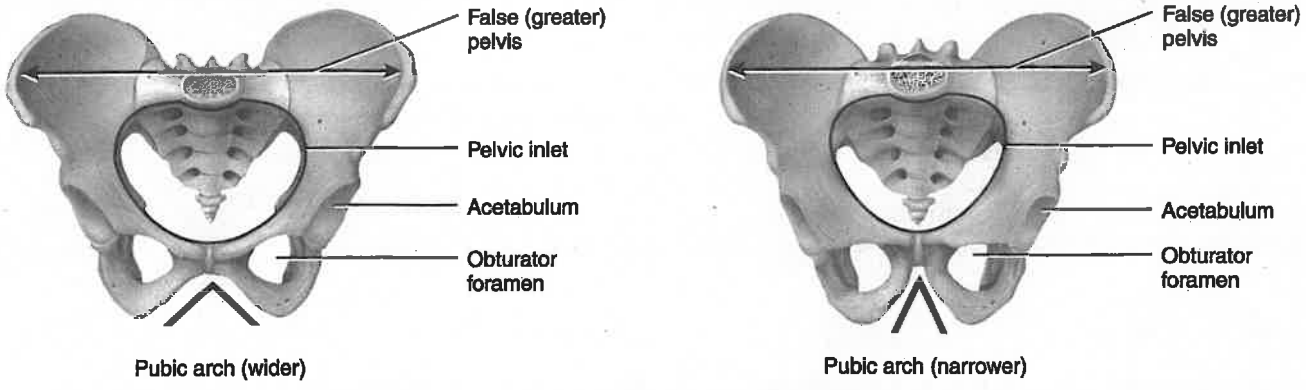
27. How does aging affect the brittleness of bone and the loss of bone mass?

• • •

To appreciate the many ways that the skeletal system contributes to homeostasis of other body systems, examine Focus on Homeostasis: The Skeletal System on page 149. Next, in Chapter 7, we will see how joints both hold the skeleton together and permit it to participate in movements.

Table 6.4 Comparison of the Pelvis in Females and Males

Point of Comparison	Female	Male
General structure	Light and thin.	Heavy and thick.
False (greater) pelvis	Shallow.	Deep.
Pelvic inlet	Larger and more oval.	Smaller and heart-shaped.
Acetabulum	Small and faces anteriorly.	Large and faces laterally.
Obturator foramen	Oval.	Round.
Pubic arch	Greater than 90° angle.	Less than 90° angle.



Anterior views

Focus on Wellness

Steps to Healthy Feet

We take the structure and function of our feet for granted—until they start to hurt. And even then we often continue to mistreat them, cramming them into shoes that are too tight, and then walking on concrete sidewalks and taking long shopping expeditions. No wonder foot problems are such a common complaint! Fortunately, most foot problems are preventable by understanding the foot's structure and function and then using good footwear to support them in their work.

These Feet Were Made for Walking

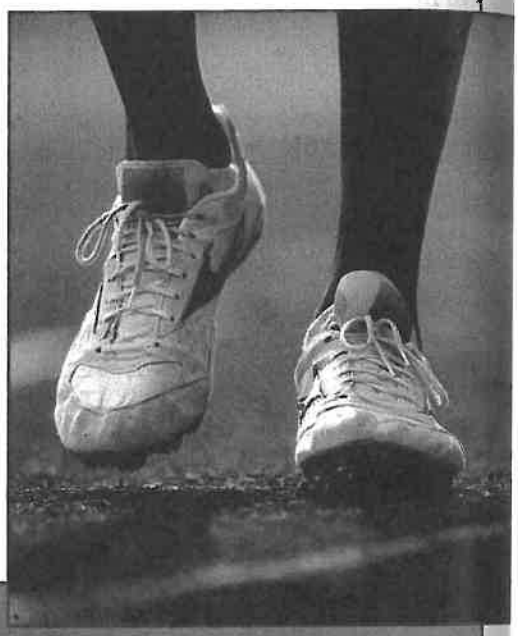
Each time you take a step, your heel strikes the ground first. Then you roll through the arches, over the ball of your foot, and onto your toes. Your arches flatten slightly as they absorb the weight of your body. One foot continues to bear your weight until the heel of the other foot touches the ground. As you walk, your big toe maintains your balance while the other toes give your foot some resiliency. The two outer metatarsals move to accommodate uneven surfaces, while the inner three stay rigid for support.

The most common cause of foot problems is ill-fitting shoes, which stress the structure and interfere with the function of the foot. The high heel is a case in point, which explains why 80% of those suffering from foot problems are women. Although many people think high heels look good and are fun to wear, they should not be used for walking because they make the body's weight fall onto the forefoot. Thus, the arches of the foot are not allowed to absorb the force of the body's weight. This unnatural stress can injure soft-tissue structures, joints, and bones.

Good Shoes for Happy Feet

Choosing shoes that are "good" to your feet can prevent many foot problems, an especially important consideration if you are doing any amount of walking. A good shoe has a sole that is strong and flexible and provides a good gripping surface. Cushioned insoles help protect feet from hard surfaces. Arch supports help distribute weight over a broader area, just like the arches in your foot.

Many people spend a great deal of time researching which brand of shoes to buy but do not spend adequate time evaluating whether or not the shoes suit their feet. A high-quality shoe is only worth buying if it fits! Shop for shoes in the late afternoon when your feet are at their largest. One foot is often bigger than the other; always buy for the bigger foot. The shoes you try on should feel comfortable immediately—don't plan on shoes stretching with wear. The heel should fit snugly, and the instep should not gape open. The toe box should be wide enough to wiggle all your toes.



► Think It Over . . .

► *Why do you think excess body weight is associated with an increased risk of foot problems?*

FOCUS ON HOMEOSTASIS

THE SKELETAL SYSTEM

BODY SYSTEM	CONTRIBUTION OF THE SKELETAL SYSTEM
For all body systems 	Bones provide support and protection for internal organs; bones store and release calcium, which is needed for proper functioning of most body tissues.
Integumentary system 	Bones provide strong support for overlying muscles and skin; joints provide flexibility while skin compensates for the change in joint angle.
Muscular system 	Bones provide attachment points for skeletal muscles and leverage for the muscles to bring about body movements; contraction of skeletal muscle requires calcium ions.
Nervous system 	The skull and vertebrae protect the brain and spinal cord; a normal blood level of calcium is needed for normal functioning of neurons and neuroglia.
Endocrine system 	Bones store and release calcium, needed for normal actions of many hormones.
Cardiovascular system 	Red bone marrow carries out hemopoiesis (blood cell formation); rhythmic beating of the heart requires calcium ions.
Lymphatic system and immunity 	Red bone marrow produces white blood cells involved in immune responses.
Respiratory system 	The axial skeleton of the thorax protects the lungs; rib movements assist breathing; some muscles used for breathing attach to bones by means of tendons.
Digestive system 	Teeth masticate (chew) food; the rib cage protects the esophagus, stomach, and liver; the pelvis protects portions of the intestines.
Urinary system 	Ribs partially protect the kidneys, and the pelvis protects the urinary bladder and urethra.
Reproductive systems 	The pelvis protects the ovaries, uterine (fallopian) tubes, and uterus in females and part of the ductus (vas) deferens and accessory glands in males; bones are an important source of calcium needed for milk synthesis during lactation.

COMMON DISORDERS

Osteoporosis

Osteoporosis (os′-tē-ō-pō-RŌ-sis; *por-* = passageway; *-osis* = condition) is literally a condition of porous bones (Figure 6.28). The basic problem is that bone destruction outpaces bone formation. In large part this is due to depletion of calcium from the body—more calcium is lost in urine, feces, and sweat than is absorbed from the diet. Bone mass becomes so depleted that bones fracture, often spontaneously, under the mechanical stresses of everyday living. For example, a hip fracture might result from simply sitting down too quickly. In the United States, osteoporosis causes more than a million fractures a year, mainly in the hip, wrist, and vertebrae. Osteoporosis afflicts the entire skeletal system. In addition to fractures, osteoporosis causes shrinkage of vertebrae, height loss, hunched backs, and bone pain.

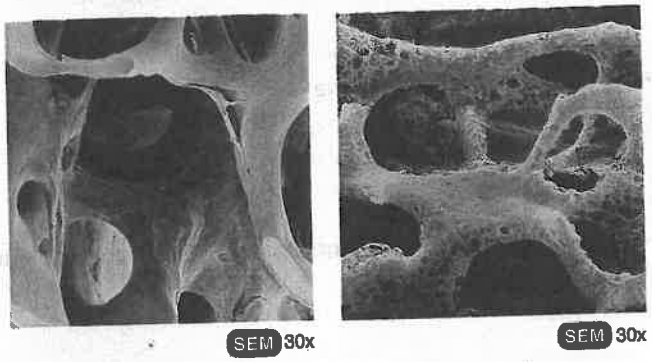
Thirty million people in the United States suffer from osteoporosis. The disorder primarily affects middle-aged and elderly people, 80% of them women. Older women suffer from osteoporosis more often than men for two reasons. Women's bones are less massive than men's bones, and production of estrogens in women declines dramatically at menopause; production of the main androgen, testosterone, in older men wanes gradually and only slightly. Estrogens and testosterone stimulate osteoblast activity and synthesis of bone extracellular matrix. Besides gender, risk factors for developing osteoporosis include a family history of the disease, European or Asian ancestry, thin or small body build, an inactive lifestyle, cigarette smoking, a diet low in calcium and vitamin D, more than two alcoholic drinks a day, and the use of certain medications.

In postmenopausal women, treatment of osteoporosis may include estrogen replacement therapy (ERT; low doses of estrogens) or hormone replacement therapy (HRT; a combination of estrogens and progesterone, another sex steroid). Although such treatments help combat osteoporosis, they increase a woman's risk of breast cancer. The drug Raloxifene® (Evista) mimics the beneficial effects of estrogens on bone without increasing the risk of breast cancer. Another drug that may be used is the nonhormone drug Alendronate (Fosamax®), which blocks resorption of bone by osteoclasts.

Perhaps more important than treatment is prevention. Adequate calcium intake and weight-bearing exercise in her early years may be more beneficial to a woman than drugs and calcium supplements when she is older.

Figure 6.28 Comparison of spongy bone tissue from (a) a normal young adult and (b) a person with osteoporosis. Notice the weakened trabeculae in (b). Compact bone tissue is similarly affected by osteoporosis.

In osteoporosis, bone resorption outpaces bone formation, so bone mass decreases.



(a) Normal bone (b) Osteoporotic bone

If you wanted to develop a drug to lessen the effects of osteoporosis, would you look for a chemical that inhibits the activity of osteoblasts or that of osteoclasts?

Rickets and Osteomalacia

Rickets and ***osteomalacia*** (os′-tē-ō-ma-LĀ-she-ah; *-malacia* = softness) are disorders in which bone calcification fails. The bones become soft or rubbery and are easily deformed. Rickets affects the growing bones of children, but osteomalacia affects the bones of adults.

Herniated Disc

If the ligaments of the intervertebral discs become injured or weakened, the resulting pressure may be great enough to rupture the surrounding fibrocartilage. When this occurs, the material inside may herniate (protrude). This condition is called a ***herniated (slipped) disc***. It occurs most often in the lumbar region because that part of the vertebral column bears much of the weight of the body and is the region of the most bending.

Spina Bifida

Spina bifida (SPĪ-na BIF-i-da) is a congenital defect of the vertebral column in which laminae fail to unite at the midline. In serious cases, protrusion of the membranes (meninges) around the spinal

cord or the spinal cord itself may produce partial or complete paralysis, partial or complete loss of urinary bladder control, and the absence of reflexes. Because an increased risk of spina bifida is associated with a low level of folic acid (one of the B vitamins) early in pregnancy, all women who might become pregnant are encouraged to take folic acid supplements.

Hip Fracture

Although any region of the hip girdle may fracture, the term ***hip fracture*** most commonly applies to a break in the bones associated with the hip joint—the head, neck, or trochanteric regions of the femur, or the bones that form the acetabulum. In the United States, 300,000 to 500,000 people sustain hip fractures each year. The incidence of hip fractures is increasing, in part due to longer life spans. Decreases in bone mass due to osteoporosis and an increased tendency to fall predispose elderly people to hip fractures.

Hip fractures often require surgical treatment, the goal of which is to repair and stabilize the fracture, increase mobility, and decrease pain. Sometimes the repair is accomplished by using surgical pins, screws, nails, and plates to secure the head of the femur. In severe hip fractures, the femoral head or the acetabulum of the hip bone may be replaced by prostheses (artificial devices). The procedure of replacing either the femoral head or the acetabulum is *hemiarthroplasty* (hem-ē-AR-thrō-plas-tē; *hemi-* = one half; *-arthro-* = joint; *-plasty* = molding). Replacement of both the femoral head and acetabulum is *total hip arthroplasty*. The acetabular prosthesis is made of plastic, and the femoral prosthesis is metal; both are designed to withstand a high degree of stress. The prostheses are attached to healthy portions of bone with acrylic cement and screws.

MEDICAL TERMINOLOGY AND CONDITIONS

Bunion (BUN-yun) A deformity of the great toe that typically is caused by wearing tightly fitting shoes. The condition produces inflammation of bursae (fluid-filled sacs at the joint), bone spurs, and calluses.

Clawfoot A condition in which the medial part of the longitudinal arch is abnormally elevated. It is often caused by muscle deformities, such as may result from diabetes.

Kyphosis (kī-FŌ-sis; *kypho-* = bent; *-osis* = condition) An exaggeration of the thoracic curve of the vertebral column. In the elderly, degeneration of the intervertebral discs leads to kyphosis; it may also be caused by osteoporosis, rickets, and poor posture.

Lordosis (lor-DŌ-sis; *lord-* = bent backward) An exaggeration of the lumbar curve of the vertebral column, also called *hollow back*. It may result from increased weight of the abdomen as in pregnancy or extreme obesity, poor posture, rickets, or tuberculosis of the spine.

Osteoarthritis (os′-tē-ō-ar-THRĪ-tis; *arthr* = joint) The degeneration of articular cartilage such that the bony ends touch; the resulting friction of bone against bone worsens the condition. Usually associated with the elderly.

Osteogenic sarcoma (os′-tē-Ō-JEN-ik sar-KŌ-ma; *sarcoma* = connective tissue tumor) Bone cancer that primarily affects osteoblasts and occurs most often in teenagers during their growth spurt; the most common sites are the metaphyses of the thigh bone (femur), shin bone (tibia), and arm bone (humerus). Metastases occur most often in lungs; treatment consists of multidrug chemotherapy and removal of the malignant growth, or amputation of the limb.

Osteomyelitis (os′-tē-ō-mī-e-LĪ-tis) An infection of bone characterized by high fever, sweating, chills, pain, nausea, pus formation, edema, and warmth over the affected bone and rigid overlying muscles. Bacteria, usually *Staphylococcus aureus*, often cause it. The bacteria may reach the bone from outside the body (through open fractures, penetrating wounds, or orthopedic surgical procedures); from other sites of infection in the body (abscessed teeth, burn infections, urinary tract infections, or upper respiratory infections) via the blood; and from adjacent soft tissue infections (as occurs in diabetes mellitus).

Osteopenia (os′-tē-ō-PĒ-nē-a; *penia* = poverty) Reduced bone mass due to a decrease in the rate of bone synthesis to a level insufficient to compensate for normal bone resorption, any decrease in bone mass below normal. An example is osteoporosis.

Scoliosis (skō′-lē-O-sis; *scolio-* = crooked) A sideways bending of the vertebral column, usually in the thoracic region. It may result from congenitally (present at birth) malformed vertebrae, chronic sciatica, paralysis of muscles on one side of the vertebral column, poor posture, or one leg being shorter than the other.

Whiplash injury Injury to the neck region due to severe hyperextension (backward tilting) of the head followed by severe hyperflexion (forward tilting) of the head, usually associated with a rear-end automobile collision. Symptoms are related to stretching and tearing of ligaments and muscles, vertebral fractures, and herniated vertebral discs.

STUDY OUTLINE

Functions of Bone and the Skeletal System (p. 114)

1. The skeletal system consists of all bones attached at joints and cartilage between joints.
2. The functions of the skeletal system include support, protection, movement, mineral homeostasis, housing blood-forming tissue, and storage of energy.

Types of Bones (p. 114)

1. On the basis of shape, bones are classified as long, short, flat, or irregular.

Structure of Bone (p. 114)

1. Parts of a long bone include the diaphysis (shaft), epiphyses (ends), metaphysis, articular cartilage, periosteum, medullary (marrow) cavity, and endosteum.
2. The diaphysis is covered by periosteum.
3. Bone tissue consists of widely separated cells surrounded by large amounts of extracellular matrix (intercellular substance). The four principal types of cells are osteogenic cells, osteoblasts, osteocytes, and osteoclasts. The extracellular matrix contains collagen fibers (organic) and mineral salts that consist mainly of calcium phosphate (inorganic).
4. Compact (dense) bone tissue consists of osteons (haversian systems) with little space between them. Compact bone composes most of the bone tissue of the diaphysis. Functionally, compact bone protects, supports, and resists stress.
5. Spongy bone tissue consists of trabeculae surrounding many red bone marrow–filled spaces. It forms most of the structure of short, flat, and irregular bones and the epiphyses of long bones. Functionally, spongy bone stores red bone marrow and provides some support.

Bone Formation (p. 118)

1. Bone forms by a process called ossification.
2. Bone formation in an embryo or fetus occurs by intramembranous and endochondral ossification, which involve the replacement of preexisting connective tissue with bone.
3. Intramembranous ossification occurs within mesenchyme arranged in sheetlike layers that resemble membranes.
4. Endochondral ossification occurs within a hyaline cartilage derived from mesenchyme. The primary ossification center of a long bone is in the diaphysis. Cartilage degenerates, leaving cavities that merge to form the medullary (marrow) cavity. Osteoblasts lay down bone. Next, ossification occurs in the epiphyses, where bone replaces cartilage, except for articular cartilage and the epiphyseal plate.
5. Because of the activity of the epiphyseal plate, the diaphysis of a bone increases in length.
6. Bone grows in diameter as a result of the addition of new bone tissue around the outer surface of the bone.
7. Old bone is constantly destroyed by osteoclasts, while new bone is constructed by osteoblasts. This process is called remodeling.
8. A fracture is any break in a bone. Fracture repair involves remodeling.
9. Normal growth depends on minerals (calcium, phosphorus, magnesium), vitamins (A, C, D), and hormones (human growth hormone, insulinlike growth factors, insulin, thyroid hormones, sex hormones, and parathyroid hormone).
10. Bones store and release calcium and phosphate, controlled mainly by parathyroid hormone (PTH). PTH raises blood calcium level.
11. Calcitonin (CT) lowers blood calcium level.

Exercise and Bone Tissue (p. 123)

1. Mechanical stress increases bone strength by increasing deposition of mineral salts and production of collagen fibers.
2. Removal of mechanical stress weakens bone through demineralization and collagen fiber reduction.

Divisions of the Skeletal System (p. 124)

1. The axial skeleton consists of bones arranged along the longitudinal axis of the body. The parts of the axial skeleton are the skull, hyoid bone, auditory ossicles, vertebral column, sternum, and ribs.
2. The appendicular skeleton consists of the bones of the girdles and the upper and lower limbs. The parts of the appendicular skeleton are the pectoral (shoulder) girdles, bones of the upper limbs, pelvic (hip) girdle, and bones of the lower limbs.

Skull and Hyoid Bone (p. 125)

1. The skull consists of cranial bones and facial bones.
2. The eight cranial bones include the frontal (1), parietal (2), temporal (2), occipital (1), sphenoid (1), and ethmoid (1).
3. The 14 facial bones are the nasal (2), maxillae (2), zygomatic (2), mandible (1), lacrimal (2), palatine (2), inferior nasal conchae (2), and vomer (1).
4. The hyoid bone, a U-shaped bone that does not articulate with any other bone, supports the tongue and provides attachment for some of its muscles as well as some neck muscles.
5. Sutures are immovable joints between bones of the skull. Examples are the coronal, sagittal, lambdoid, and squamous sutures.
6. Paranasal sinuses are cavities in bones of the skull that communicate with the nasal cavity. They are lined by mucous membranes. Cranial bones containing paranasal sinuses are the frontal, sphenoid, ethmoid, and maxillae.
7. Fontanels are mesenchyme-filled spaces between the cranial bones of fetuses and infants. The major fontanels are the anterior, posterior, anterolaterals, and posterolaterals.

Vertebral Column (p. 133)

1. The bones of the adult vertebral column are the cervical vertebrae (7), thoracic vertebrae (12), lumbar vertebrae (5), the sacrum (5, fused), and the coccyx (4, fused).
2. The vertebral column contains normal curves that give strength, support, and balance.
3. The vertebrae are similar in structure, each consisting of a body, vertebral arch, and seven processes. Vertebrae in the different regions of the column vary in size, shape, and detail.

Thorax (p. 137)

1. The thoracic skeleton consists of the sternum, ribs, costal cartilages, and thoracic vertebrae.
2. The thoracic cage protects vital organs in the chest area.

Pectoral (Shoulder) Girdle (p. 139)

1. Each pectoral (shoulder) girdle consists of a clavicle and scapula.
2. Each attaches an upper limb to the trunk.

Upper Limb (p. 140)

1. There are 30 bones in each upper limb.
2. The upper limb bones include the humerus, ulna, radius, carpals, metacarpals, and phalanges.

Pelvic (Hip) Girdle (p. 143)

1. The pelvic (hip) girdle consists of two hip bones.
2. It attaches the lower limbs to the trunk at the sacrum.
3. Each hip bone consists of three fused components: ilium, pubis, and ischium.

Lower Limb (p. 144)

1. There are 30 bones in each lower limb.
2. The lower limb bones include the femur, patella, tibia, fibula, tarsals, metatarsals, and phalanges.
3. The bones of the foot are arranged in two arches, the longitudinal arch and the transverse arch, to provide support and leverage.

Comparison of Female and Male Skeletons (p. 146)

1. Male bones are generally larger and heavier than female bones and have more prominent markings for muscle attachment.
2. The female pelvis is adapted for pregnancy and childbirth. Differences in pelvic structure are listed in Table 6.4 on page 147.

Aging and the Skeletal System (p. 147)

1. The main effect of aging is a loss of calcium from bones, which may result in osteoporosis.
2. Another effect of aging is a decreased production of extracellular matrix proteins (mostly collagen fibers), which makes bones more brittle and thus more susceptible to fracture.

SELF-QUIZ

1. Match the following cell types to their functions:

____ a. chondroblasts	A. mature bone cells
____ b. osteoclasts	B. cells that form bone
____ c. chondrocytes	C. secrete cartilage matrix
____ d. osteocytes	D. mature cartilage cells
____ e. osteoblasts	E. involved in bone resorption

2. When trying to locate a foramen in a bone, you would look for
   a. a large, rough projection
   b. a ridge
   c. a rounded projection
   d. a shallow depression
   e. an opening or hole
3. The ribs articulate with the
   a. thoracic vertebrae
   b. sacrum
   c. cervical vertebrae
   d. lumbar vertebrae
   e. atlas and axis
4. Match the following:

____ a. run lengthwise through bone	A. lamellae
____ b. connect central canals with lacunae	B. lacunae
____ c. concentric rings of matrix	C. perforating (volkmann's) canal
____ d. connect nutrient arteries and nerves from the periosteum to the central canals	D. canaliculi
____ e. spaces that contain osteocytes	E. central (haversian) cana

5. The presence of an epiphyseal line in a long bone indicates that the bone
   a. is undergoing resorption
   b. has stopped growing in length
   c. is growing in diameter
   d. is still capable of growing in length
   e. is broken

6. The hyoid bone is unique because it
   a. is the smallest bone in the skull
   b. can malform causing a cleft palate
   c. forms the paranasal sinuses
   d. is often broken when an individual falls forward
   e. does not articulate with any other bone

7. The bones that form the pectoral girdle are the
   a. clavicle and scapula b. scapula and sternum
   c. humerus and scapula d. clavicle and humerus
   e. coxal bones

8. The main hormone that regulates the Ca^{2+} balance between bone and blood is
   a. parathyroid hormone b. insulin c. testosterone
   d. insulinlike growth factors e. human growth hormone

9. Spongy bone differs from compact bone because spongy bone
   a. is made up of numerous osteons
   b. is found primarily in the diaphyses of long bones
   c. has latticework walls known as trabeculae
   d. contains few, small spaces known as lacunae
   e. has lamellae arranged in concentric rings

10. In which of the following individuals might you expect to find the smallest bone mass?
    a. 20-year-old male weightlifter
    b. 45-year-old female weightlifter
    c. 45-year-old male astronaut
    d. 80-year-old bedridden female
    e. 65-year-old bedridden male

11. Place the following steps of endochondral ossification in the correct order:
    1. Hyaline cartilage remains on the articular surfaces and epiphyseal plates
    2. Chondroblasts produce a growing hyaline cartilage model surrounded by the perichondrium
    3. Osteoblasts in perichondrium produce compact bone
    4. Secondary ossification centers form
    5. Primary ossification center and medullary cavity form

    a. 2, 3, 4, 5, 1 b. 2, 3, 5, 4, 1 c. 5, 2, 1, 3, 4
    d. 3, 2, 5, 4, 1 e. 5, 3, 2, 1, 4

12. Match each bone to its shape:

____ a. humerus	A. flat
____ b. carpus	B. irregular
____ c. vertebra	C. long
____ d. sternum	D. short

13. Where long bones form joints, the epiphyses are covered with
    a. yellow bone marrow b. osteoclasts c. periosteum
    d. endosteum e. hyaline cartilage

14. What substance in bone contributes to its tensile strength?
    a. red bone marrow
    b. collagen
    c. yellow bone marrow
    d. calcium phosphate
    e. loose fibrous connective tissue

15. The skeletal system is responsible for
    a. protecting internal organs from injury
    b. producing movement
    c. providing a supporting framework for the body
    d. hemopoiesis
    e. all of the above

16. For each of the following bones, place an AX in the blank if it belongs to the axial skeleton and an AP in the blank if it is part of the appendicular skeleton.

____ a. lacrimal	____ l. metatarsals	____ w. maxilla
____ b. clavicle	____ m. temporal	____ x. frontal
____ c. radius	____ n. metacarpals	____ y. inferior nasal concha
____ d. mandible	____ o. vomer	
____ e. patella	____ p. fibula	
____ f. carpals	____ q. palatine	____ z. humerus
____ g. scapula	____ r. hyoid	____ aa. ulna
____ h. sternum	____ s. tibia	____ bb. femur
____ i. phalanges	____ t. sphenoid	____ cc. ribs
____ j. tarsals	____ u. vertebrae	____ dd. occipital
____ k. ethmoid	____ v. coxal	

CRITICAL THINKING APPLICATIONS

1. J.R. was riding his motorcycle across the Big Span Bridge when he had a collision with a nearsighted sea gull. In the resulting crash, J.R. crushed his left leg, fracturing both leg bones; snapped the pointy distal end of his lateral forearm bone; and broke the most lateral and proximal bone in his wrist. The sea gull flew off when the ambulance arrived. Name the bones that J.R. broke.
2. While investigating her new baby brother, a 4-year-old girl discovers a soft spot on the baby's skull and announces that the baby needs to go back because "it's not finished yet." Explain the presence of soft spots in the infant's skull and the lack of soft spots in yours.
3. Old Grandma Olga is a tiny, stooped woman with a big sens of humor. Her favorite movie line is from *The Wizard of O* when the wicked witch says "I'm melting." "That's me," laugh Olga, "melting away, getting shorter every year." What is hap pening to Grandma Olga?
4. During the volleyball game, Kate jumped, twisted, spike scored, and screamed! She couldn't put any weight on her le leg and her left knee swelled rapidly to twice its usual size. X rays revealed a fracture of the proximal tibia. In layman's term what is the location of Kate's fracture? What caused the rapi swelling? What are the body's requirements for bone healing

ANSWERS TO FIGURE QUESTIONS

6.1 The articular cartilage reduces friction at joints; red bone marrow produces blood cells; and the endosteum lines the medullary cavity.

6.2 Because the central canals are the main blood supply to the osteocytes, their blockage would lead to death of osteocytes.

6.3 The flat bones of the skull and mandible develop by intramembranous ossification.

6.4 The epiphyseal lines are indications of growth zones that have ceased to function.

6.5 Heartbeat, respiration, nerve cell functioning, enzyme functioning, and blood clotting are all processes that depend on proper levels of calcium.

6.6 Axial skeleton: skull and vertebral column. Appendicular skeleton: clavicle, shoulder girdle, humerus, pelvic girdle, and femur.

6.7 The cranial bones are the frontal, parietal, occipital, sphenoid, ethmoid, and temporal bones.

6.8 The foramen magnum is the largest foramen in the skull.

6.9 Crista galli of ethmoid bone, frontal, parietal, temporal, occipital, temporal, parietal, frontal, and crista galli of ethmoid bone articulate in clockwise order with the sphenoid bone.

6.10 The perpendicular plate of the ethmoid bone forms the top part of the nasal septum.

6.11 The paranasal sinuses produce mucus and serve as resonating chambers for vocalization.

6.12 The thoracic and sacral curves are concave.

6.13 The vertebral foramina enclose the spinal cord, and the intervertebral foramina provide spaces for spinal nerves to exit the vertebral column.

6.14 The atlas and axis permit movement of the head to signify "no."

6.15 The lumbar vertebrae support more weight than the thoracic and cervical vertebrae.

6.16 The sacral foramina are passageways for nerves and blood vessels.

6.17 The true ribs are pairs 1 through 7; the false ribs are pairs 8 through 12; and the floating ribs are pairs 11 and 12.

6.18 A pectoral girdle consists of a clavicle and a scapula.

6.19 The glenoid cavity of the scapula articulates with the humerus.

6.20 The "elbow" part of the ulna is the olecranon.

6.21 The knuckles are the heads of the metacarpals.

6.22 The true pelvis surrounds the pelvic organs in the pelvic cavity.

6.23 The femur fits into the acetabulum.

6.24 The distal end of the femur articulates with the tibia and th patella.

6.25 The tibia is the weight-bearing bone of the leg.

6.26 The talus articulates with the tibia and fibula.

6.27 The arches are not rigid, yielding when weight is applied and springing back when weight is lifted to allow them to absorb the shock of walking and running.

6.28 A drug that inhibits the activity of osteoclasts might lessen the effects of osteoporosis.