7 Skeletal System: The Appendicular Skeleton

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FIGURE: Currently, physicians have an array of techniques available to treat fractured bones. It wasn't so long ago that the only procedure used was to align the parts of a broken bone and then immobilize the area with a tightly bound splint.

Clinical Case Study

A 12-year-old boy was hit by a car while crossing a street. He was brought to the emergency room in stable condition, complaining of severe pain in his left leg. Radiographs revealed a 4-inch fracture extending superiorly from the distal articular surface of the tibia into the anterior body of the bone. The fragment of bone created by the fracture was moderately displaced. With the radiographs in hand, the orthopedic surgeon went into the waiting room and conferred with the boy's parents. He told them that this kind of injury was more serious in children and growing adolescents than in adults. He went on to say that future growth of the bone might be jeopardized and that surgery, although recommended, could not guarantee normal growth. The parents asked, "What is it about this particular fracture that threatens future growth?"

If you were the surgeon, how would you respond?

Hints: Review the section on bone growth in chapter 6. Carefully examine figures 6.5 and 6.9 in chapter 6 and figures 7.18 and 7.23 in this chapter.

PECTORAL GIRDLE AND UPPER EXTREMITY

The structure of the pectoral girdle and upper extremities is adaptive for freedom of movement and extensive muscle attachment.

Objective 1 Describe the bones of the pectoral girdle and the articulations between them.

Objective 2 Identify the bones of the upper extremity and list the distinguishing features of each.

Pectoral Girdle

Two *scapulae* and two *clavicles* make up the **pectoral** (*shoulder*) **girdle** (fig. 7.1). It is not a complete girdle, having only an anterior attachment to the axial skeleton, via the sternoclavicular joint (see fig. 8.24) at the sternum. As an axial bone, the sternum was described in chapter 6 (see fig. 6.38). Lacking a posterior attachment to the axial skeleton, the pectoral girdle has a wide range of movement. Because it is not weight-bearing, it is structurally more delicate than the pelvic girdle. The primary function of the pectoral girdle is to provide attachment areas for the numerous muscles that move the shoulder and elbow joints.

Clavicle

The slender S-shaped clavicle (*klav′ĭ-kul*; "collarbone") connects the upper extremity to the axial skeleton and holds the shoulder joint away from the trunk to permit freedom of movement. The articulation of the medial **sternal extremity** (fig. 7.2) of the clavicle to the manubrium of the sternum is referred to as the *sternoclavicular joint*. The lateral **acromial** (*a-kro′me-al*) **extremity** of the clavicle articulates with the acromion of the scapula (fig. 7.3). This articulation is referred to as the *acromioclavicular joint*. A **conoid tubercle** is present on the acromial extremity of the clavicle, and a **costal tuberosity** is present on the inferior surface of the sternal extremity. Both processes serve as attachments for ligaments.

The long, delicate clavicle is the most commonly broken bone in the body. When a person receives a blow to the shoulder, or attempts to break a fall with an outstretched hand, the force is transmitted to the clavicle, possibly causing it to fracture. The most vulnerable part of this bone is through its center, immediately proximal to the conoid tubercle. Because the clavicle is directly beneath the skin and is not covered with muscle, a fracture can easily be palpated, and frequently seen.

clavicle: L. *clavicula*, a small key
acromial: Gk. *akros*, peak; *omos*, shoulder
conoid tubercle: Gk. *konus*, cone; L. *tuberculum*, a small swelling
costal tuberosity: L. *costa*, rib; *tuberous*, a knob

Scapula

The scapula (*skap′you-lă;* "shoulder blade") is a large, triangular flat bone on the posterior side of the rib cage, overlying ribs 2 through 7. The **spine** of the scapula is a prominent diagonal bony ridge seen on the posterior surface (fig. 7.3). The spine strengthens the scapula, making it more resistant to bending. Above the spine is the **supraspinous fossa,** and below the spine is the **infraspinous fossa.** The spine broadens toward the shoulder as the **acromion** (figs. 7.3 and 7.4). This process serves for the attachment of several muscles, as well as for articulation with the clavicle. Inferior to the acromion is a shallow depression, the **glenoid** (*gle′noid*) **cavity,** into which the head of the humerus fits. The **coracoid** (*kor′ă-koid*) **process** is a thick upward projection lying superior and anterior to the glenoid cavity. On the anterior surface of the scapula is a slightly concave area known as the **subscapular fossa.**

The scapula has three borders delimited by three angles. The superior edge is called the **superior border.** The **medial border** is nearest to the vertebral column, and the **lateral border** is directed toward the arm. The **superior angle** is located between the superior and medial borders; the **inferior angle,** at the junction of the medial and lateral borders; and the **lateral angle,** at the junction of the superior and lateral borders. It is at the lateral angle that the scapula articulates with the head of the humerus. Along the superior border, a distinct depression called the **scapular notch** is a passageway for the suprascapular nerve.

The scapula has numerous surface features because 15 muscles attach to it. Clinically, the pectoral girdle is significant because the clavicle and acromion of the scapula are frequently broken in trying to break a fall. The acromion is used as a landmark for identifying the site for an injection in the arm. This site is chosen because the musculature of the shoulder is quite thick and contains few nerves.

scapula: L. *scapula*, shoulder
glenoid: Gk. *glenoeides*, shallow form
coracoid: Gk. *korakodes*, like a crow's beak

Brachium (Arm)

The brachium (*bra′ke-um*) extends from the shoulder to the elbow. In strict anatomical usage, *arm* refers only to this portion of the upper limb. The brachium contains a single bone—the *humerus*.

Humerus

The humerus (fig. 7.5) is the longest bone of the upper extremity. It consists of a proximal **head,** which articulates with the glenoid cavity of the scapula; a **body** ("shaft"); and a distal end, which is modified to articulate with the two bones of the

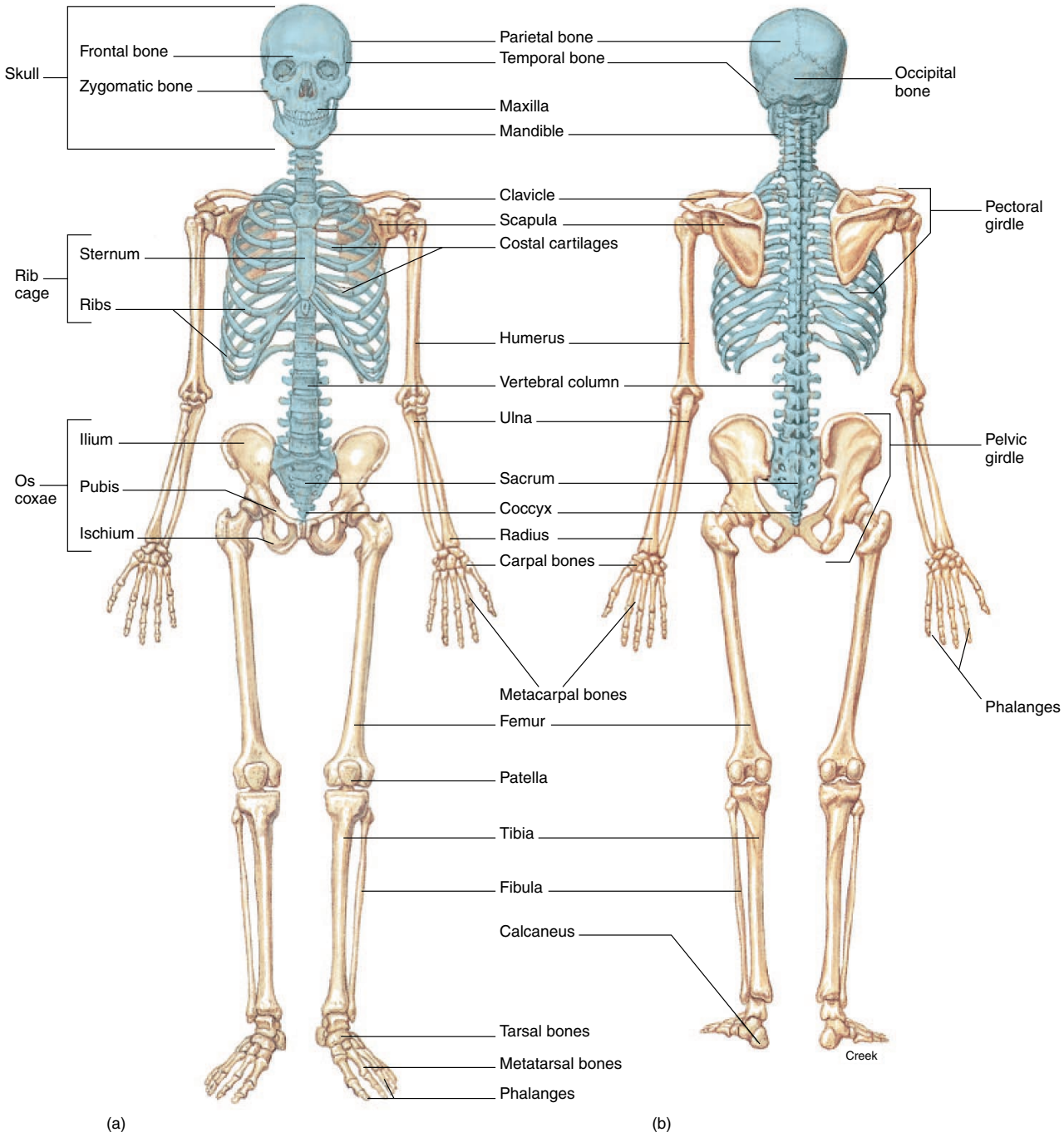

FIGURE 7.1 The human skeleton. (*a*) An anterior view and (*b*) a posterior view. The axial portion is colored light blue.

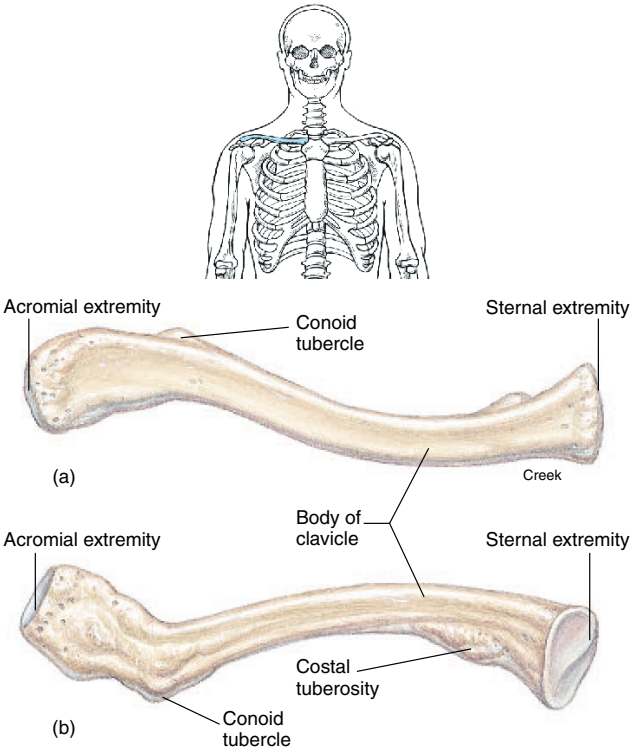

FIGURE 7.2 The right clavicle. (*a*) A superior view and (*b*) an inferior view.

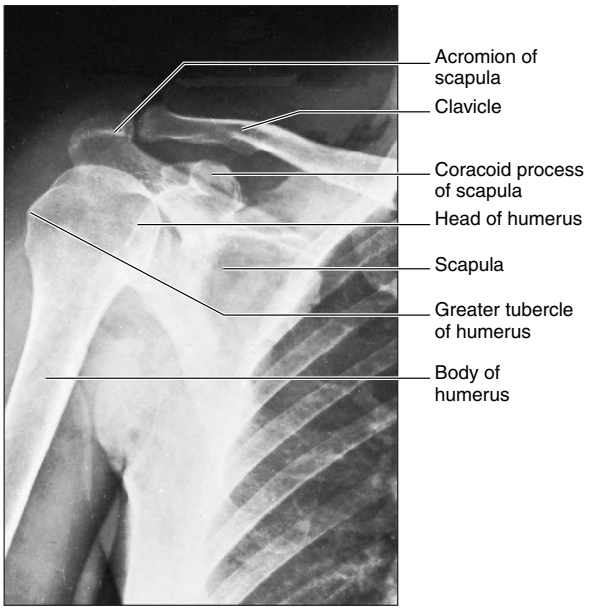

FIGURE 7.3 This radiograph of the right shoulder shows the positions of the clavicle, scapula, and humerus.

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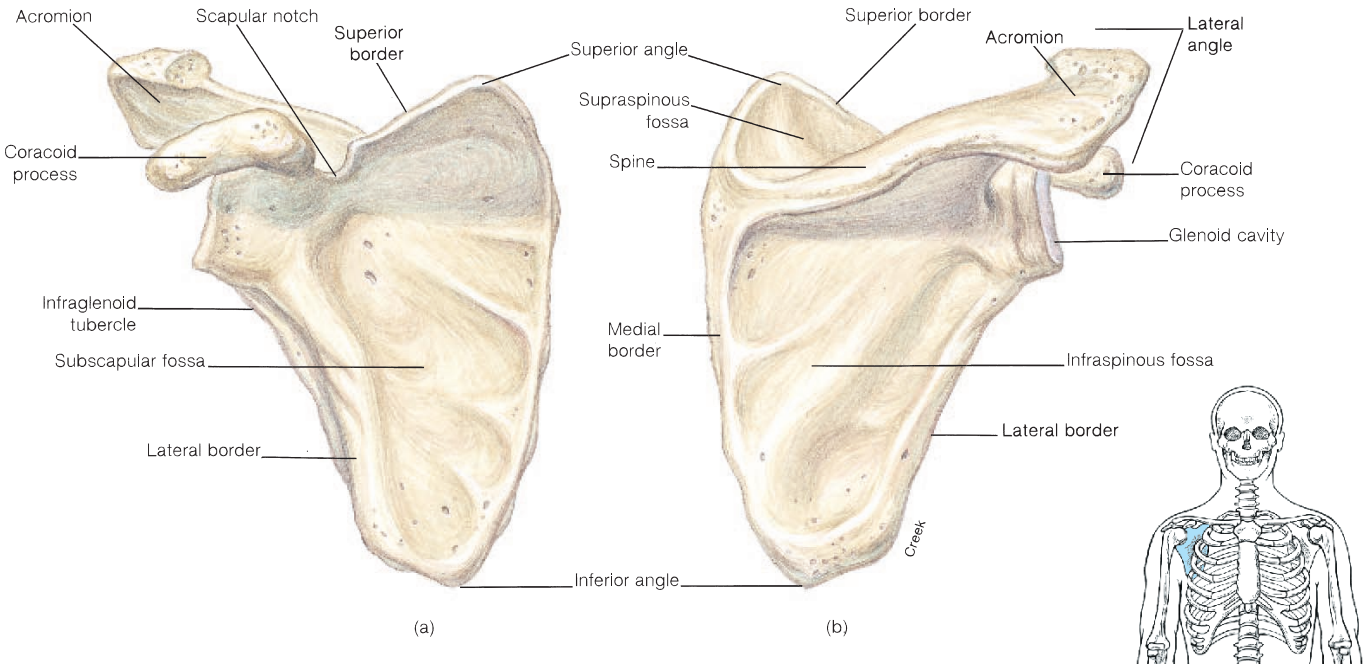


FIGURE 7.4 The right scapula. (*a*) An anterior view and (*b*) a posterior view.

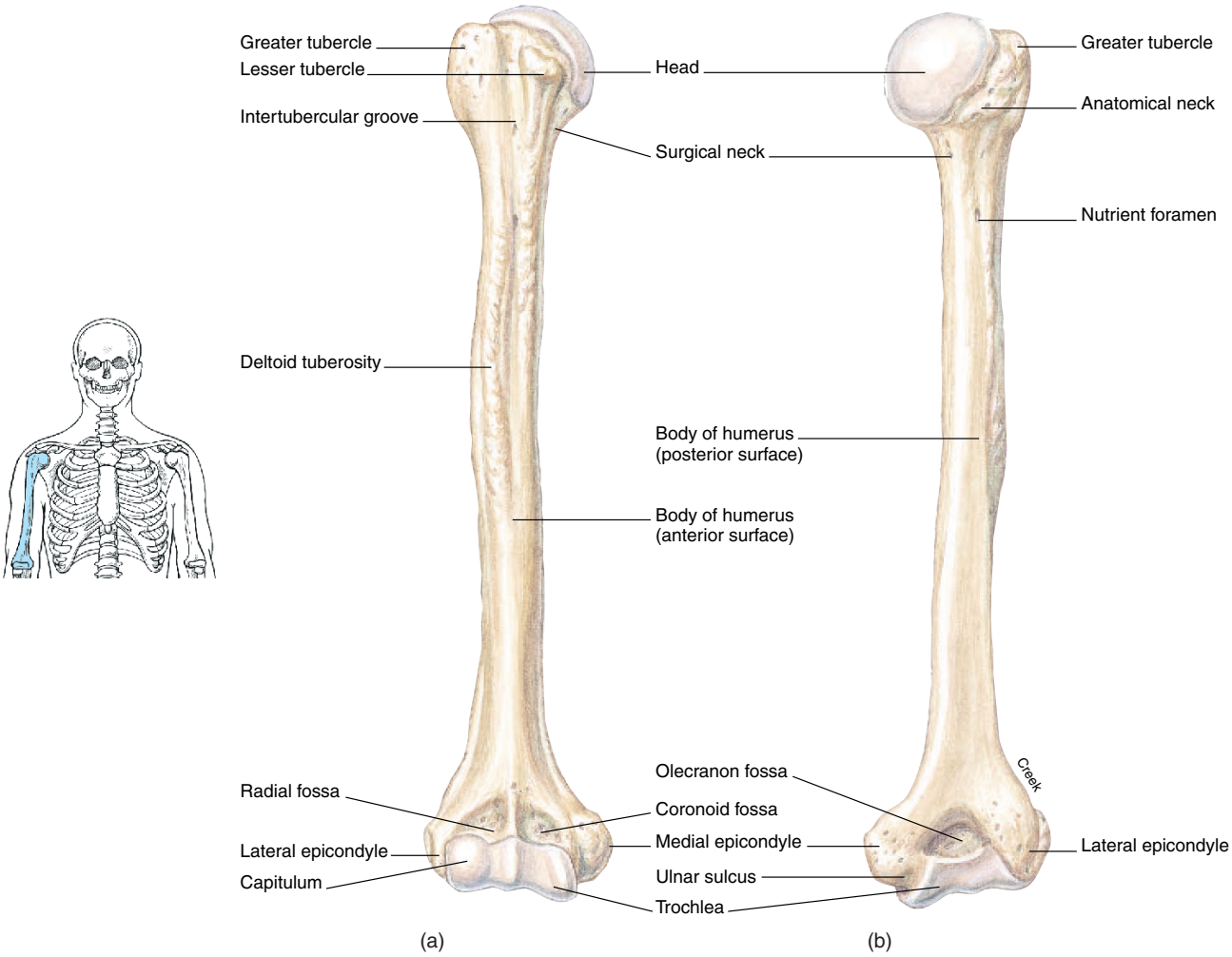


FIGURE 7.5 The right humerus. (*a*) An anterior view and (*b*) a posterior view.

forearm. Surrounding the margin of the head is a slightly indented groove denoting the **anatomical neck.** The **surgical neck,** the constriction just below the head, is a frequent fracture site. The **greater tubercle** is a large knob on the lateral proximal portion of the humerus. The **lesser tubercle** is slightly anterior to the greater tubercle and is separated from the greater by an **intertubercular groove.** The tendon of the long head of the biceps brachii muscle passes through this groove. Along the lateral midregion of the body of the humerus is a roughened area, the **deltoid tuberosity,** for the attachment of the deltoid muscle. Small openings in the body are called **nutrient foramina.**

The **humeral condyle** on the distal end of the humerus has two articular surfaces. The **capitulum** (*kă-pit′yoo-lum*) is the lateral rounded part that articulates with the radius. The **trochlea** (*trok′le-ă*) is the pulleylike medial part that articulates with the ulna. On either side above the condyle are the **lateral** and **medial epicondyles.** The large medial epicondyle protects the ulnar nerve that passes posteriorly through the **ulnar sulcus**. It is popularly known as the "funny bone" because striking the elbow on the edge of a table, for example, stimulates the ulnar nerve and produces a tingling sensation. The **coronoid fossa** is a depression above the trochlea on the anterior surface. The **olecranon** (*o-lek′ră-non*) **fossa** is a depression on the distal posterior surface. Both fossae are adapted to work with the ulna during movement of the forearm.

deltoid: Gk. *deltoeides*, shaped like the letter Δ
capitulum: L. *caput*, little head

trochlea: Gk. *trochilia*, a pulley
olecranon: Gk. *olene*, ulna; *kranion*, head

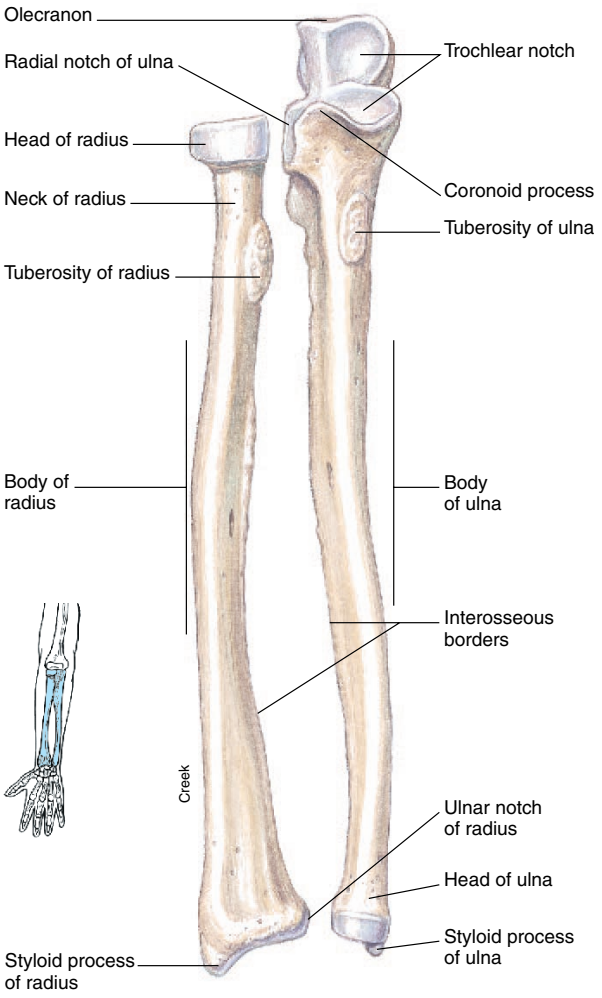


FIGURE 7.6 An anterior view of the right radius and ulna.

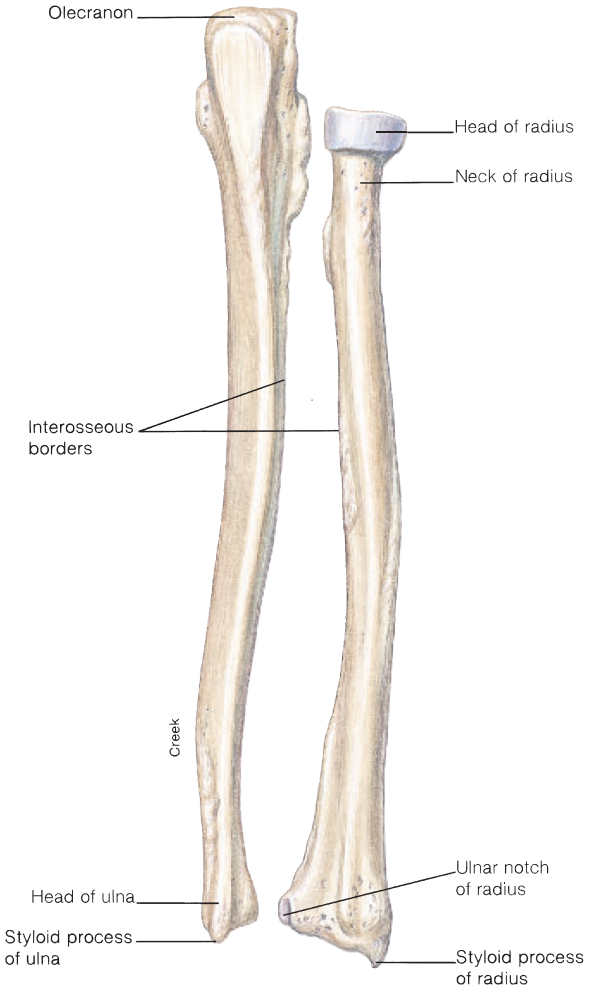


FIGURE 7.7 A posterior view of the right radius and ulna.

The medical term for tennis elbow is *lateral epicondylitis,* which means inflammation of the tissues surrounding the lateral epicondyle of the humerus. At least six muscles that control backward (extension) movement of the wrist and finger joints originate on the lateral epicondyle. Repeated strenuous contractions of these muscles, as in stroking with a tennis racket, may strain the periosteum and muscle attachments, resulting in swelling, tenderness, and pain around the epicondyle. Binding usually eases the pain, but only rest can eliminate the causative factor, and recovery generally follows.

Antebrachium (Forearm)

The skeletal structures of the antebrachium are the *ulna* on the medial side and the *radius* on the lateral (thumb) side (figs. 7.6 and 7.7). The ulna is more firmly connected to the humerus than the radius, and it is longer than the radius. The radius, however, contributes more significantly to the articulation at the wrist joint than does the ulna.

Ulna

The proximal end of the ulna articulates with the humerus and radius. A distinct depression, the **trochlear notch,** articulates with the trochlea of the humerus. The **coronoid process** forms the anterior lip of the trochlear notch, and the **olecranon** forms the posterior portion. Lateral and inferior to the coronoid process is the **radial notch,** which accommodates the head of the radius.

On the tapered distal end of the ulna is a knobbed portion, the **head,** and a knoblike projection, the **styloid process.** The ulna articulates at both ends with the radius.

styloid: Gk. *stylos*, pillar

Radius

The radius consists of a **body** with a small proximal end and a large distal end. A proximal disc-shaped **head** articulates with the capitulum of the humerus and the radial notch of the ulna. The prominent **tuberosity of radius** (radial tuberosity), for attachment of the biceps brachii muscle, is located on the medial side of the body, just below the head. On the distal end of the radius is a double-faceted surface for articulation with the proximal carpal bones. The distal end of the radius also has a **styloid process** on the lateral tip and an **ulnar notch** on the medial side that receives the distal end of the ulna. The styloid processes on the ulna and radius provide lateral and medial stability for articulation at the wrist.

When a person falls, the natural tendency is to extend the hand to break the fall. This reflexive movement frequently results in fractured bones. Common fractures of the radius include a fracture of the head, as it is driven forcefully against the capitulum; a fracture of the neck; or a fracture of the distal end (*Colles' fracture*), caused by landing on an outstretched hand.

When falling, it is less traumatic to the body to withdraw the appendages, bend the knees, and let the entire body hit the surface. Athletes learn that this is the safe way to fall.

Manus (Hand)

The hand contains 27 bones, grouped into the *carpus*, *metacarpus*, and *phalanges* (figs. 7.8, 7.9, and 7.10).

Carpus

The carpus, or wrist, contains eight carpal bones arranged in two transverse rows of four bones each. The proximal row, naming from the lateral (thumb) to the medial side, consists of the **scaphoid** (navicular), **lunate,** triquetrum (*tri-kwé-trum*) and **pisiform.** The pisiform forms in a tendon as a sesamoid bone. The distal row, from lateral to medial, consists of the **trapezium** (greater multangular), **trapezoid** (lesser multangular), **capitate,** and **hamate.** The scaphoid and lunate of the proximal row articulate with the distal end of the radius.

Metacarpus

The metacarpus, or palm of the hand, contains five metacarpal bones. Each metacarpal bone consists of a proximal **base,** a **body,** and a distal **head** that is rounded for articulation with the base of each proximal phalanx. The heads of the metacarpal bones are distally located and form the knuckles of a clenched fist.

carpus: Gk. *karpos*, wrist
navicular: L. *navicula*, small ship
lunate: L. *lunare*, crescent or moon-shaped
triquetrum: L. *triquetrous*, three-cornered
pisiform: Gk. *pisos*, pea
trapezium: Gk. *trapesion*, small table
capitate: L. *capitatus*, head
hamate: L. *hamatus*, hook

Phalanges

The 14 phalanges are the bones of the digits. A single finger bone is called a **phalanx** (*fa'langks*). The phalanges of the fingers are arranged in a proximal row, a middle row, and a distal row. The thumb, or *pollex* (adjective, *pollicis*), lacks a middle phalanx. The digits are sequentially numbered I to V starting with the thumb—the lateral side, in reference to anatomical position.

A summary of the bones of the upper extremities is presented in table 7.1.

The hand is a marvel of structural complexity that can withstand considerable abuse. Other than sprained ligaments of the fingers and joint dislocations, the most common bone injury is a fracture to the scaphoid—a wrist bone that accounts for about 70% of carpal fractures. When immobilizing the wrist joint, the wrist is positioned in the plane of relaxed function. This is the position in which the hand is about to grasp an object between the thumb and index finger.

Knowledge Check

1. Describe the structure of the pectoral girdle. Why is the pectoral girdle considered an incomplete girdle?
2. Identify the fossae and processes of the scapula.
3. Describe each of the long bones of the upper extremity.
4. Where are the styloid processes of the wrist area? What are their functions?
5. Name the bones in the proximal row of the carpus. Which of these bones articulate(s) with the radius?

PELVIC GIRDLE AND LOWER EXTREMITY

The structure of the pelvic girdle and lower extremities is adaptive for support and locomotion. Extensive processes and surface features on certain bones of the pelvic girdle and lower extremities accommodate massive muscles used in body movement and in maintaining posture.

Objective 3 Describe the structure of the pelvic girdle and list its functions.

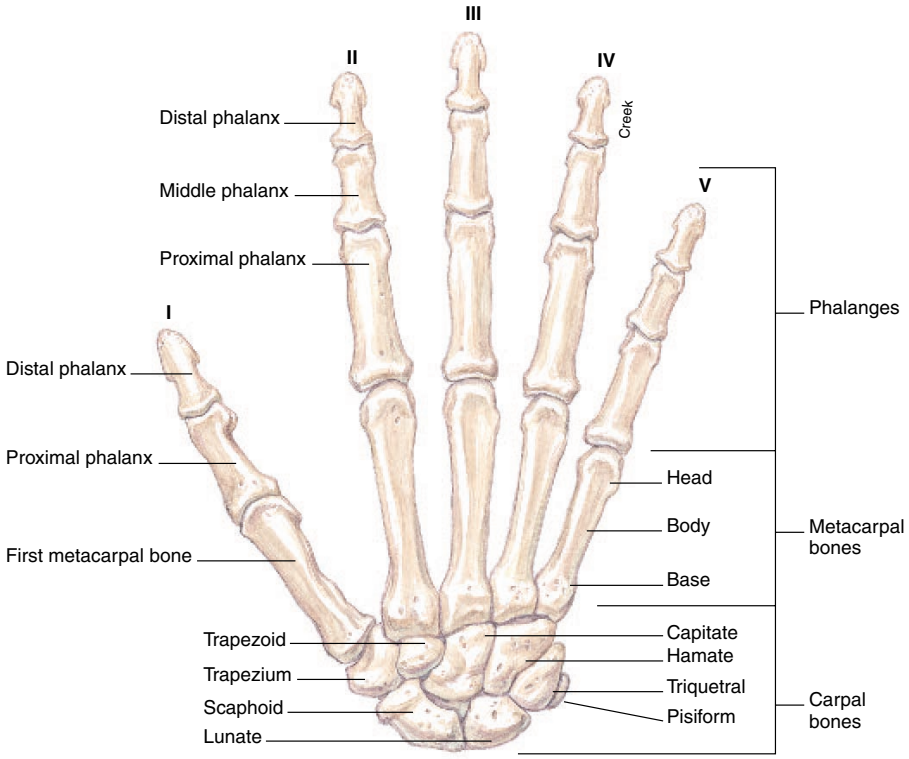
Objective 4 Describe the structural differences in the male and female pelves.

Objective 5 Identify the bones of the lower extremity and list the distinguishing features of each.

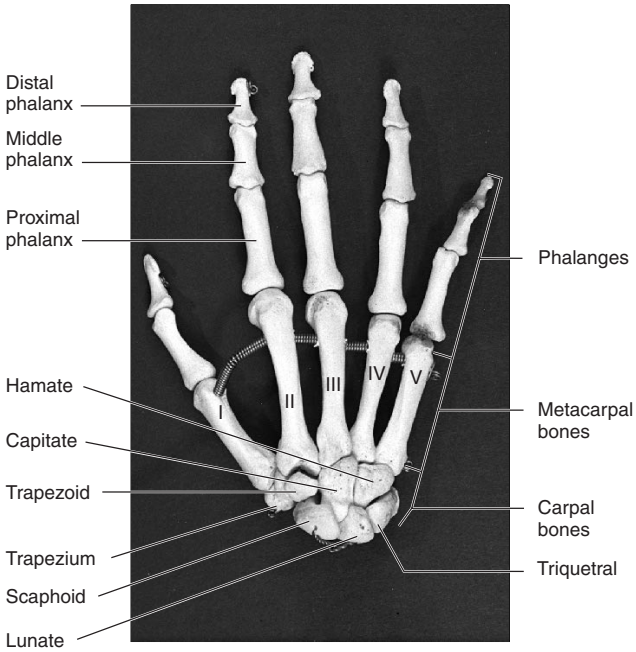
Objective 6 Describe the structural features and functions of the arches of the foot.

phalanx: Gk. *phalanx*, finger bone or toe bone

CHAPTER 7



(a)



(b)

FIGURE 7.8 A posterior view of the bones of the right hand as shown in (*a*) a drawing and (*b*) a photograph. Each digit (finger) is indicated by a Roman numeral, the first digit, or thumb, being Roman numeral I.

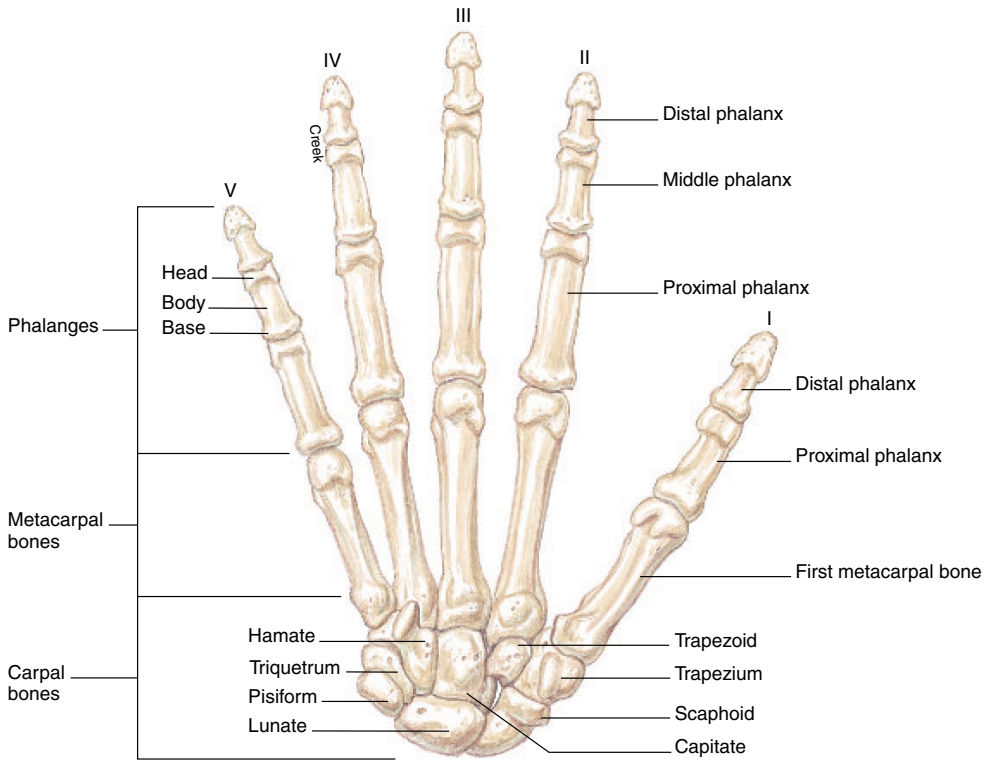


FIGURE 7.9 An anterior view of the bones of the right hand.

FIGURE 7.10 A radiograph of the right hand shown in an anteroposterior projection. (Note the presence of a sesamoid bone at the thumb joint.)

Pelvic Girdle

The **pelvic girdle** is formed by two *ossa coxae* (*os'ă kuk'se;* "hipbones"), united anteriorly at the *symphysis pubis* (figs. 7.11 and 7.12). It is attached posteriorly to the sacrum of the vertebral column. The sacrum, a bone of the axial skeleton, was described in chapter 6 (see fig. 6.37). The deep, basinlike structure formed by the ossa coxae, together with the sacrum and coccyx, is called the **pelvis** (plural, *pelves* or *pelvises*). The pelvic girdle and its associated ligaments support the weight of the body from the vertebral column. The pelvic girdle also supports and protects the lower viscera, including the urinary bladder, the reproductive organs, and in a pregnant woman, the developing fetus.

The pelvis is divided into a **greater** (false) **pelvis** and a **lesser** (true) **pelvis** (see fig. 7.15). These two components are divided by the **pelvic brim,** a curved bony rim passing inferiorly from the sacral promontory to the upper margin of the symphysis pubis. The greater pelvis is the expanded portion of the pelvis, superior to the pelvic brim. The pelvic brim not only divides the two portions but surrounds the **pelvic inlet** of the lesser pelvis. The lower circumference of the lesser pelvis bounds the **pelvic outlet.**

coxae: L. *coxae,* hips

TABLE 7.1 Bones of the Pectoral Girdle and Upper Extremities

Name and Number	Location	Major Distinguishing Features
Clavicle (2)	Anterior base of neck, between sternum and scapula	S-shaped; sternal and acromial extremities; conoid tubercle; costal tuberosity
Scapula (2)	Upper back forming part of the shoulder	Triangular; spine; subscapular, supraspinous, and infraspinous fossae; glenoid cavity; coracoid process; acromion
Humerus (2)	Brachium, between scapula and elbow	Longest bone of upper extremity; greater and lesser tubercles; intertubercular groove; surgical neck, deltoid tuberosity; capitulum; trochlea; lateral and medial epicondyles; coronoid and olecranon fossae
Ulna (2)	Medial side of forearm	Trochlear notch; olecranon; coronoid and styloid processes; radial notch
Radius (2)	Lateral side of forearm	Head; radial tuberosity; styloid process; ulnar notch
Carpal bone (16)	Wrist	Short bones arranged in two rows of four bones each
Metacarpal bone (10)	Palm of hand	Long bones, each aligned with a digit
Phalanx (28)	Digits	Three in each digit, except two in thumb

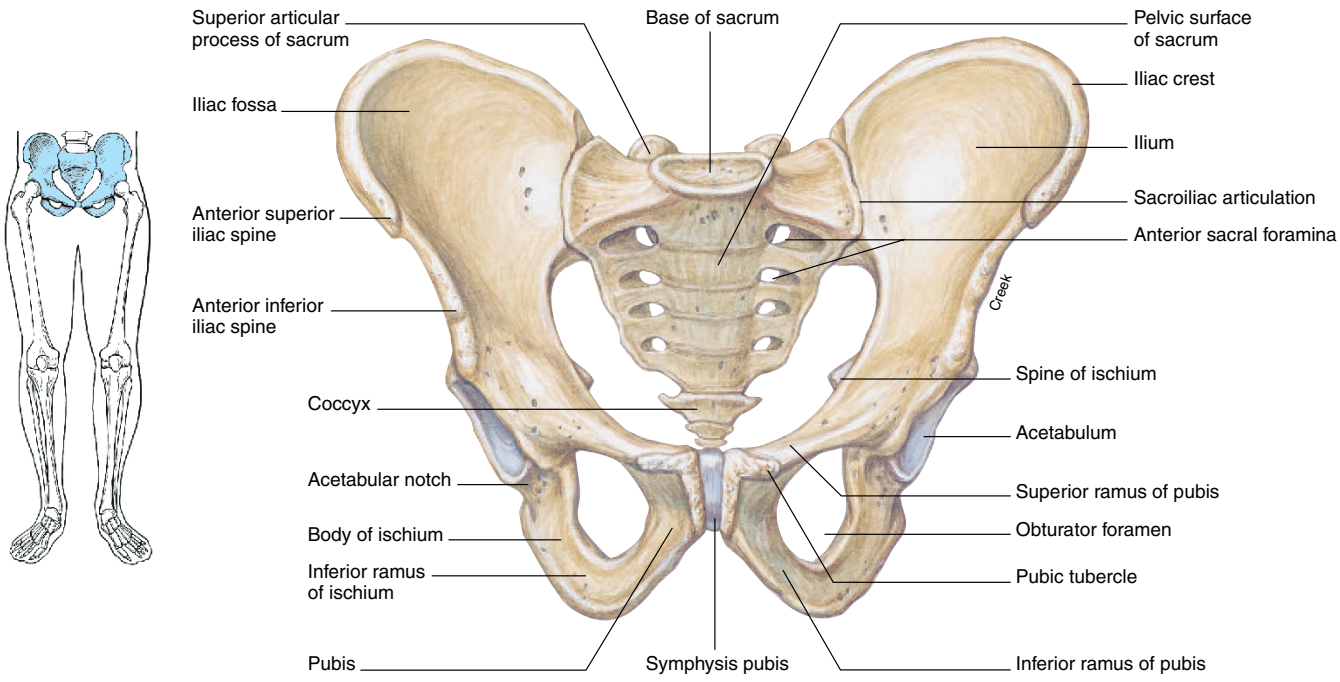


FIGURE 7.11 An anterior view of the pelvic girdle.

Each os coxae ("hipbone") actually consists of three separate bones: the *ilium*, the *ischium*, and the *pubis* (figs. 7.13 and 7.14). These bones are fused together in the adult. On the lateral surface of the os coxae, where the three bones ossify, is a large circular depression, the **acetabulum** (*as″ĕ-tab′yŭ-lum*) which receives the head of the femur. Although both ossa coxae are single bones in the adult, the three components of each one are considered separately for descriptive purposes.

ilium: L. *ilia*, loin
ischium: Gk. *ischion*, hip joint
pubis: L. *pubis*, genital area
acetabulum: L. *acetabulum*, vinegar cup

Ilium

The ilium is the uppermost and largest of the three pelvic bones. It has a crest and four angles, or spines—important surface landmarks that serve for muscle attachment. The **iliac crest** forms the prominence of the hip. This crest terminates anteriorly as the **anterior superior iliac spine.** Just below this spine is the **anterior**

FIGURE 7.12 A radiograph of the pelvic girdle and the articulating femurs.

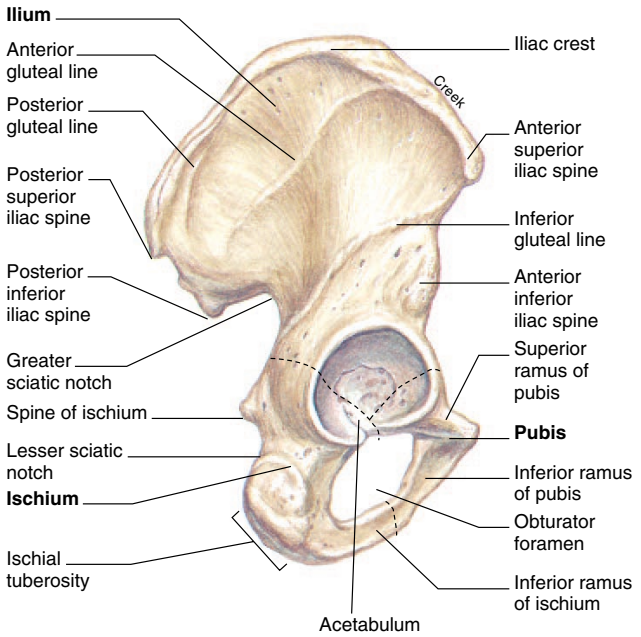


FIGURE 7.13 The lateral aspect of the right os coxae. (The three bones comprising the os coxae are labeled in boldface type.)

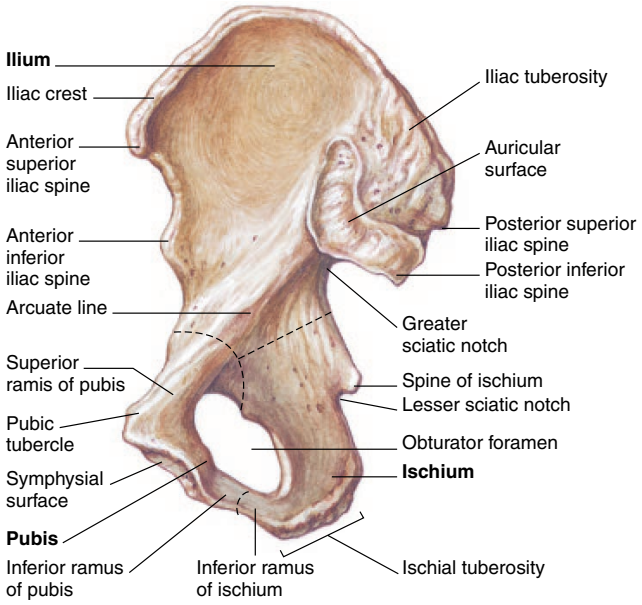


FIGURE 7.14 The medial aspect of the right os coxae. (The three bones comprising the os coxae are labeled in boldface type.)

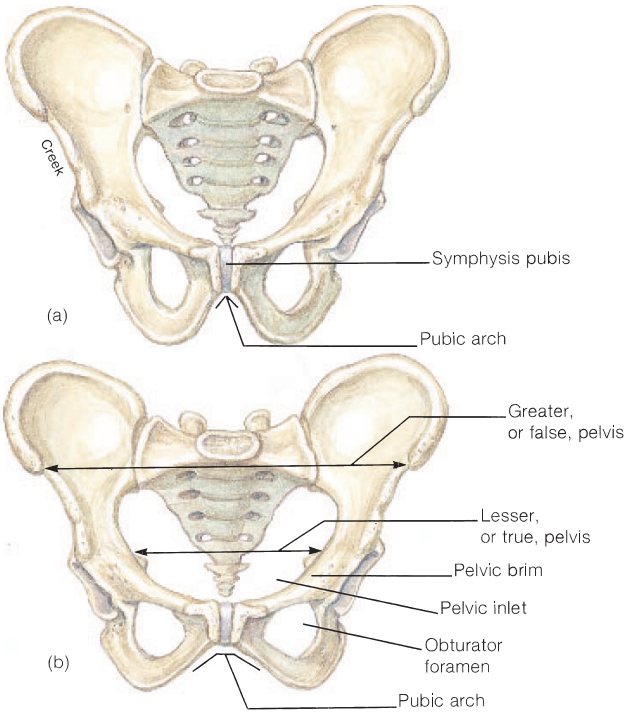


FIGURE 7.15 A comparison of (*a*) the male and (*b*) the female pelvic girdle.

inferior iliac spine. The posterior termination of the iliac crest is the **posterior superior iliac spine,** and just below this is the **posterior inferior iliac spine.**

Below the posterior inferior iliac spine is the **greater sciatic notch,** through which the sciatic nerve passes. On the medial surface of the ilium is the roughened **auricular surface,** which articulates with the sacrum. The **iliac fossa** is the smooth, concave surface on the anterior portion of the ilium. The iliacus muscle originates from this fossa. The **iliac tuberosity,** for the attachment of the sacroiliac ligament, is positioned posterior to the iliac fossa. Three roughened ridges are present on the **gluteal surface** of the posterior aspect of the ilium. These ridges, which serve to attach the gluteal muscles, are the **inferior, anterior,** and **posterior gluteal lines** (see fig. 7.13).

Ischium

The ischium (*is′ke-um*) is the posteroinferior bone of the os coxae. This bone has several distinguishing features. The **spine of the ischium** is the projection immediately posterior and inferior to the greater sciatic notch of the ilium. Inferior to this spine is the **lesser sciatic notch** of the ischium. The **ischial tuberosity** is the bony projection that supports the weight of the body in the sitting position. A deep **acetabular** (*as″ĕ-tab′yŭ-lar*) **notch** is present on the inferior portion of the acetabulum. The large **obturator** (*ob′tŭ-ra″tor*) **foramen** is formed by the inferior **ramus** of the ischium, together with the pubis. The obturator foramen is covered by the obturator membrane, to which several muscles attach.

TABLE 7.2 **Comparison of the Male and Female Pelves**

Characteristics	Male Pelvis	Female Pelvis
General structure	More massive; prominent processes	More delicate; processes not so prominent
Pelvic inlet	Heart-shaped	Round or oval
Pelvic outlet	Narrower	Wider
Anterior superior iliac spines	Not as wide apart	Wider apart
Obturator foramen	Oval	Triangular
Acetabulum	Faces laterally	Faces more anteriorly
Symphysis pubis	Deeper, longer	Shallower, shorter
Pubic arch	Angle less than 90°	Angle greater than 90°

Pubis

The pubis is the anterior bone of the os coxae. It consists of a **superior ramus** and an **inferior ramus** that support the **body** of the pubis. The body contributes to the formation of the symphysis pubis—the joint between the two ossa coxae. At the lateral end of the anterior border of the body is the **pubic tubercle,** one of the attachments for the inguinal ligament.

The structure of the human pelvis, in its attachment to the vertebral column, permits an upright posture and locomotion on two appendages (bipedal locomotion). An upright posture may cause problems, however. The sacroiliac joint may weaken with age, causing lower back pains. The weight of the viscera may weaken the walls of the lower abdominal area and cause hernias. Some of the problems of childbirth are related to the structure of the mother's pelvis. Finally, the hip joint tends to deteriorate with age, so that many elderly people suffer from degenerative arthritis (*osteoarthrosis*).

Sex-Related Differences in the Pelvis

Structural differences between the pelvis of an adult male and that of an adult female (fig. 7.15 and table 7.2) reflect the female's role in pregnancy and parturition. In a vaginal delivery, a baby must pass through its mother's lesser pelvis. *Pelvimetry* (*pelvim′ĕ-tre*) is the measurement of the dimensions of the pelvis—especially of the adult female pelvis—to determine whether a cesarean section might be necessary. Diameters may be determined by vaginal palpation or by sonographic images.

Thigh

The *femur* is the only bone of the thigh. In the following discussion, however, the *patella* will also be discussed.

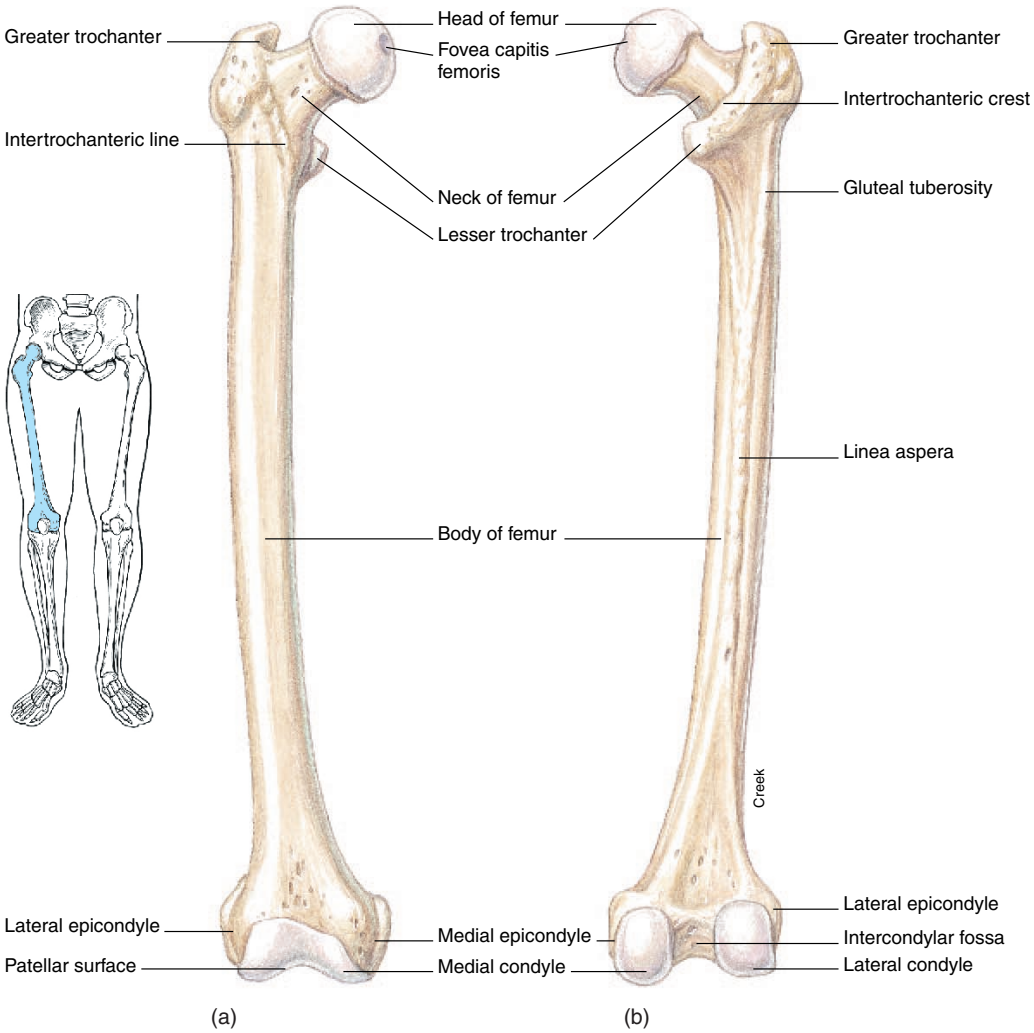


FIGURE 7.16 The right femur. (*a*) An anterior view and (*b*) a posterior view.

Femur

The (*fe′mur*; "thighbone") is the longest, heaviest, strongest bone in the body (fig. 7.16). The proximal rounded **head** of the femur articulates with the acetabulum of the os coxae. A roughened shallow pit, the **fovea capitis femoris,** is present in the lower center of the head of the femur. The fovea capitis femoris provides the point of attachment for the ligamentum capitis femoris (see fig. 8.30), which helps to support the head of the femur against the acetabulum. It also provides the site for the entry of an artery into the head of the femur. The constricted region supporting the head is called the **neck** and is a common site for fractures in the elderly.

The **body** of the femur has a slight medial curve to bring the knee joint in line with the body's plane of gravity. The degree of curvature is greater in the female because of the wider pelvis. The body of the femur has several distinguishing features for muscle attachment. On the proximolateral side of the body is the **greater trochanter,** and on the medial side is the **lesser trochanter.** On the anterior side, between the trochanters, is the **intertrochanteric** (*in″ter-tro″kan-ter′ik*) **line.** On the posterior side, between the trochanters, is the **intertrochanteric crest.** The **linea aspera** (*lin′e-ă as′per-ă*) is a roughened vertical ridge on the posterior surface of the body of the femur.

The distal end of the femur is expanded for articulation with the tibia. The **medial** and **lateral condyles** are the articular

femur: L. *femur*, thigh

linea aspera: L. *linea*, line; *asperare*, rough

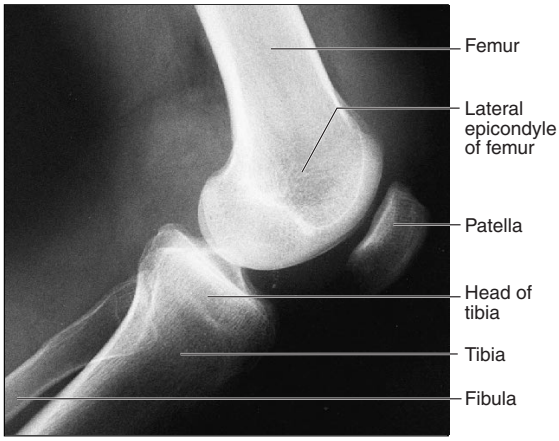


FIGURE 7.17 A radiograph of the right knee.

processes for this joint. The shallow depression between the condyles on the posterior aspect is called the **intercondylar fossa.** The **patellar surface** is located between the condyles on the anterior side. Above the condyles on the lateral and medial sides are the **epicondyles,** which serve for ligament and tendon attachment.

Patella

The patella (*pă-tel′ă;* "kneecap") is a large, triangular sesamoid bone positioned on the anterior side of the distal femur (figs. 7.17 and 7.18). It develops in response to strain in the patellar tendon. It has a broad **base** and an inferiorly pointed **apex.** Articular facets on the **articular surface** of the patella articulate with the medial and lateral condyles of the femur.

The functions of the patella are to protect the knee joint and to strengthen the patellar tendon. It also increases the leverage of the quadriceps femoris muscle as it extends (straightens) the knee joint.

The patella can be fractured by a direct blow. It usually does not fragment, however, because it is confined within the patellar tendon. Dislocations of the patella may result from injury or from underdevelopment of the lateral condyle of the femur.

Leg

Technically speaking, *leg* refers only to that portion of the lower limb between the knee and foot. The *tibia* and *fibula* are the bones of the leg. The tibia is the larger and more medial of the two.

patella: L. *patina,* small plate

Tibia

The tibia (*tib′eă;* "shinbone") articulates proximally with the femur at the knee joint and distally with the talus of the ankle. It also articulates both proximally and distally with the fibula. Two slightly concave surfaces on the proximal end of the tibia, the **medial** and **lateral condyles** (fig. 7.18) articulate with the condyles of the femur. The condyles are separated by a slight upward projection called the **intercondylar eminence,** which provides attachment for the cruciate ligaments of the knee joint (see figs. 8.31 and 8.32). The **tibial tuberosity,** for attachment of the patellar ligament, is located on the proximoanterior part of the body of the tibia. The **anterior crest,** commonly called the "shin," is a sharp ridge along the anterior surface of the body.

The **medial malleolus** (*mă-le′o-lus*) is a prominent medial knob of bone located on the distomedial end of the tibia. A **fibular notch,** for articulation with the fibula, is located on the distolateral end. In that the tibia is the weight-bearing bone of the leg, it is much larger than the fibula.

Fibula

The fibula (*fib′yŭ-lă*) is a long, slender bone that is more important for muscle attachment than for support. The **head** of the fibula articulates with the proximolateral end of the tibia. The distal end has a prominent knob called the **lateral malleolus.**

The lateral and medial malleoli are positioned on either side of the talus and help to stabilize the ankle joint. Both processes can be seen as prominent surface features and are easily palpated. Fractures to the fibula above the lateral malleolus are common in skiers. Clinically referred to as *Pott's fracture,* it is caused by a shearing force acting at a vulnerable spot on the leg.

Pes (Foot)

The foot contains 26 bones, grouped into the *tarsus*, *metatarsus*, and *phalanges* (fig. 7.19). Although similar to the bones of the hand, the bones of the foot have distinct structural differences in order to support the weight of the body and provide leverage and mobility during walking.

Tarsus

There are seven tarsal bones. The most superior in position is the **talus,** which articulates with the tibia and fibula to form the ankle joint. The calcaneus (*kal-ka′ne-us*) is the largest of the tarsal bones and provides skeletal support for the heel of the foot. It has a large posterior extension, called the **tuberosity of the**

tibia: L. *tibia,* shinbone, pipe, flute
fibula: L. *fibula,* clasp or brooch
malleolus: L. *malleolus,* small hammer
tarsus: Gk. *tarsos,* flat of the foot
talus: L. *talus,* ankle

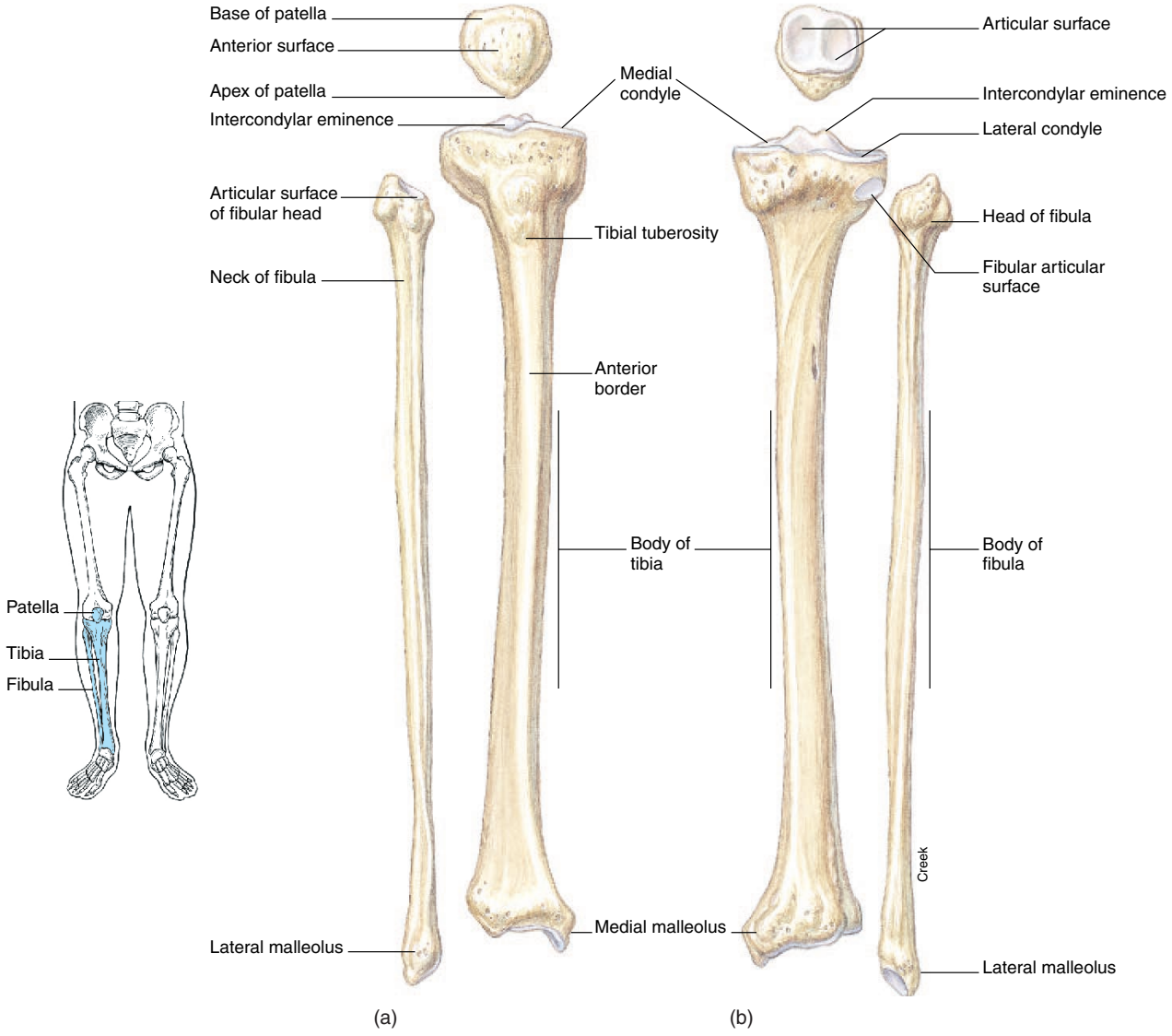


FIGURE 7.18 The right tibia, fibula, and patella. (*a*) An anterior view and (*b*) a posterior view.

calcaneus, for the attachment of the calf muscles. Anterior to the talus is the block-shaped **navicular bone.** The remaining four tarsal bones form a distal series that articulate with the metatarsal bones. They are, from the medial to the lateral side, the **medial, intermediate,** and **lateral cuneiform** (*kyoo-ne′ĭ-form*) **bones** and the **cuboid bone.**

Metatarsus

The metatarsal bones and phalanges are similar in name and number to the metacarpals and phalanges of the hand. They differ in shape, however, because of their load-bearing role. The metatarsal bones are numbered I to V, starting with the medial (great toe) side of the foot. The first metatarsal bone is larger than the others because of its major role in supporting body weight.

The metatarsal bones each have a **base, body,** and **head.** The proximal bases of the first, second, and third metatarsals articulate proximally with the cuneiform bones. The heads of the metatarsals articulate distally with the proximal phalanges. The proximal joints are called *tarsometatarsal joints*, and the distal joints are called *metatarsophalangeal (met′′ă-tar′′so-fă-lan′je-al) joints*. The ball of the foot is formed by the heads of the first two metatarsal bones.

calcaneus: L. *calcis*, heel

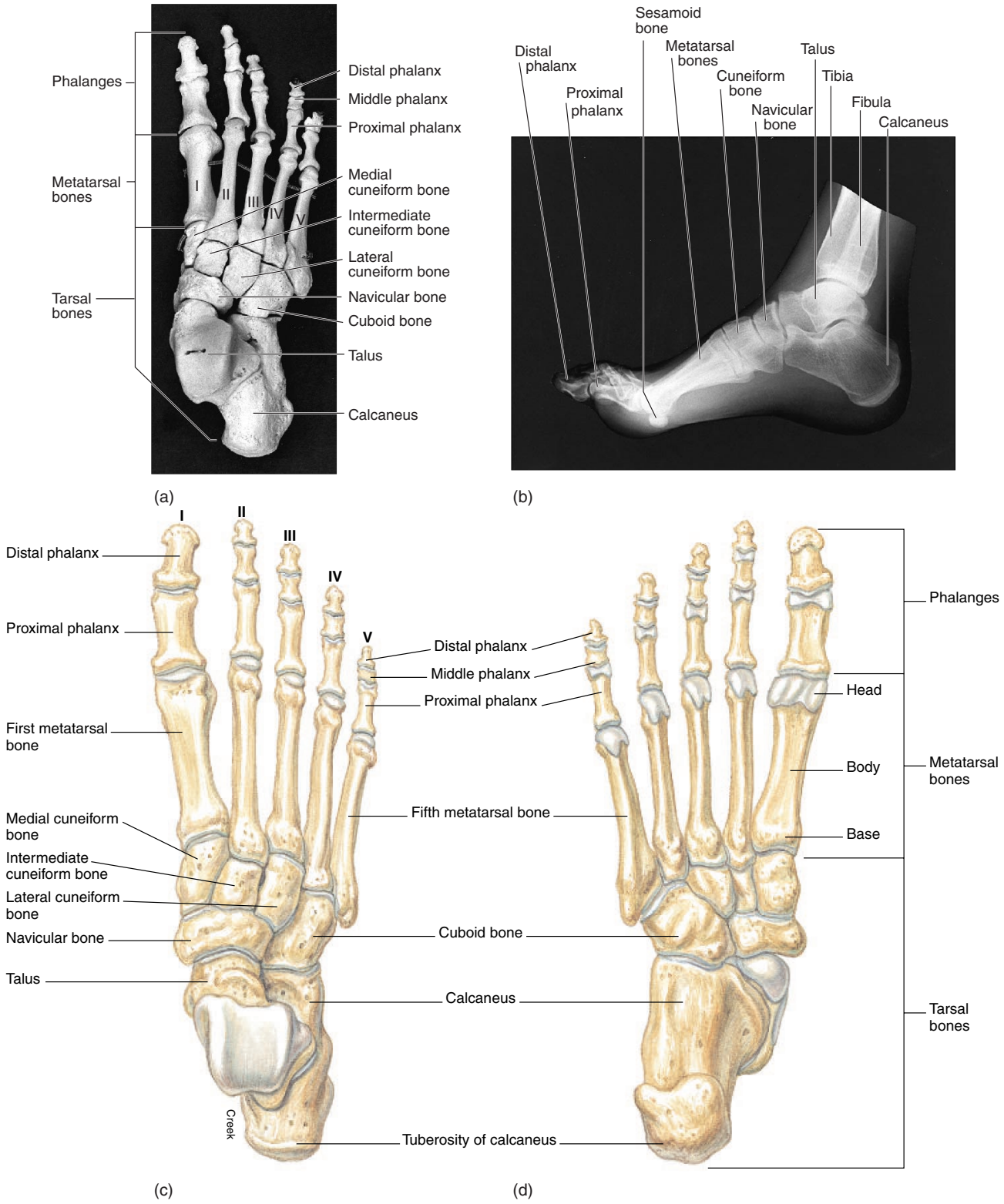


FIGURE 7.19 The bones of the right foot. (*a*) A photograph of a superior view, (*b*) a radiograph of a medial view, (*c*) a superior view, and (*d*) an inferior view. Each digit (toe) is indicated by a Roman numeral, the first digit, or great toe, being Roman numeral I.

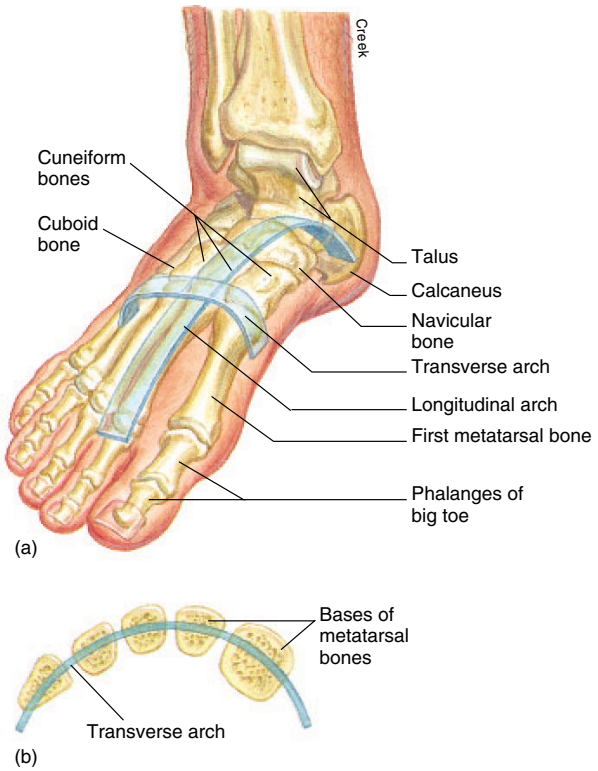


FIGURE 7.20 The arches of the foot. (*a*) A medial view of the right foot showing both arches and (*b*) a transverse view through the bases of the metatarsal bones showing a portion of the transverse arch.

Phalanges

The 14 phalanges are the skeletal elements of the toes. As with the fingers of the hand, the phalanges of the toes are arranged in a proximal row, a middle row, and a distal row. The great toe, or *hallux* (adjective, *hallucis*) has only a proximal and a distal phalanx.

Arches of the Foot

The foot has two arches. They are formed by the structure and arrangement of the bones and maintained by ligaments and tendons (fig. 7.20). The arches are not rigid; they "give" when weight is placed on the foot, and they spring back as the weight is lifted.

The **longitudinal arch** is divided into medial and lateral parts. The medial part is the more elevated of the two. The talus is keystone of the medial part, which originates at the calcaneus, rises at the talus, and descends to the first three metatarsal bones. The shallower lateral part consists of the calcaneus, cuboid, and fourth and fifth metatarsal bones. The cuboid is the keystone bone of this arch.

The **transverse arch** extends across the width of the foot and is formed by the calcaneus, navicular, and cuboid bones posteriorly and the bases of all five metatarsal bones anteriorly.

A weakening of the ligaments and tendons of the foot may cause the arches to "fall"—a condition known as *pes planus*, or, more commonly, "flatfoot."

The bones of the lower extremities are summarized in table 7.3.

CHAPTER 7

TABLE 7.3 Bones of the Pelvic Girdle and Lower Extremities

Name and Number	Location	Major Distinguishing Features
Os coxae (2)	Hip, part of the pelvic girdle; composed of the fused ilium, ischium, and pubis	Iliac crest; acetabulum; anterior superior iliac spine; greater sciatic notch of the ilium; ischial tuberosity; lesser sciatic notch of the ischium; obturator foramen; pubic tubercle
Femur (2)	Bone of the thigh, between hip and knee	Head; fovea capitis femoris; neck; greater and lesser trochanters; linea aspera; lateral and medial condyles; lateral and medial epicondyles
Patella (2)	Anterior surface of distal femur	Triangular sesamoid bone
Tibia (2)	Medial side of leg, between knee and ankle	Medial and lateral condyles; intercondylar eminence; tibial tuberosity; anterior crest; medial malleolus; fibular notch
Fibula (2)	Lateral side of leg, between knee and ankle	Head; lateral malleolus
Tarsal bones (14)	Ankle	Large talus and calcaneus to receive weight of leg; five other wedge-shaped bones to help form arches of foot
Metatarsal bones (10)	Sole of foot	Long bones, each in line with a digit
Phalanx (28)	Digits	Three in each digit except two in great toe

FIGURE 7.21 Polydactyly is the condition in which there are extra digits. It is the most common congenital deformity of the foot, although it also occurs in the hand. Syndactyly is the condition in which two or more digits are webbed together. It is a common congenital deformity of the hand, although it also occurs in the foot. Both conditions can be surgically corrected.

Knowledge Check

6. Describe the structure and functions of the pelvic girdle. How does its structure reflect its weight-bearing role?
7. How can female and male pelves be distinguished? Why is the lesser pelvis clinically significant in females?
8. Describe the structure of each of the long bones of the lower extremity and the position of each of the tarsal bones.
9. Which bones of the foot contribute to the formation of the arches? What are the functions of the arches?

CLINICAL CONSIDERATIONS

Developmental Disorders

Minor defects of the extremities are relatively common malformations. Extra digits, a condition called **polydactyly** (*pol″e-dak′tĭ-le;* fig. 7.21), is the most common limb deformity. Usually an extra digit is incompletely formed and does not function. **Syndactyly** (*sin-dak′tĭ-le*), or webbed digits, is also common. Polydactyly is inherited as a dominant trait, whereas syndactyly is a recessive trait.

Talipes (*tal′ĭ-pēz*) or "clubfoot" (fig. 7.22), is a congenital malformation in which the sole of the foot is twisted medially. It is not certain whether it is abnormal positioning or restricted movement in utero that causes this condition, but both genetics and environmental conditions are involved in most cases.

polydactyly: Gk. *polys*, many; *daktylos*, finger
syndactyly: Gk. *syn*, together; *daktylos*, finger
talipes: L. *talus*, heel; *pes*, foot

FIGURE 7.22 Talipes, or clubfoot, is a congenital malformation of a foot or both feet. The condition can be effectively treated surgically if the procedure is done at an early age.

Trauma and Injury

The most common type of bone injury is a **fracture**—the cracking or breaking of a bone. Radiographs are often used to diagnose the precise location and extent of a fracture. Fractures may be classified in several ways, and the type and severity of the fracture is often related to the age and general health of the individual. **Pathologic fractures,** for example, result from diseases that weaken the bones. Most fractures, however, are called **traumatic fractures** because they are caused by injuries. The following are descriptions of several kinds of traumatic fractures (fig. 7.23).

1. **Simple,** or **closed.** The fractured bone does not break through the skin.
2. **Compound,** or **open.** The fractured bone is exposed to the outside through an opening in the skin.
3. **Partial (fissured).** The bone is incompletely broken.
4. **Complete.** The fracture has separated the bone into two pieces.
5. **Comminuted** (*kom′ĭ-noot′ed*). The bone is splintered into several fragments.
6. **Spiral.** The fracture line is twisted as it is broken.
7. **Greenstick.** An incomplete break (partial fracture), in which one side of the bone is broken, and the other side is bowed.
8. **Impacted.** One end of a broken bone is driven into the other.
9. **Transverse.** The fracture occurs across the bone at a right angle to the long axis.
10. **Oblique.** The fracture occurs across the bone at an oblique angle to the long axis.

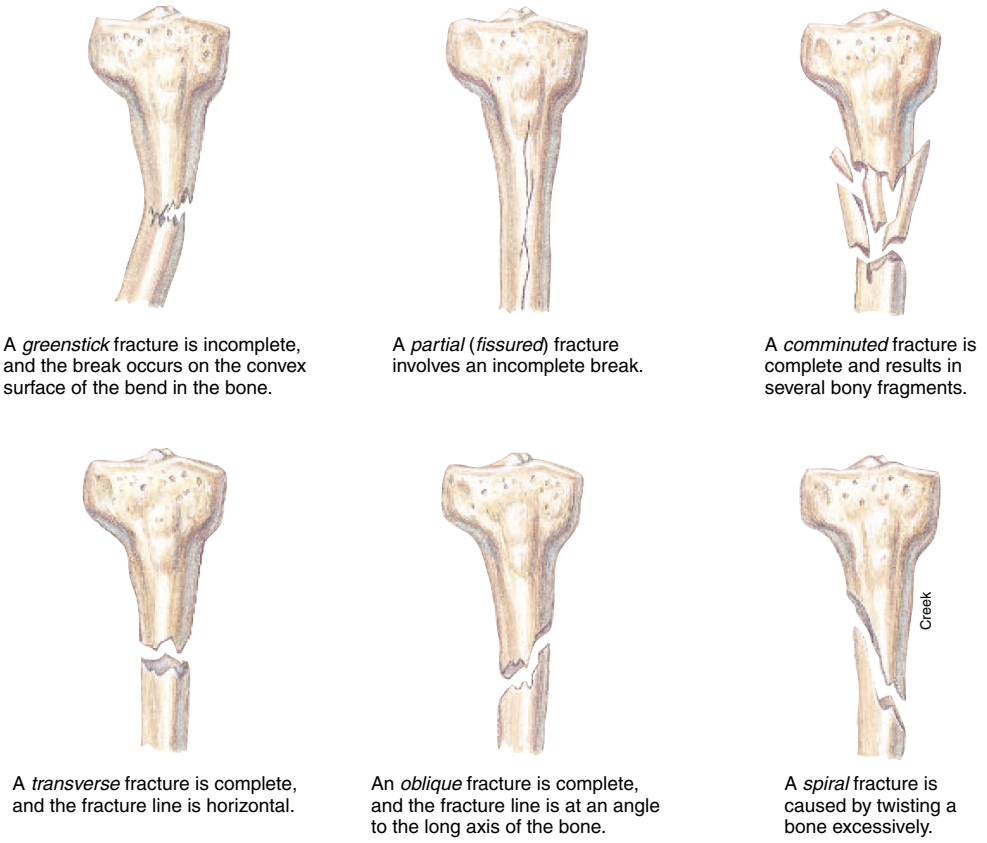


FIGURE 7.23 Examples of fractures.

11. **Colles'.** A fracture of the distal portion of the radius.
12. **Pott's.** A fracture of either or both of the distal ends of the tibia and fibula at the level of the malleoli.
13. **Avulsion.** A portion of a bone is torn off.
14. **Depressed.** The broken portion of the bone is driven inward, as in certain skull fractures.
15. **Displaced.** A fracture in which the bone fragments are not in anatomical alignment.
16. **Nondisplaced.** A fracture in which the bone fragments remain in anatomical alignment.

When a bone fractures, medical treatment involves realigning the broken ends and then immobilizing them until new bone tissue has formed and the fracture has healed. The site and severity of the fracture and the age of the patient determines the type of immobilization. The methods of immobilization include tape, splints, casts, straps, wires, screws, plates, and steel pins. Certain fractures seem to resist healing, however, even with this array of treatment options. New techniques for treating fractures include applying weak electrical currents to fractured bones. This method has shown promise in promoting healing and significantly reducing the time of immobilization.

Physicians can realign and immobilize a fracture, but the ultimate repair of the bone occurs naturally within the bone itself. Several steps are involved in this process (fig. 7.24).

1. When a bone is fractured, the surrounding periosteum is usually torn and blood vessels in both tissues are ruptured. A blood clot called a **fracture hematoma** (*hēm″ă-to′mă*) soon forms throughout the damaged area. A disrupted blood supply to osteocytes and periosteal cells at the fracture site causes localized cellular death. This is followed by swelling and inflammation.

Colles' fracture: from Abraham Colles, Irish surgeon, 1773–1843
Pott's fracture: from Percivall Pott, British surgeon, 1713–88

hematoma: Gk. *hema*, blood; *oma*, tumor

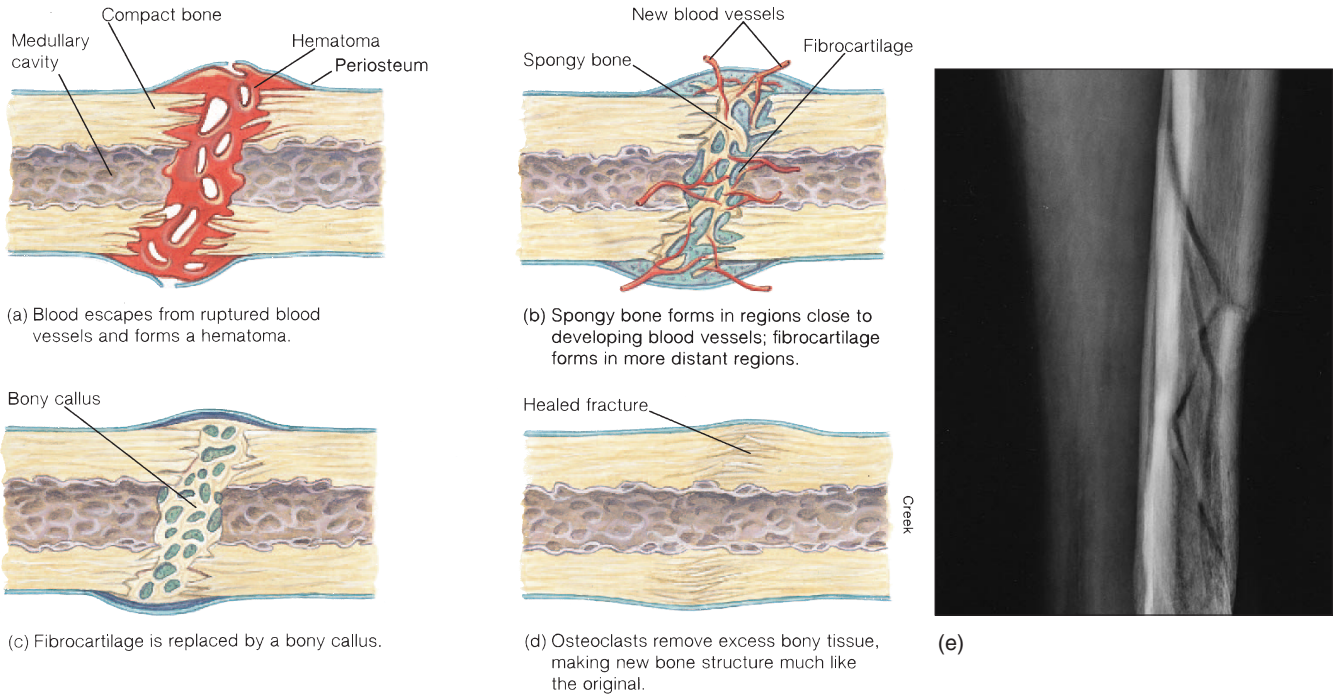


FIGURE 7.24 Stages (*a–d*) of the repair of a fracture. (*e*) A radiograph of a healing fracture.

2. The traumatized area is "cleaned up" by the activity of phagocytic cells within the blood and osteoclasts that resorb bone fragments. As the debris is removed, fibrocartilage fills the gap within the fragmented bone, and a cartilaginous mass called a **bony callus** is formed. The bony callus becomes the precursor of bone formation in much the same way that hyaline cartilage serves as the precursor of developing bone.
3. The remodeling of the bony callus is the final step in the healing process. The cartilaginous callus is broken down, a new vascular supply is established, and compact bone develops around the periphery of the fracture. A healed fracture line is frequently undetectable in a radiograph, except that for a period of time the bone in this area may be slightly thicker.

callus: L. *callosus*, hard

Clinical Case Study Answer

The injury involves the cartilaginous epiphyseal growth plate, which is the site of linear growth in long bones. At cessation of growth, this plate disappears as the epiphysis and diaphysis fuse. Until this occurrence, however, disruption of the growth plate can adversely affect growth of the bone.

Developmental Exposition

The Appendicular Skeleton

EXPLANATION

The development of the upper and lower extremities is initiated toward the end of the fourth week with the appearance of four small elevations called **limb buds** (exhibit I). The superior pair are the arm buds, whose development precedes that of the inferior pair of leg buds by a few days. Each limb bud consists of a mass of undifferentiated mesoderm partially covered with a layer of ectoderm. This **apical** (*a′pĭ-kal*) **ectodermal ridge** promotes bone and muscle development.

As the limb buds elongate, migrating mesenchymal tissues differentiate into specific cartilaginous bones. Primary ossification centers soon form in each bone, and the hyaline cartilage tissue is gradually replaced by bony tissue in the process of *endochondral ossification* (see chapter 6).

Initially, the developing limbs are directed caudally, but later there is a lateral rotation in the upper extremity and a medial rotation in the lower extremity. As a result, the elbows are directed backward and the knees directed forward.

Digital rays that will form the hands and feet are apparent by the fifth week, and the individual digits separate by the end of the sixth week.

A large number of limb deformities occurred in children born between 1957 and 1962. During this period, the sedative thalidomide was used by large numbers of pregnant women to relieve "morning sickness." It is estimated that 7,000 infants suffered severe limb malformations as a result of exposure to this drug in their early intrauterine life. The malformations ranged from *micromelia* (short limbs) to *amelia* (absence of limbs).

micromelia: Gk. *mikros*, small; *melos*, limb

amelia: Gk. *a*, without; *melos*, limb

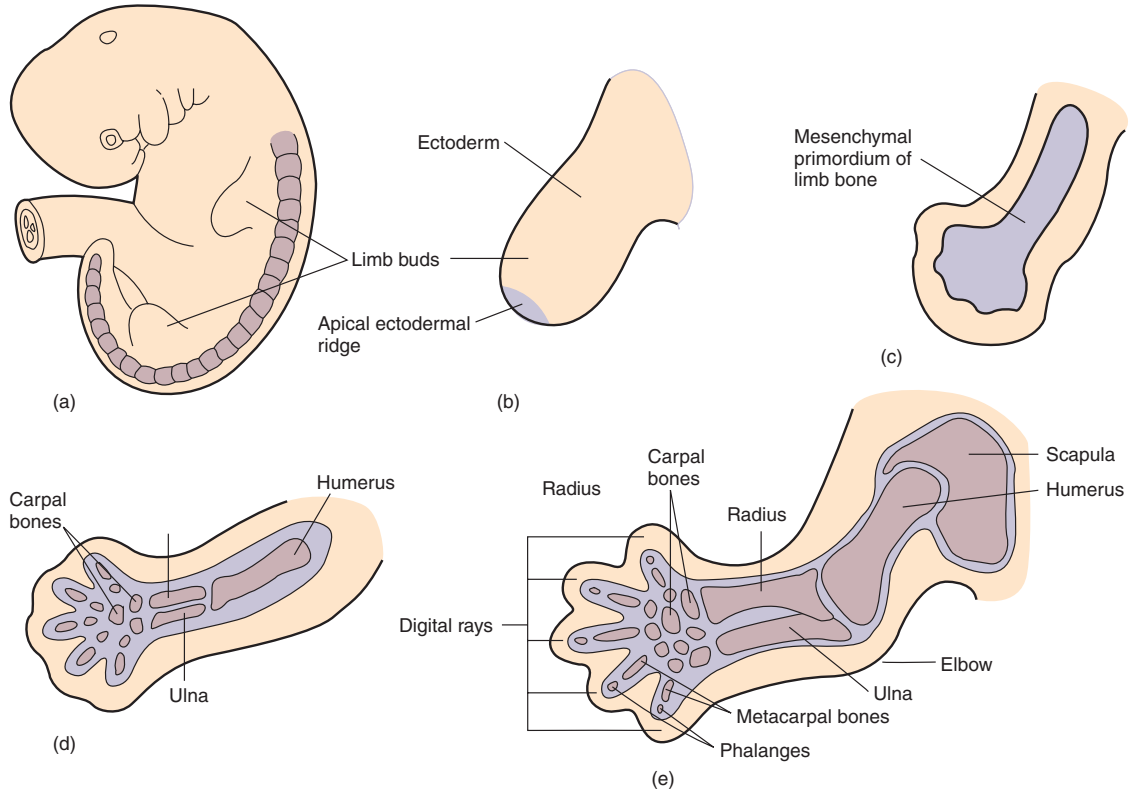


EXHIBIT I The development of the appendicular skeleton. (*a*) Limb buds are apparent in an embryo at 28 days and (*b*) an ectodermal ridge is the precursor of the skeletal and muscular structures. (*c*) Mesenchymal primordial cells are present at 33 days. (*d*) Hyaline cartilaginous models of individual bones develop early in the sixth week. (*e*) Later in the sixth week, the cartilaginous skeleton of the upper extremity is well formed.

CLINICAL PRACTICUM 7.1

A 40-year-old male fell from a 10-foot ladder while trimming a tree. He landed on an outstretched hand and heard a horrible crack. He comes to your emergency room for evaluation. On examination, you note a markedly deformed forearm with an open wound. You note that the patient has mildly weakened strength in the hand, normal sensation, as well as normal capillary refill and normal radial pulse. You order radiographs of the forearm for further evaluation.

QUESTIONS

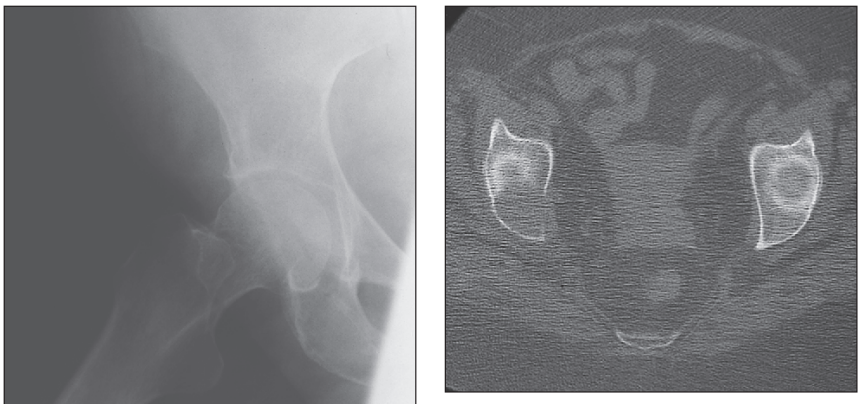
1. Describe this fracture.
2. What is the danger of an open fracture?
3. Why is it important to evaluate neuromuscular and vascular function in the hand in this case?

CLINICAL PRACTICUM 7.2

A 70-year-old female patient with known thyroid cancer presents to you for a follow-up appointment several months after completing her chemotherapy. At the current appointment, she complains of a new pain in her right hip. This pain began approximately one month before and has been slowly progressing. On physical exam, you find nothing remarkable with the exception that the patient is now walking with a noticeable limp. A conventional radiograph (left) and a CT scan (right) of the hip are shown here.

QUESTIONS

1. Why is the patient having pain in the hip?
2. What does this finding put the patient at risk for?



Chapter Summary

Pectoral Girdle and Upper Extremity (pp. 173–178)

1. The pectoral girdle consists of the paired scapulae and clavicles. Anteriorly, each clavicle articulates with the sternum at the sternoclavicular joint.
   (a) Distinguishing features of the clavicle include the acromial and sternal extremities, conoid tubercle, and costal tuberosity.
   (b) Distinguishing features of the scapula include the spine, acromion, and coracoid process; the supraspinous, infraspinous, and subscapular fossae; the glenoid cavity; the coracoid process; superior, medial, and lateral borders; and superior, inferior, and lateral angles.
2. The brachium contains the humerus, which extends from the shoulder to the elbow.
   (a) Proximally, distinguishing features of the humerus include a rounded head, greater and lesser tubercles, an anatomical neck, and an intertubercular groove. Distally, they include medial and lateral epicondyles, coronoid and olecranon fossae, a capitulum, and a trochlea.
   (b) The head of the humerus articulates proximally with the glenoid cavity of the scapula; distally, the trochlea and capitulum articulate with the ulna and radius, respectively.
3. The antebrachium contains the ulna (medially) and the radius (laterally).
   (a) Proximally, distinguishing features of the ulna include the olecranon and coronoid processes, the trochlear notch, and the radial notch. Distally, they include the styloid process and head of ulna.
   (b) Proximally, distinguishing features of the radius include the head and neck of radius and the tuberosity of radius. Distally, they include the styloid process and ulnar notch.
4. The hand contains 27 bones including 8 carpal bones, 5 metacarpal bones, and 14 phalanges. The thumb lacks a middle phalanx.

Pelvic Girdle and Lower Extremity (pp. 178–189)

1. The pelvic girdle is formed by two ossa coxae, united anteriorly at the symphysis pubis. It is attached posteriorly to the sacrum—a bone of the axial skeleton.
2. The pelvis is divided into a greater pelvis, which helps to support the pelvic viscera, and a lesser pelvis, which forms the walls of the birth canal.
3. Each os coxae consists of an ilium, ischium, and pubis. Distinguishing features of the os coxae include an obturator foramen and an acetabulum, the latter of which is the socket for articulation with the head of the femur.
   (a) Distinguishing features of the ilium include an iliac crest, iliac fossa, anterior superior iliac spine, anterior inferior iliac spine, and greater sciatic notch.
   (b) Distinguishing features of the ischium include the body, ramus, ischial tuberosity, and lesser sciatic notch.
   (c) Distinguishing features of the pubis include the ramus and pubic tubercle. The two pubic bones articulate at the symphysis pubis.
4. The thigh contains the femur, which extends from the hip to the knee, where it articulates with the tibia and the patella.
   (a) Proximally, distinguishing features of the femur include the head, fovea capitus femoris, neck, and greater and lesser trochanters. Distally, they include the lateral and medial epicondyles, the lateral and medial condyles, and the patellar surface. The linea aspera is a roughened ridge positioned vertically along the posterior aspect of the body of the femur.
   (b) The head of the femur articulates proximally with the acetabulum of the os coxae and distally with the condyles of the tibia and the articular facets of the patella.
5. The leg contains the tibia medially and the fibula laterally.
   (a) Proximally, distinguishing features of the tibia include the medial and lateral condyles, intercondylar eminence, and tibial tuberosity. Distally, they include the medial malleolus and fibular notch. The anterior crest is a sharp ridge extending the anterior length of the tibia.
   (b) Distinguishing features of the fibula include the head proximally and the lateral malleolus distally.
6. The foot contains 26 bones including 7 tarsal bones, 5 metatarsal bones, and 14 phalanges. The great toe lacks a middle phalanx.

Review Activities

Objective Questions

1. In anatomical position, the subscapular fossa of the scapula faces
   (a) anteriorly. (c) posteriorly.
   (b) medially. (d) laterally.
2. The clavicle articulates with
   (a) the scapula and the humerus.
   (b) the humerus and the manubrium.
   (c) the manubrium and the scapula.
   (d) the manubrium, the scapula, and the humerus.
3. Which of the following bones has a conoid tubercle?
   (a) the scapula
   (b) the humerus
   (c) the radius
   (d) the clavicle
   (e) the ulna
4. The proximal process of the ulna is
   (a) the lateral epicondyle.
   (b) the olecranon.
   (c) the coronoid process.
   (d) the styloid process.
   (e) the medial epicondyle.
5. Which of the following statements concerning the carpus is *false?*
   (a) It consists of eight carpal bones arranged in two transverse rows of four bones each.
   (b) All of the carpal bones are considered sesamoid bones.
   (c) The scaphoid and the lunate articulate with the radius.

(d) The trapezium, trapezoid, capitate, and hamate articulate with the metacarpals.

6. Pelvimetry is a measurement of
   (a) the os coxae.
   (b) the symphysis pubis.
   (c) the pelvic brim.
   (d) the lesser pelvis.
7. Which of the following is *not* a structural feature of the os coxae?
   (a) the obturator foramen
   (b) the acetabulum
   (c) the auricular surface
   (d) the greater sciatic notch
   (e) the linea aspera
8. A fracture across the intertrochanteric line would involve
   (a) the ilium.
   (b) the femur.
   (c) the tibia.
   (d) the fibula.
   (e) the patella.
9. Relative to the male pelvis, the female pelvis
   (a) is more massive.
   (b) is narrower at the pelvic outlet.
   (c) is tilted backward.
   (d) has a shallower symphysis pubis.
10. Clubfoot is a congenital foot deformity that is clinically referred to as
    (a) talipes.
    (b) syndactyly.
    (c) pes planus.
    (d) polydactyly.

Essay Questions

1. Contrast the structure of the pectoral and pelvic girdles. How do the structural differences relate to differences in function?
2. Explain why the clavicle is more frequently fractured than the scapula.
3. List the processes of the bones of the upper and lower extremities that can be palpated. Why are these bony landmarks important to know?
4. The bones of the hands are similar to those of the feet, but there are some important differences in structure and arrangement. Compare and contrast the anatomy of these appendages, taking into account their functional roles.
5. Define *bipedal locomotion* and discuss the adaptations of the pelvic girdle and lower extremities that allow for this type of movement.
6. Explain how the female pelvis is adapted to the needs of pregnancy and childbirth.
7. Explain the significance of the limb buds, apical ectodermal ridges, and digital rays in limb development. When does limb development begin and when is it complete?
8. What is meant by a congenital skeletal malformation? Give two examples of such abnormalities that occur within the appendicular skeleton.
9. What are the differences between pathological and traumatic fractures? Give some examples of traumatic fractures.
10. How does a fractured bone repair itself? Why is it important that the fracture be immobilized?

Critical-Thinking Questions

1. James Smithson, benefactor of the Smithsonian Institution, died in 1829 at the age of 64. Although his body had been buried in Italy, it was reinterred in 1904 near the front entry of the Smithsonian in Washington, D.C. Before the reburial, scientists at the Smithsonian carefully examined Smithson's skeleton to learn more about him. From the bones they concluded that Smithson was rather slightly built but athletic—he had a large chest and powerful arms and hands. His teeth were worn on the left side from chewing a pipe. The scientists also reported that "certain peculiarities of the right little finger suggest that he may have played the harpsichord, piano, or a stringed instrument such as a violin." Preserved bones can serve as a storehouse of information. Considering current technology, what other types of information might be gleaned from examination of a preserved skeleton?
2. Which would you say has been more important in human evolution—adaptation of the hand or adaptation of the foot? Explain your reasoning.
3. Speculate as to why a single bone is present in both the brachium and the thigh, whereas the antebrachium and leg each have two bones.
4. Compare the tibia and fibula with respect to structure and function. Which would be more debilitating, a compound fracture of the tibia or a compound fracture of the fibula?