PEARSON NEW INTERNATIONAL EDITION

Human Anatomy

Martini Timmons Tallitsch

Seventh Edition

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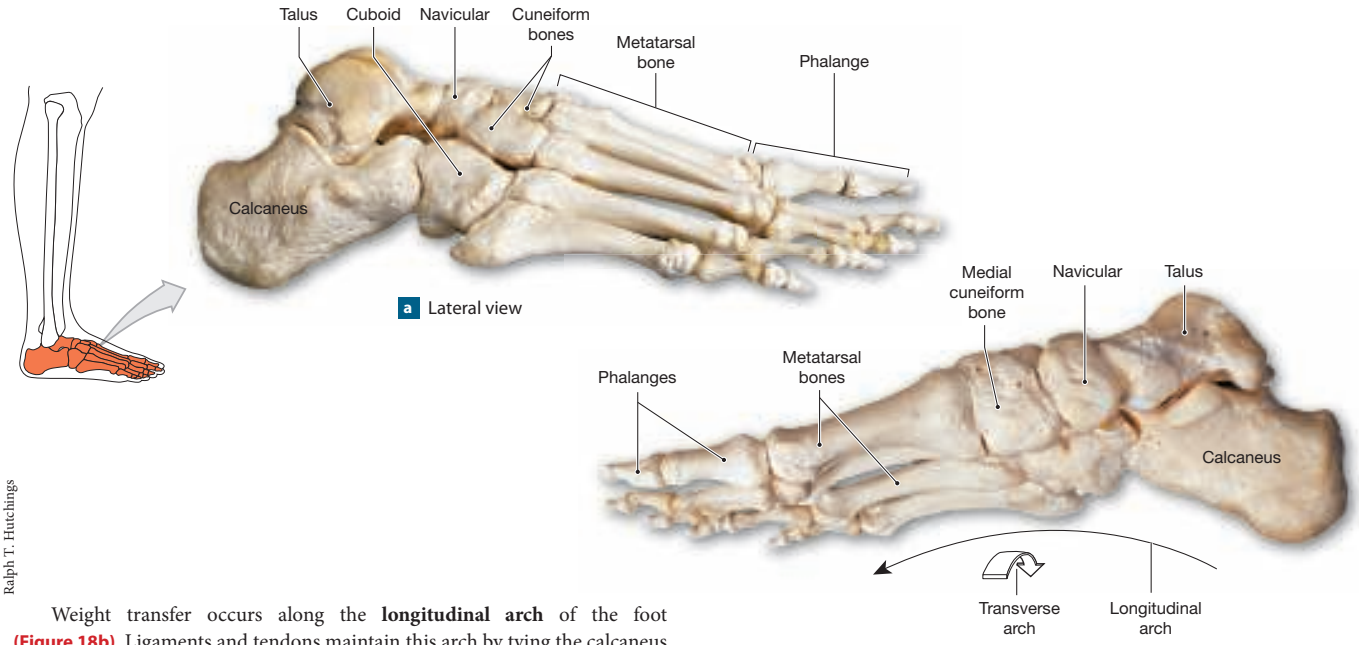
Figure 18 Bones of the Ankle and Foot, Part II



Ralph T. Hutchings

a Lateral view

b Medial view showing the relative positions of the tarsal bones and the orientation of the transverse and longitudinal arches

Weight transfer occurs along the **longitudinal arch** of the foot **(Figure 18b)**. Ligaments and tendons maintain this arch by tying the calcaneus to the distal portions of the metatarsal bones. The lateral side of the foot carries most of the weight of the body while standing normally. This calcaneal portion of the arch has less curvature than the medial, talar portion. The talar portion also has more elasticity than the calcaneal portion of the longitudinal arch. As a result, the medial, plantar (sole) surface remains elevated, and the muscles, nerves, and blood vessels that supply the inferior surface of the foot are not squeezed between the metatarsal bones and the ground. This elasticity also helps absorb the shocks that accompany sudden changes in weight loading. For example, the stresses involved with running or ballet dancing are cushioned by the elasticity of this portion of the longitudinal arch. Because the degree of curvature changes from the medial to the lateral borders of the foot, a **transverse arch** also exists.

When you stand normally, your body weight is distributed evenly between the calcaneus and the distal ends of the metatarsal bones. The amount of weight transferred forward depends on the position of the foot and the placement of body weight. During dorsiflexion of the foot, as when "digging in the heels," all of the body weight rests on the calcaneus. During plantar flexion and "standing on tiptoe," the talus and calcaneus transfer the weight to the metatarsal bones and phalanges through more anterior tarsal bones.

Concept Check 2 See the blue ANSWERS tab at the end of the chapter.

1. What three bones make up the hip bone?
2. The fibula does not participate in the knee joint, nor does it bend; but when it is fractured, walking is difficult. Why?
3. While jumping off the back steps of his house, 10-year-old Mark lands on his right heel and breaks his foot. What foot bone is most likely broken?
4. Describe at least three differences between the female and male pelvis.
5. Where does the weight of the body rest during dorsiflexion? During plantar flexion?

Individual Variation in the Skeletal System [Tables 1 • 2]

A comprehensive study of a human skeleton can reveal important information about the individual. For example, there are characteristic racial differences in portions of the skeleton, especially the skull, and the development of various ridges and general bone mass can permit an estimation of muscular development. Details such as the condition of the teeth or the presence of healed fractures can provide information about the individual's medical history. Two important details, sex and age, can be determined or closely estimated on the basis of measurements indicated in Tables 1 and 2. Table 1 identifies characteristic differences between the skeletons of males and females, but not every skeleton shows every feature in classic detail. Many differences, including markings on the skull, cranial capacity, and general skeletal features, reflect differences in average body size, muscle mass, and muscular strength. The general changes in the skeletal system that take place with age are summarized in Table 2. Note how these changes begin at age 3 months and continue throughout life. For example, fusion of the epiphyseal cartilages begins at about age 3, while degenerative changes in the normal skeletal system, such as a reduction in mineral content in the bony matrix, do not begin until age 30–45.

CLINICAL NOTE

Problems with the Ankle and Foot

THE ARCHES OF THE FOOT are usually present at birth. Sometimes, however, they fail to develop properly. In **congenital talipes equinovarus (clubfoot),** abnormal muscle development distorts growing bones and joints. One or both feet may be involved. In most cases, the tibia, ankle, and foot are affected; the longitudinal arch is exaggerated, and the feet are turned medially and inverted. If both feet are involved, the soles face one another. This condition, which affects 2 in 1000 births, is roughly twice as common in boys as in girls. Prompt treatment with casts or other supports in infancy helps alleviate the problem, and fewer than half the cases require surgery.

Someone with **flatfeet** loses or never develops the longitudinal arch. "Fallen arches" develop as tendons and ligaments stretch and become less elastic. Up to 40 percent of adults may have flatfeet, but no action is necessary unless pain develops. Individuals with abnormal arch development are most likely to suffer metatarsal injuries. Children have very mobile articulations and elastic ligaments, so they commonly have flexible, flat feet. Their feet look flat only while they are standing, and the arch appears when they stand on their toes or sit down. In most cases, the condition disappears as growth continues.

Claw feet are produced by muscular abnormalities. In individuals with a claw foot, the median longitudinal arch becomes exaggerated because the plantar flexors overpower the dorsiflexors. Causes include muscle degeneration and nerve paralysis. The condition tends to get progressively worse with age.

Even the normal ankle and foot are subjected to a variety of stresses during daily activities. In a **sprain,** a ligament is stretched to the point at which some of the collagen fibers are torn. The ligament remains functional, and the structure of the joint is not affected. The most common cause of a sprained ankle is a forceful inversion of the foot that stretches the lateral ligament. An ice pack is generally required to reduce swelling. With rest and support, the ankle should heal in about three weeks.

In more serious incidents, the entire ligament can be torn apart, or the connection between the ligament and the lateral malleolus can be so strong that the bone breaks instead of the ligament. A dislocation may accompany such injuries.

In a **dancer's fracture,** the proximal portion of the fifth metatarsal is broken. Most such cases occur while the body weight is being supported by the longitudinal arch of the foot. A sudden shift in weight from the medial portion of the arch to the lateral, less elastic border breaks the fifth metatarsal close to its distal articulation.

Table 1 Sexual Differences in the Adult Human Skeleton

Region/Feature	Male	Female
SKULL		
General appearance	Heavier; rougher surface	Lighter; smoother surface
Forehead	More sloping	More vertical
Sinuses	Larger	Smaller
Cranium	About 10% larger (average)	About 10% smaller
Mandible	Larger, more robust	Lighter, smaller
Teeth	Larger	Smaller
PELVIS		
General appearance	Narrow; robust; heavier; rougher surface	Broad; light; smoother surface
Pelvic inlet	Heart shaped	Oval to round
Iliac fossa	Deeper	Shallower
Ilium	More vertical; extends farther superior	Less vertical; less extension superior to the sacro-iliac joint
Angle inferior to pubic symphysis	Less than 90°	100° or more
Acetabulum	Directed laterally	Faces slightly anteriorly as well as laterally
Obturator foramen	Oval	Triangular
Ischial spine	Points medially	Points posteriorly
Sacrum	Long, narrow triangle with pronounced sacral curvature	Broad, short triangle with less curvature
Coccyx	Points anteriorly	Points inferiorly
OTHER SKELETAL ELEMENTS		
Bone weight	Heavier	Lighter
Bone markings	More prominent	Less prominent

Table 2 **Age-Related Changes in the Skeleton**

Region/Structure	Event(s)	Age (Years)
GENERAL SKELETON		
Bony matrix	Reduction in mineral content	Begins at age 30–45; values differ for males versus females between ages 45 and 65; similar reductions occur in both sexes after age 65.
Markings	Reduction in size, roughness	Gradual reduction with increasing age and decreasing muscular strength and mass
SKULL		
Fontanels	Closure	Completed by age 2
Frontal suture	Fusion	2–8
Occipital bone	Fusion of ossification centers	1–6
Styloid process	Fusion with temporal bone	12–16
Hyoid bone	Complete ossification and fusion	25–30 or later
Teeth	Loss of "baby teeth"; appearance of permanent teeth; eruption of permanent molars	
Mandible	Loss of teeth; reduction in bone mass; change in angle at mandibular notch	Accelerates in later years (age 60)
VERTEBRAE		
Curvature	Appearance of major curves	3 months–10 years
Intervertebral discs	Reduction in size, percentage contribution to height	Accelerates in later years (age 60)
LONG BONES		
Epiphyseal cartilages	Fusion	Ranges vary according to specific bone under discussion, but general analysis permits determination of approximate age (3–7, 15–22, etc.)
PECTORAL AND PELVIC GIRDLES		
Epiphyseal cartilages	Fusion	Overlapping ranges are somewhat narrower than the above, including 14–16, 16–18, 22–25 years

Clinical Terms

- **congenital talipes equinovarus (clubfoot):** A congenital deformity affecting one or both feet. It develops secondary to abnormalities in neuromuscular development.
- **dancer's fracture:** A fracture of the fifth metatarsal, usually near its proximal articulation.
- **flatfeet:** The loss or absence of a longitudinal arch.
- **sprain:** Condition caused when a ligament is stretched to the point where some of the collagen fibers are torn. Unless torn completely, the ligament remains functional, and the structure of the joint is not affected.

Study Outline

Introduction

1. The **appendicular skeleton** includes the bones of the upper and lower limbs and the pectoral and pelvic girdles that support the limbs and connect them to the trunk. *(see Figure 1)*

The Pectoral Girdle and Upper Limb

1. Each upper limb articulates with the trunk through the **pectoral girdle**, or *shoulder girdle*, which consists of the **clavicle** (collarbone) and the **scapula** (shoulder blade). *(see Figures 2 to 5)*

The Pectoral Girdle

2. The clavicle and scapula position the shoulder joint, help move the upper limb, and provide a base for muscle attachment. *(see Figures 3/4)*
3. The **clavicle** is an S-shaped bone that extends between the manubrium of the sternum and the **acromion** of the scapula. This bone provides the only direct connection between the pectoral girdle and the axial skeleton.
4. The **scapula** articulates with the round head of the humerus at the **glenoid cavity** of the scapula, the **glenohumeral joint** (*shoulder joint*). Two scapular processes, the **coracoid** and the **acromion**, are attached to ligaments and tendons associated with the shoulder joint. The acromion articulates with the clavicle at the **acromioclavicular joint**. The acromion is continuous with the **scapular spine**, which crosses the posterior surface of the scapular body. *(see Figure 5)*

The Upper Limb

5. The **humerus** articulates with the glenoid cavity of the scapula. The articular capsule of the shoulder attaches distally to the humerus at its **anatomical neck**. Two prominent projections, the **greater tubercle** and **lesser tubercle**, are important sites for muscle attachment. Other prominent surface features include the **deltoid tuberosity**, site of *deltoid muscle* attachment; the articular **condyle**, divided into two articular regions, the **trochlea** (medial) and **capitulum** (lateral); the **radial groove**, marking the path of the *radial nerve*; and the **medial** and **lateral epicondyles** for other muscle attachment. *(see Figures 2/6 to 8)*
6. Distally the humerus articulates with the ulna (at the trochlea) and the radius (at the capitulum). The trochlea extends from the **coronoid fossa** to the **olecranon fossa**. *(see Figure 6)*
7. The **ulna** and **radius** are the parallel bones of the forearm. The olecranon fossa of the humerus accommodates the **olecranon** of the ulna during straightening (extension) of the elbow joint. The coronoid fossa accommodates the **coronoid process** of the ulna during bending (flexion) of the elbow joint. *(see Figures 2/7)*
8. The **carpal bones** of the wrist form two rows, **proximal** and **distal**. From lateral to medial, the proximal row consists of the **scaphoid**, **lunate**, **triquetrum**, and **pisiform**. From lateral to medial, the distal row consists of the **trapezium**, **trapezoid**, **capitate**, and **hamate**. *(see Figure 8)*
9. Five **metacarpal bones** articulate with the distal carpal bones. Distally, the metacarpal bones articulate with the phalanges. Four of the fingers contain three **phalanges**; the **pollex** (thumb) has only two. *(see Figure 8)*

The Pelvic Girdle and Lower Limb

The Pelvic Girdle

1. The pelvic girdle consists of two **hip bones**, also called *coxal bones* or *innominate bones*; each hip bone forms through the fusion of three bones—an ilium, an ischium, and a pubis. *(see Figures 9/10)*
2. The **ilium** is the largest of the hip bones. Inside the **acetabulum** (the fossa on the lateral surface of the hip bone that accommodates the **head** of the femur) the ilium is fused to the **ischium** (posteriorly) and to the **pubis** (anteriorly). The **pubic symphysis** limits movement between the pubic bones of the left and right hip bones. *(see Figures 11/13)*
3. The **pelvis** consists of the two hip bones, the sacrum, and coccyx. It may be subdivided into the **greater** (*false*) **pelvis** and the **lesser** (*true*) **pelvis**. The lesser pelvis encloses the **pelvic cavity**. *(see Figures 11 to 13)*

The Lower Limb

4. The **femur** is the longest bone in the body. At its rounded **head**, it articulates with the pelvis at the acetabulum, and at its distal end its **medial** and **lateral condyles** articulate with the tibia at the knee joint. The **greater** and **lesser trochanters** are projections near the head where large tendons attach to the femur. *(see Figures 9/12d/14)*
5. The **patella** is a large sesamoid bone that forms within the tendon of the *quadriceps femoris* muscle group. The patellar ligament extends from the patella to the **tibial tuberosity**. *(see Figures 14f/15)*
6. The **tibia** is the large medial bone of the leg. The prominent rough surface markings of the tibia include the **tibial tuberosity**, the **anterior margin**, the **interosseous border**, and the **medial malleolus**. The medial malleolus is a large process that provides medial support for the **talocrural joint** (ankle). *(see Figure 16)*
7. The **fibula** is the slender leg bone lateral to the tibia. The **head** articulates with the tibia inferior to the knee, inferior and slightly posterior to the lateral tibial condyle. A fibular process, the **lateral malleolus**, stabilizes the ankle joint by preventing medial movement of the tibia across the talus. *(see Figures 16/17)*
8. The **tarsus**, or ankle, includes seven **tarsal bones**; only the smooth superior surface of the trochlea of the talus articulates with the tibia and fibula. It has lateral and medial extensions that articulate with the lateral and medial malleoli of the fibula and tibia, respectively. When standing normally, most of the body weight is transferred to the calcaneus, and the rest is passed on to the **metatarsal bones**.
9. The basic organizational pattern of the **metatarsal bones** and **phalanges** of the foot is the same as that of the metacarpal bones and phalanges of the hand. *(see Figures 17/18)*
10. Weight transfer occurs along the **longitudinal arch** and **transverse arch** of the foot. *(see Figures 17/18)*

Individual Variation in the Skeletal System

1. Studying a human skeleton can reveal important information such as gender, race, medical history, body size, muscle mass, and age. (*see Tables 1/2*)
2. A number of age-related changes and events take place in the skeletal system. These changes begin at about age 3 and continue throughout life. *(see Tables 1/2)*

Chapter Review

For answers, see the blue ANSWERS tab at the end of the chapter.

Level 1 Reviewing Facts and Terms

Match each numbered item with the most closely related lettered item. Use letters for answers in the spaces provided.

1. shoulder ____
2. hip ____
3. scapula ____
4. trochlea ____
5. ulnar notch ____
6. one coxal bone ____
7. greater trochanter ____
8. medial malleolus ____
9. heel bone ____
10. toes ____

a. tibia
b. pectoral girdle
c. radius
d. phalanges
e. pelvic girdle
f. femur
g. infraspinous fossa
h. calcaneus
i. ilium
j. humerus

11. **Structural characteristics of the pectoral girdle that adapt it to a wide range of movement include**
    (a) heavy bones
    (b) relatively weak joints
    (c) limited range of motion at the shoulder joint
    (d) joints stabilized by ligaments and tendons to the thoracic cage
12. **The broad, relatively flat portion of the clavicle that articulates with the scapula is the**
    (a) sternal end
    (b) conoid tubercle
    (c) acromial end
    (d) costal tuberosity

13. **What bone articulates with the hip bone at the acetabulum?**
    (a) sacrum
    (b) humerus
    (c) femur
    (d) tibia
14. **The protuberance that can be palpated on the lateral side of the ankle is the**
    (a) lateral malleolus
    (b) lateral condyle
    (c) tibial tuberosity
    (d) lateral epicondyle
15. **Structural characteristics of the pelvic girdle that adapt it to the role of bearing the weight of the body include**
    (a) heavy bones
    (b) stable joints
    (c) limited range of movement
    (d) all of the above at some joints
16. **Which of the following is a characteristic of the male pelvis?**
    (a) triangular obturator foramen
    (b) coccyx points into the pelvic outlet
    (c) sacrum broad and short
    (d) ischial spine points posteriorly
17. **Which of the following is not a carpal bone?**
    (a) scaphoid
    (b) hamate
    (c) cuboid
    (d) triquetrum
18. **The _____ of the radius assists in the stabilization of the wrist joint.**
    (a) olecranon
    (b) coronoid process
    (c) styloid process
    (d) radial tuberosity
19. **The olecranon is found on the**
    (a) humerus
    (b) radius
    (c) ulna
    (d) femur
20. **The small, anterior projection of the scapula that extends over the superior margin of the glenoid cavity is the**
    (a) scapular spine
    (b) acromion
    (c) coracoid process
    (d) supraspinous process

Level 2 Reviewing Concepts

1. **The observable differences between the male and female pelvis are a result of which of the following?**
    (a) smoother surface and lighter bones of the female pelvis
    (b) less curvature of the sacrum and coccyx in the female
    (c) a more circular pelvic outlet
    (d) all of the above
2. **Identification of an individual by examination of the skeleton can be made by use of which of the following?**
    (a) matching of dental records from prior to death
    (b) relative density of the bones
    (c) strength of the ligamentous attachments of the bones
    (d) relative length of the elements of the hands and feet
3. **Characteristics that specifically identify a skeletal element as belonging to a male include**
    (a) heavy orbital ridges on the frontal bones
    (b) a more vertical forehead
    (c) a relatively shallow iliac fossa
    (d) a smaller cranial cavity
4. In determining the age of a skeleton, what pieces of information would be helpful?
5. What is the importance of maintaining the correct amount of curvature of the longitudinal arch of the foot?
6. Why are fractures of the clavicle so common?
7. Why is the tibia, but not the fibula, involved in the transfer of weight to the ankle and foot?
8. What is the function of the olecranon of the ulna?
9. How is body weight passed to the metatarsal bones?

Level 3 Critical Thinking

1. Why would a person who has osteoporosis be more likely to suffer a broken hip than a broken shoulder?
2. Archaeologists find the pelvis of a primitive human and are able to tell the sex, the relative age, and some physical characteristics of the individual. How is this possible from the pelvis only?
3. How would a forensic scientist decide whether a partial skeleton found in the forest is that of a male or female?
4. The condition of lower-than-normal longitudinal arches is known as "flatfeet." What structural problem causes flatfeet?

Online Resources

Access more review material online in the Study Area at www.masteringaandp.com. There, you'll find:

- **Chapter guides**
- **Chapter quizzes**
- **Chapter practice tests**
- **Flashcards**
- **A glossary with pronunciations**

Practice Anatomy Lab™ (PAL) is an indispensable virtual anatomy practice tool. Follow these navigation paths in PAL for concepts in this chapter:

- **PAL > Human Cadaver > Appendicular Skeleton**
- **PAL > Anatomical Models > Appendicular Skeleton**

Answers to Concept Check and Chapter Review Questions

Concept Check 1

1. The clavicle attaches the scapula to the sternum and thus restricts the scapula's range of movement. If the clavicle is broken, the scapula will have a greater range of movement and will be less stable.
2. The radius is in a lateral position when the forearm is in the anatomical position.
3. The olecranon is the point of the elbow. During extension of the elbow, the olecranon swings into the olecranon fossa on the posterior surface of the humerus to prevent overextension.
4. The clavicle articulates with the manubrium of the sternum, and this provides the only direct connection between the pectoral girdle and the axial skeleton.

Concept Check 2

1. The three bones that make up the hip bone are the ilium, ischium, and pubic bones.
2. Although the fibula is not part of the knee joint and does not bear weight, it is an important point of attachment for many leg muscles. When the fibula is fractured, these muscles cannot function properly to move the leg, and walking is difficult and painful. The fibula also helps stabilize the ankle joint.
3. Mark has most likely fractured his calcaneus (heel bone).
4. There are six differences that are adaptations for childbearing: an enlarged pelvic outlet; less curvature on the sacrum and coccyx, which in the male arc anteriorly into the pelvic outlet; a wider, more circular pelvic inlet; a relatively broad, low pelvis; ilia that project farther laterally, but do not extend as far superior to the sacrum; and a broader pubic arch, with the inferior angle between the pubic bones greater than 100°.
5. During dorsiflexion, as when "digging in the heels," all of the body weight rests on the calcaneus. During plantar flexion and "standing on tiptoe," the talus and calcaneus transfer the weight to the metatarsal bones and phalanges through more anterior tarsal bones.

Chapter Review

Level 1 Reviewing Facts and Terms

1. B	**6.** I	**11.** B	**16.** B
2. E	**7.** F	**12.** C	**17.** C
3. G	**8.** A	**13.** C	**18.** C
4. J	**9.** H	**14.** A	**19.** C
5. C	**10.** D	**15.** D	**20.** C

Level 2 Reviewing Concepts

1. D
2. A
3. A
4. To determine the age of a skeleton, one would consider some or all of the following: the fusion of the epiphyseal plates, the amount of mineral content, the size and roughness of bone markings, teeth, bone mass of the mandible, and intervertebral disc size.
5. Weight transfer occurs along the longitudinal arch of the foot. Ligaments and tendons maintain this arch by tying the calcaneus to the distal portions of the metatarsal bones. The lateral, calcaneal side of the foot carries most of the weight of the body while standing normally. This portion of the arch has less curvature than the medial, talar portion.
6. Fractures of the medial portion of the clavicle are common because a fall on the palm of the hand of an outstretched upper limb produces compressive forces that are conducted to the clavicle and its articulation with the manubrium.
7. The tibia is part of the knee joint and is involved in the transfer of weight to the ankle and foot. The fibula is excluded from the knee joint and does not transfer weight to the ankle and foot.
8. The olecranon of the ulna is the point of the elbow. During extreme extension, this process swings into the olecranon fossa on the posterior surface of the humerus to prevent overextension of the forearm relative to the arm.
9. Body weight is passed to the metatarsal bones through the cuboid and the cuneiform bones.

Level 3 Critical Thinking

1. In osteoporosis, a decrease in the calcium content of the body leads to bones that are weak and brittle. Since the hip joint and leg bones must support the weight of the body, any weakening of these bones may result in insufficient strength to support the body mass, and as a result the bone will break under the great weight. The shoulder joint is not a load-bearing joint and is not subject to the same great stresses or strong muscle contractions as the hip joint. As a result, breaks in the bones of this joint occur less frequently.
2. The general appearance of the pelvis, the shape of the pelvic inlet, the depth of the iliac fossa, the characteristics of the ilium, the angle inferior to the pubic symphysis, the position of the acetabulum, the shape of the obturator foramen, and the characteristics of the ischium are all important in determining an individual's sex from a skeleton. Age can be determined by the size, degree of mineralization, and various markings on the bone. The individual's general appearance can be reconstructed by looking at the markings where muscles attach to the bones. This can indicate the size and shape of the muscles and thus the individual.
3. Many cranial characteristics would reveal the sex of the individual, but there are also characteristics in other skeletal elements, such as the robustness of the bones, the angles at which the pubic bones meet, the width of the pelvis, the angles of the femurs, and many more.
4. The condition known as flatfeet is due to a lower-than-normal longitudinal arch in the foot. A weakness in the ligaments and tendons that attach the calcaneus to the distal ends of the metatarsals would most likely contribute to this condition.