Colorized SEM of bone trabeculae.

Skeletal System

Gross Anatomy

CHAPTER

7

If the body had no skeleton, it may look somewhat like a poorly stuffed rag doll. Without a skeletal system, we would have no framework to help maintain shape and we wouldn't be able to move much either. Most muscles act on bone to produce movement, often pulling on the bones with considerable force. So without the skeleton, muscles wouldn't make the body move. Human bones are very strong and can resist tremendous bending and compression forces without breaking. Nonetheless, each year nearly 2 million Americans manage to break a bone.

The skeletal system includes the bones, cartilage, ligaments, and tendons. To study skeletal gross anatomy, however, dried, prepared bones are used. This allows the major features of individual bones to be seen clearly without being obstructed by associated soft tissues, such as muscles, tendons, ligaments, cartilage, nerves, and blood vessels. As a consequence, however, it's easy to ignore the important relationships among bones and soft tissues and the fact that living bones have soft tissue, such as the periosteum (see chapter 6).

This chapter includes a discussion of *general considerations* (198). It then proceeds to discuss the two catagories of the named bones: the *axial skeleton* (200), which includes the skull, hyoid bone, vertebral column, and thoracic (rib) cage, and the *appendicular skeleton* (225), consisting of the limbs and their girdles.

General Considerations

Objective

- *List the bones of the body.*
- *Define the general anatomic terms that describe the features of bone.*

The average adult skeleton has 206 bones (figure 7.1 and table 7.1). Although this is the traditional number, the actual number of bones varies from person to person and decreases with age as some bones become fused.

Many of the anatomic features of bones are listed in table 7.2. Most of these features are based on the relationship between the bones and associated soft tissues. If a bone possesses a **tubercle** (too′ber-kl; lump) or **process** (projection), such structures usually exist because a ligament or tendon was attached to that tubercle or process during life. If a bone has a

Table 7.1 Number of Named Bones Listed by Category

Bones		Number
Axial Skeleton		
Skull (cranium)		
Neurocranium (braincase)		
Paired	Parietal	2
	Temporal	2
Unpaired	Frontal	1
	Sphenoid	1
	Occipital	1
	Ethmoid	1
Viscerocranium (face)		
Paired	Maxilla	2
	Zygomatic	2
	Palatine	2
	Lacrimal	2
	Nasal	2
	Inferior nasal concha	2
Unpaired	Mandible	1
	Vomer	1
	Total Skull	22
Bones Associated with the Skull		
Auditory ossicles		
Malleus		2
Incus		2
Stapes		2
Hyoid		1
	Total Associated	7
Vertebral Column		
Cervical vertebrae		7
Thoracic vertebrae		12
Lumbar vertebrae		5
Sacrum		1
Coccyx		1
	Total Vertebral Column	26
Thoracic Cage (rib cage)		
Ribs		24
Sternum		1
	Total Thoracic Cage	25
	Total Axial Skeleton	80

Bones		Number
Appendicular Skeleton		
Pectoral Girdle		
Scapula		2
Clavicle		2
Upper Limb		
Humerus		2
Ulna		2
Radius		2
Carpals		16
Metacarpals		10
Phalanges		28
	Total Upper Limb and Girdle	64
Pelvic Girdle		
Coxa		2
Lower Limb		
Femur		2
Tibia		2
Fibula		2
Patella		2
Tarsals		14
Metatarsals		10
Phalanges		28
	Total Lower Limb and Girdle	62
	Total Appendicular Skeleton	126
	Total Axial Skeleton	80
	Total Appendicular Skeleton	126
	Total Bones	206

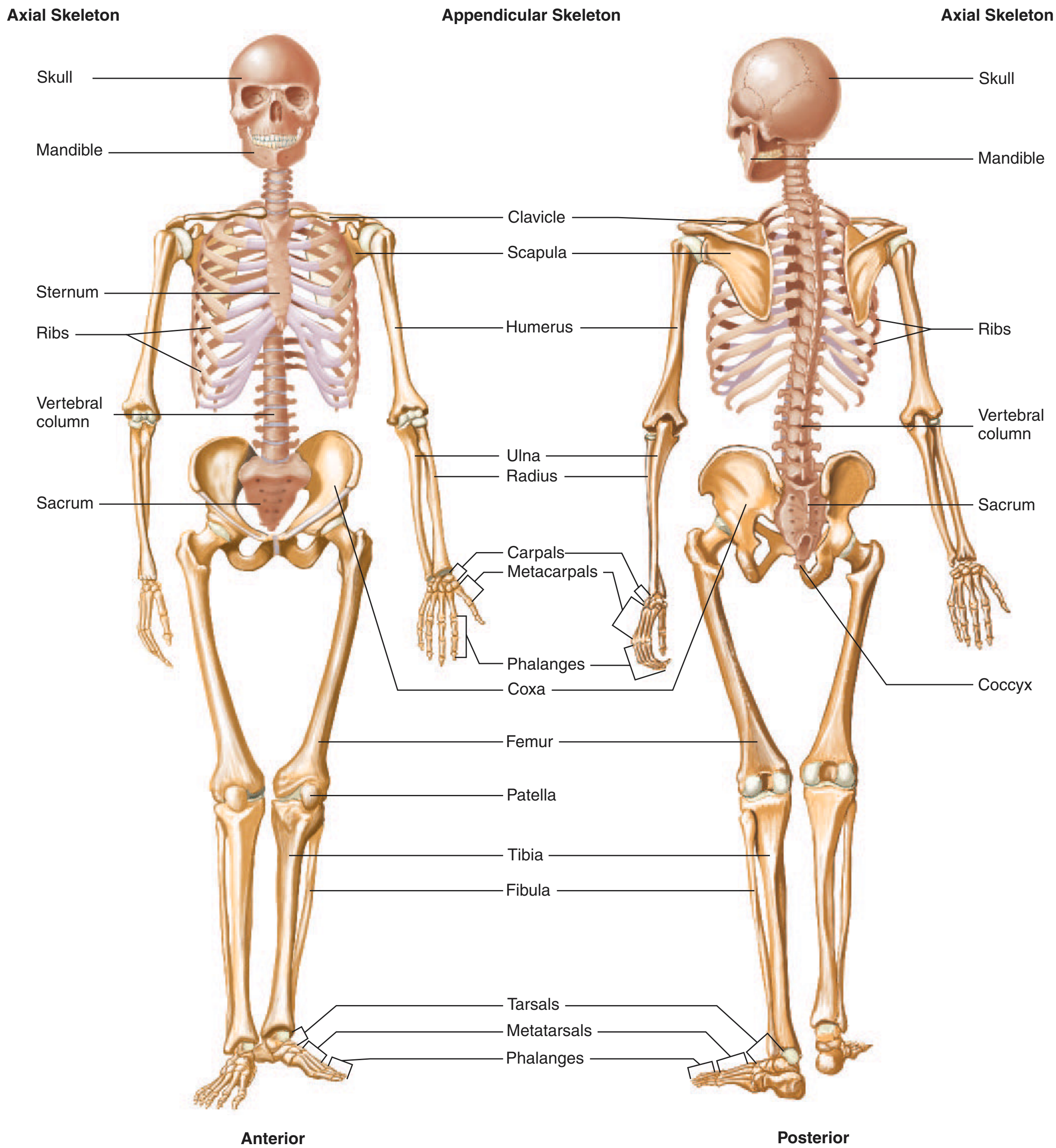


Figure 7.1 **The Complete Skeleton**

(The skeleton is not shown in the anatomical position.)

smooth, articular surface, that surface was part of a joint and was covered with articular cartilage. If the bone has a **foramen** (fō-rā′men; pl. foramina; fō-ram′i-nă; a hole) in it, that foramen was occupied by something such as a nerve or blood vessel. Some bones contain mucous membrane-lined air spaces called **sinuses.** These bones are composed of paper-thin, translucent compact bone only and have little or no cancellous center (see chapter 6).

Table 7.2 General Anatomic Terms for Various Features of Bones

Term	Description
Body	Main part
Head	Enlarged (often rounded) end
Neck	Constriction between head and body
Margin or border	Edge
Angle	Bend
Ramus	Branch off the body (beyond the angle)
Condyle	Smooth, rounded articular surface
Facet	Small, flattened articular surface
Ridges	
Line or linea	Low ridge
Crest or crista	Prominent ridge
Spine	Very high ridge
Projections	
Process	Prominent projection
Tubercle	Small, rounded bump
Tuberosity or tuber	Knob; larger than a tubercle
Trochanter	Tuberosities on the proximal femur
Epicondyle	Near or above a condyle
Lingula	Flat, tongue-shaped process
Hamulus	Hook-shaped process
Cornu	Horn-shaped process
Openings	
Foramen	Hole
Canal or meatus	Tunnel
Fissure	Cleft
Sinus or labyrinth	Cavity
Depressions	
Fossa	General term for a depression
Notch	Depression in the margin of a bone
Fovea	Little pit
Groove or sulcus	Deeper, narrow depression

1. *How many bones are there in an average adult skeleton?*
2. *How are lumps, projections, and openings in bones related to soft tissues?*

Axial Skeleton

The **axial skeleton** is divided into the skull, hyoid bone, vertebral column, and thoracic cage, or rib cage. The axial skeleton forms the upright axis of the body. It also protects the brain, the spinal cord, and the vital organs housed within the thorax.

Skull

Objectives

- *Describe the major features of the skull as seen from various views.*
- *List and describe the bones of the neurocranium and viscerocranium.*

The **skull,** or **cranium** (krā′nē-ŭm) protects the brain; supports the organs of vision, hearing, smell, and taste; and provides a foundation for the structures that take air, food, and water into the body. When the skull is disassembled, the mandible is easily separated from the rest of the skull, which remains intact. Special effort is needed to separate the other bones. For this reason, it's convenient to think of the skull, except for the mandible, as a single unit. The top of the skull is usually cut off to reveal its interior. The exterior and interior of the skull have ridges, lines, processes, and plates. These structures are important for the attachment of muscles or for articulations between the bones of the skull. Selected features of the intact skull are listed in table 7.3.

Superior View of the Skull

The skull appears quite simple when viewed from above. Only four bones are seen from this view: the frontal bone, two parietal bones, and a small part of the occipital bone. The paired **parietal bones** are joined at the midline by the **sagittal suture,** and the parietal bones are connected to the **frontal bone** by the **coronal suture** (figure 7.2).

Posterior View of the Skull

The parietal and occipital bones are the major structures seen from the posterior view (figure 7.3). The parietal bones are joined to the **occipital bone** by the **lambdoid** (lam′doyd; the shape resembles the Greek letter lambda) **suture.** Occasionally, extra small bones called **sutural** (soo′choor-ăl) **bones** form along the lambdoid suture.

P R E D I C T 1

Explain the basis for the names *sagittal* and *coronal sutures.*

Inca Bone

Sutural bones are usually small and bilateral and in many cases are apparently genetically determined. A large midline bone, called an Inca bone, may form at the junction of the lambdoid and sagittal sutures. The bone was common in the skulls of Incas and is still present in their Andean descendants.

An **external occipital protuberance** is present on the posterior surface of the occipital bone (see figure 7.3). It can be felt through the scalp at the base of the head and varies considerably in size from person to person. The external occipital protuberance is the site of attachment of the **ligamentum nuchae** (noo′kē; nape of neck), an elastic ligament that extends down the neck and helps keep the head erect by pulling on the occipital region of the skull. **Nuchal lines** are a set of small ridges that extend laterally from the protuberance and are the points of attachment for several neck muscles.

Table 7.3 Processes and Other Features of the Skull

Feature	Bone on Which Feature Is Found	Description
External Features		
Alveolar process	Mandible, maxilla	Ridges on the mandible and maxilla containing the teeth
Angle	Mandible	The posterior, inferior corner of the mandible
Coronoid process	Mandible	Attachment point for the temporalis muscle
Genu	Mandible	Chin (resembles a bent knee)
Horizontal plate	Palatine	Posterior third of the hard palate
Mandibular condyle	Mandible	Region where the mandible articulates with the skull
Mandibular fossa	Temporal	Depression where the mandible articulates with the skull
Mastoid process	Temporal	Enlargement posterior to the ear; attachment site for several muscles that move the head
Nuchal lines	Occipital	Attachment points for several posterior neck muscles
Occipital condyle	Occipital	Point of articulation between the skull and the vertebral column
Palatine process	Maxilla	Anterior two-thirds of the hard palate
Pterygoid hamulus	Sphenoid	Hooked process on the inferior end of the medial pterygoid plate, around which the tendon of one palatine muscle passes; an important dental landmark
Pterygoid plates (medial and lateral)	Sphenoid	Bony plates on the inferior aspect of the sphenoid bone; the lateral pterygoid plate is the site of attachment for two muscles of mastication (chewing)
Ramus	Mandible	Portion of the mandible superior to the angle
Styloid process	Temporal	Attachment site for three muscles (to the tongue, pharynx, and hyoid bone) and some ligaments
Temporal lines	Parietal	Where the temporalis muscle, which closes the jaw, attaches
Internal Features		
Crista galli	Ethmoid	Process in the anterior part of the cranial vault to which one of the connective tissue coverings of the brain (dura mater) connects
Petrous portion	Temporal	Thick, interior part of temporal bone containing the middle and inner ears and the auditory ossicles
Sella turcica	Sphenoid	Bony structure resembling a saddle in which the pituitary gland is located

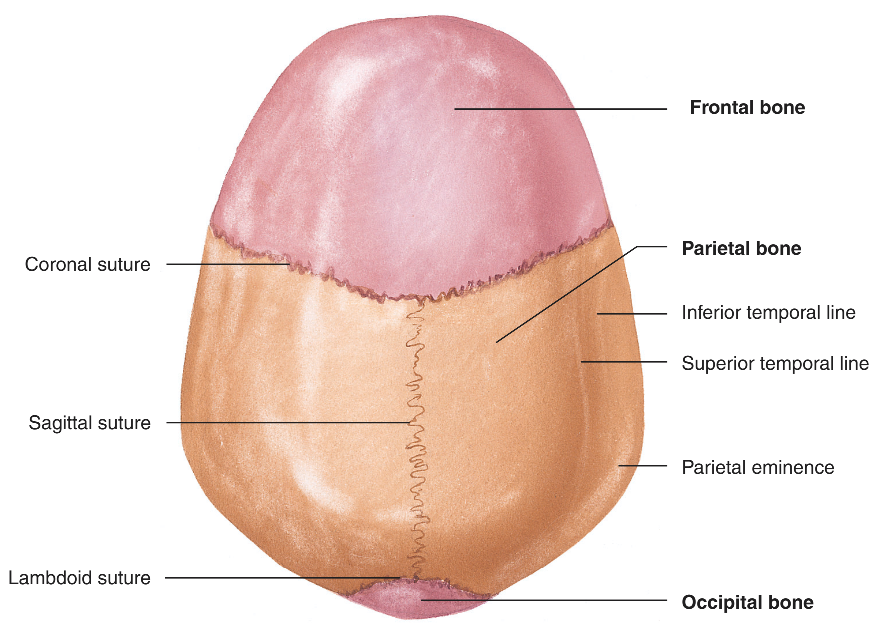


Figure 7.2 Skull as Seen from the Superior View

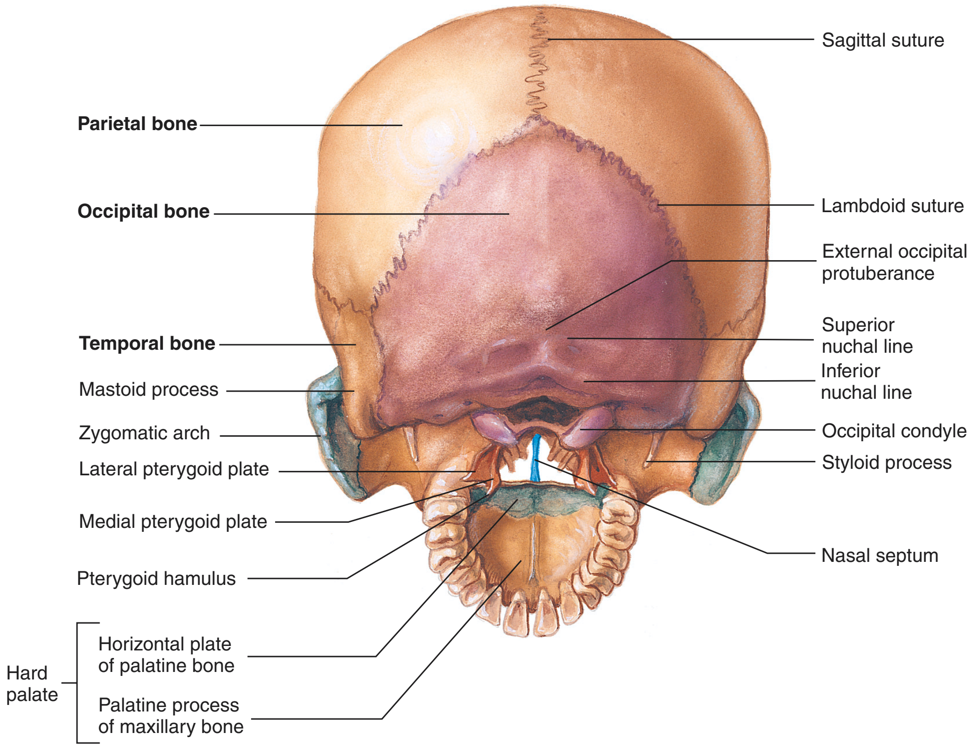


Figure 7.3 Skull as Seen from the Posterior View

Nuchal Lines

The ligamentum nuchae and neck muscles in humans are not as strong as comparable structures in other animals; therefore, the human bony prominence and lines of the posterior skull are not as well developed as they are in those animals. The location of the human foramen magnum allows the skull to balance above the vertebral column and allows for an upright posture. Thus human skulls require less ligamental and muscular effort to balance the head on the spinal column than do the skulls of other animals, including other primates, such as chimpanzees, whose skulls are not balanced over the vertebral column. The presence of small nuchal lines in hominids (i.e., animals with an upright stance like humans) reflects this decreased musculature and is one way used by paleontologists to establish probable upright posture in hominids.

Lateral View of the Skull

The parietal bone and the squamous part of the temporal bone form a large part of the side of the head (figure 7.4). The term *temporal* means related to time, and the temporal bone is so named because the hair of the temples is often the first to turn white, indicating the passage of time. The **squamous suture** joins these bones. A prominent feature of the temporal bone is a large hole, the **external auditory meatus** (mē-ā′tŭs; passageway or tunnel), which transmits sound waves toward the eardrum. The external ear, or auricle, surrounds the meatus. Just posterior and inferior to the external auditory meatus is a large inferior projection, the **mastoid** (mas′toyd; resembling a breast) **process.** The process can be seen and felt as a prominent lump just posterior to the ear. The process is not solid bone but is filled with cavities called the **mastoid air cells,** which are connected to the middle ear. Important neck muscles involved in rotation of the head attach to the mastoid process. The superior and inferior **temporal lines,** which are attachment points of the temporalis muscle, one of the major muscles of mastication, arch across the lateral surface of the parietal bone.

Temporal Lines

The temporal lines are important to anthropologists because a heavy temporal line suggests a strong temporalis muscle supporting a heavy jaw. In a male gorilla, the temporalis muscles are so large that the temporal lines meet in the midline of the skull to form a heavy sagittal crest. The temporal lines are much smaller in humans.

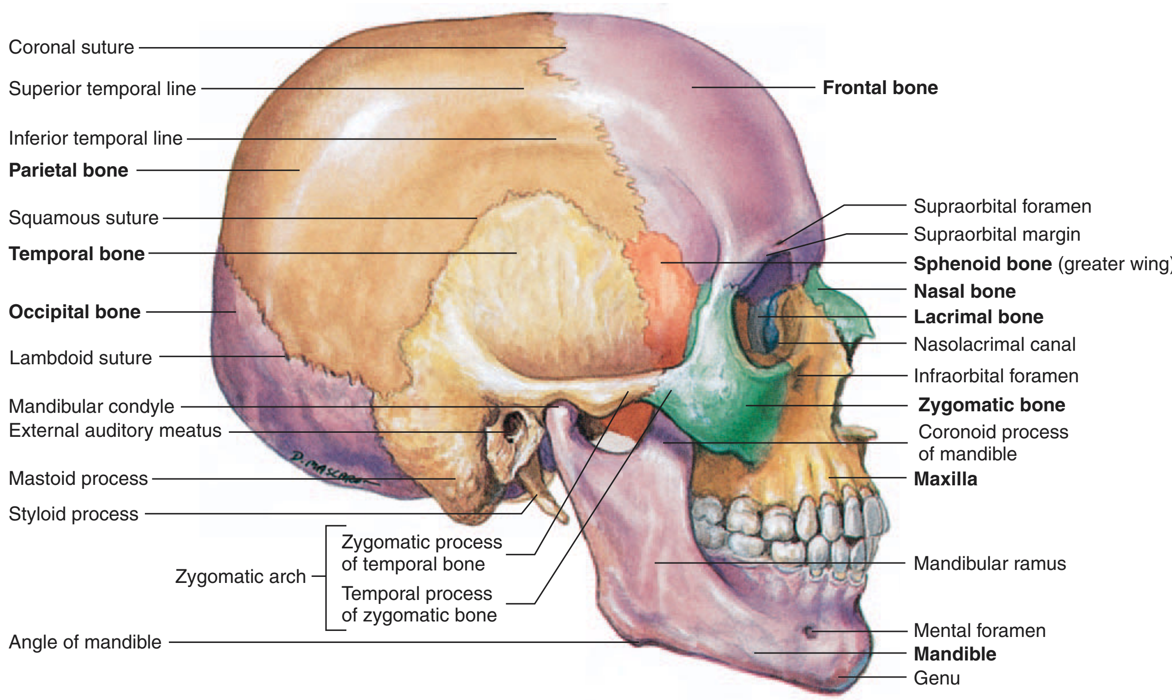


Figure 7.4 Lateral View of the Skull as Seen from the Right Side

The lateral surface of the **greater wing** of the **sphenoid** (sfē′noyd; wedge-shaped) **bone** is immediately anterior to the temporal bone (see figure 7.4). Although appearing to be two bones, one on each side of the skull, the sphenoid bone is actually a single bone that extends completely across the skull. Anterior to the sphenoid bone is the **zygomatic** (zī′gō-mat′ik; a bar or yoke) **bone,** or cheekbone, which can be easily seen and felt on the face (figure 7.5).

The **zygomatic arch,** which consists of joined processes from the temporal and zygomatic bones, forms a bridge across the side of the skull (see figure 7.4). The zygomatic arch is easily felt on the side of the face, and the muscles on either side of the arch can be felt as the jaws are opened and closed (see figure 7.5).

The **maxilla** (mak-sil′ă; upper jaw) is anterior and inferior to the zygomatic bone to which it is joined. The **mandible** (lower jaw) is inferior to the maxilla and articulates posteriorly with the temporal bone (see figure 7.4). The mandible consists of two main portions: the **body,** which extends anteroposteriorly, and the **ramus** (branch), which extends superiorly from the body toward the temporal bone. The superior end of the ramus has a mandibular **condyle,** which articulates with the mandibular fossa of the temporal bone, and the **coronoid** (kōr′ŏ-noyd; shaped like a crow's beak) **process** to which the powerful temporalis muscle, one of the chewing muscles, attaches. The alveolar process of the maxilla contains the superior set of teeth, and the alveolar process of the mandible contains the inferior teeth.

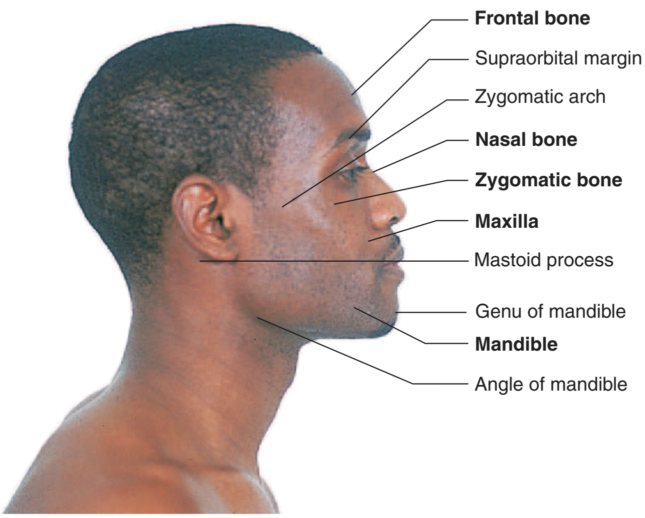


Figure 7.5 Lateral View of Bony Landmarks on the Face

Frontal View of the Skull

The major structures seen from the frontal view are the frontal bone (forehead), the zygomatic bones (cheekbones), the maxillae, and the mandible (figure 7.6). The teeth, which are very prominent

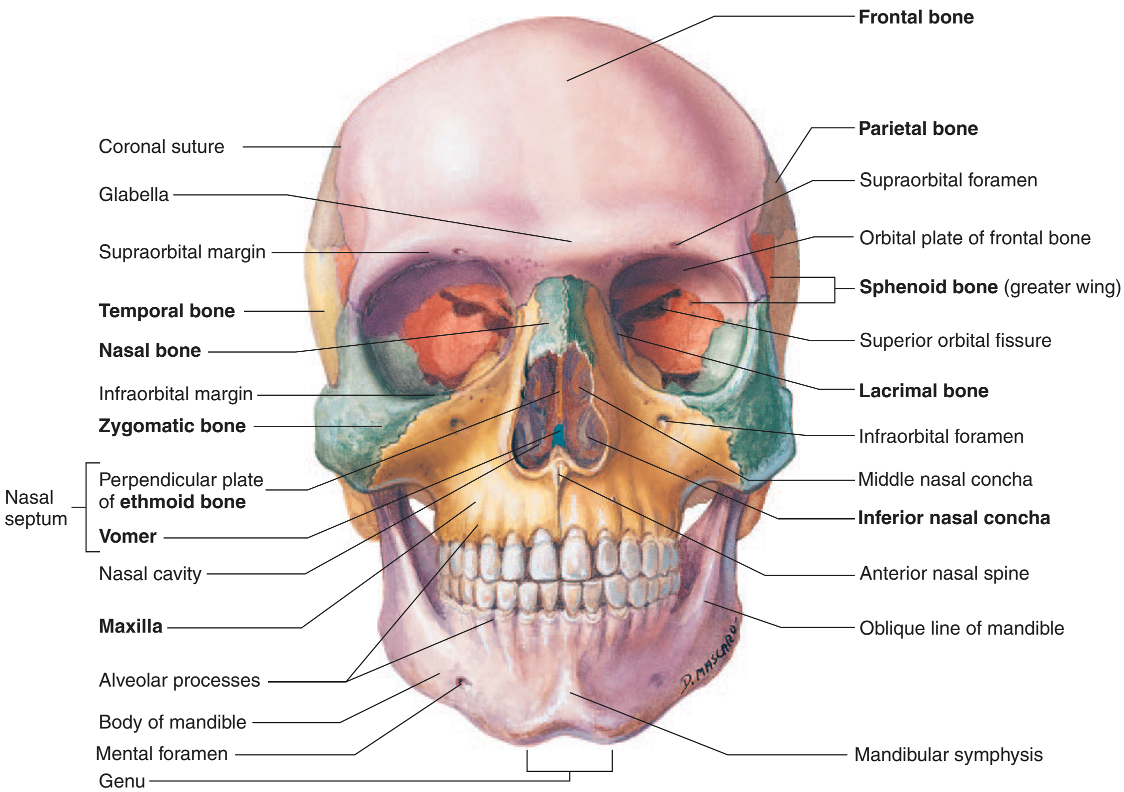


Figure 7.6 Skull as Seen from the Frontal View

in this view, are discussed in chapter 24. Many bones of the face can be easily felt through the skin of the face (figure 7.7).

From this view the most prominent openings into the skull are the orbits and the nasal cavity. The **orbits** are cone-shaped fossae with their apices directed posteriorly (see figures 7.6 and 7.8). They are called orbits because of the rotation of the eyes within the fossae. The bones of the orbits provide both protection for the eyes and attachment points for the muscles that move the eyes. The major portion of each eyeball is within the orbit, and the portion of the eye visible from the outside is relatively small. Each orbit contains blood vessels, nerves, and fat, as well as the eyeball and the muscles that move it. The bones forming the orbit are listed in table 7.4.

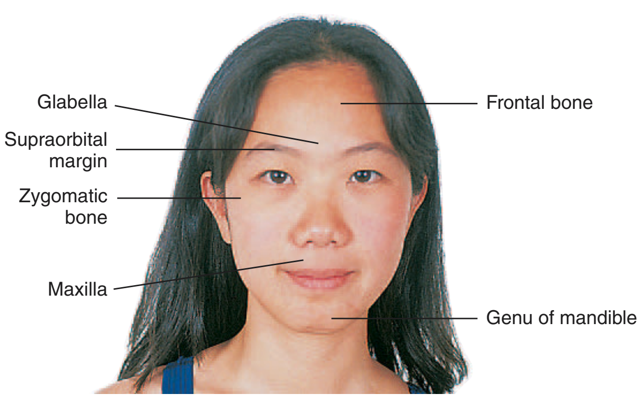


Figure 7.7 Anterior View of Bony Landmarks on the Face

Orbit Weak Point

The superolateral corner of the orbit, where the zygomatic and frontal bones join, is a weak point in the skull that is easily fractured by a blow to that region of the head. The bone tends to collapse into the orbit, resulting in an injury that is difficult to repair.

The orbit has several openings through which structures communicate between it and other cavities. The nasolacrimal duct passes from the orbit into the nasal cavity through the **nasolacrimal canal** and carries tears from the eyes to the nasal cavity. The optic nerve for the sense of vision passes from the eye through the **optic foramen** at the posterior apex of the orbit and enters the cranial cavity. Superior and inferior fissures in the posterior region of the orbit provide openings through which nerves and blood vessels communicate with structures in the orbit or pass to the face.

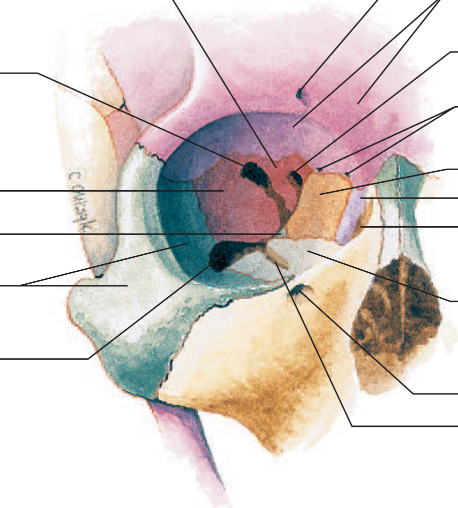


Figure 7.8 Bones of the Right Orbit

Table 7.4 Bones Forming the Orbit (see figures 7.6 and 7.8)

Bone	Part of Orbit
Frontal	Roof
Sphenoid	Roof and lateral wall
Zygomatic	Lateral wall
Maxilla	Floor
Lacrimal	Medial wall
Ethmoid	Medial wall
Palatine	Medial wall

Table 7.5 Bones Forming the Nasal Cavity (see figures 7.6 and 7.9)

Bone	Part of Nasal Cavity
Frontal	Roof
Nasal	Roof
Sphenoid	Roof
Ethmoid	Roof, septum, and lateral wall
Inferior nasal concha	Lateral wall
Lacrimal	Lateral wall
Maxilla	Floor
Palatine	Floor and lateral wall
Vomer	Septum

The **nasal cavity** (table 7.5 and figure 7.9; see figure 7.6) has a pear-shaped opening anteriorly and is divided into right and left halves by a **nasal septum** (sep′tŭm; wall). The bony part of the nasal septum consists primarily of the vomer and the perpendicular plate of the ethmoid bone. Hyaline cartilage forms the anterior part of the nasal septum.

Deviated Nasal Septum

The nasal septum usually is located in the midsagittal plane until a person is 7 years old. Thereafter it tends to deviate, or bulge slightly to one side or the other. The septum can also deviate abnormally at birth or, more commonly, as a result of injury. Deviations can be severe enough to block one side of the nasal passage, and interfere with normal breathing. Repair of severe deviations requires surgery.

The external part of the nose, formed mostly of hyaline cartilage, is almost entirely absent in the dried skeleton and is represented mainly by the nasal bones and the frontal processes of the maxillary bones, which form the bridge of the nose.

PREDICT 2

A direct blow to the nose may result in a "broken nose." List at least three bones that may be broken.

The lateral wall of the nasal cavity has three bony shelves, the **nasal conchae** (kon′kē; resembling a conch shell), which are directed inferiorly (see figure 7.9). The inferior nasal concha is a separate bone, and the middle and superior nasal conchae are projections from the ethmoid bone. The conchae function to

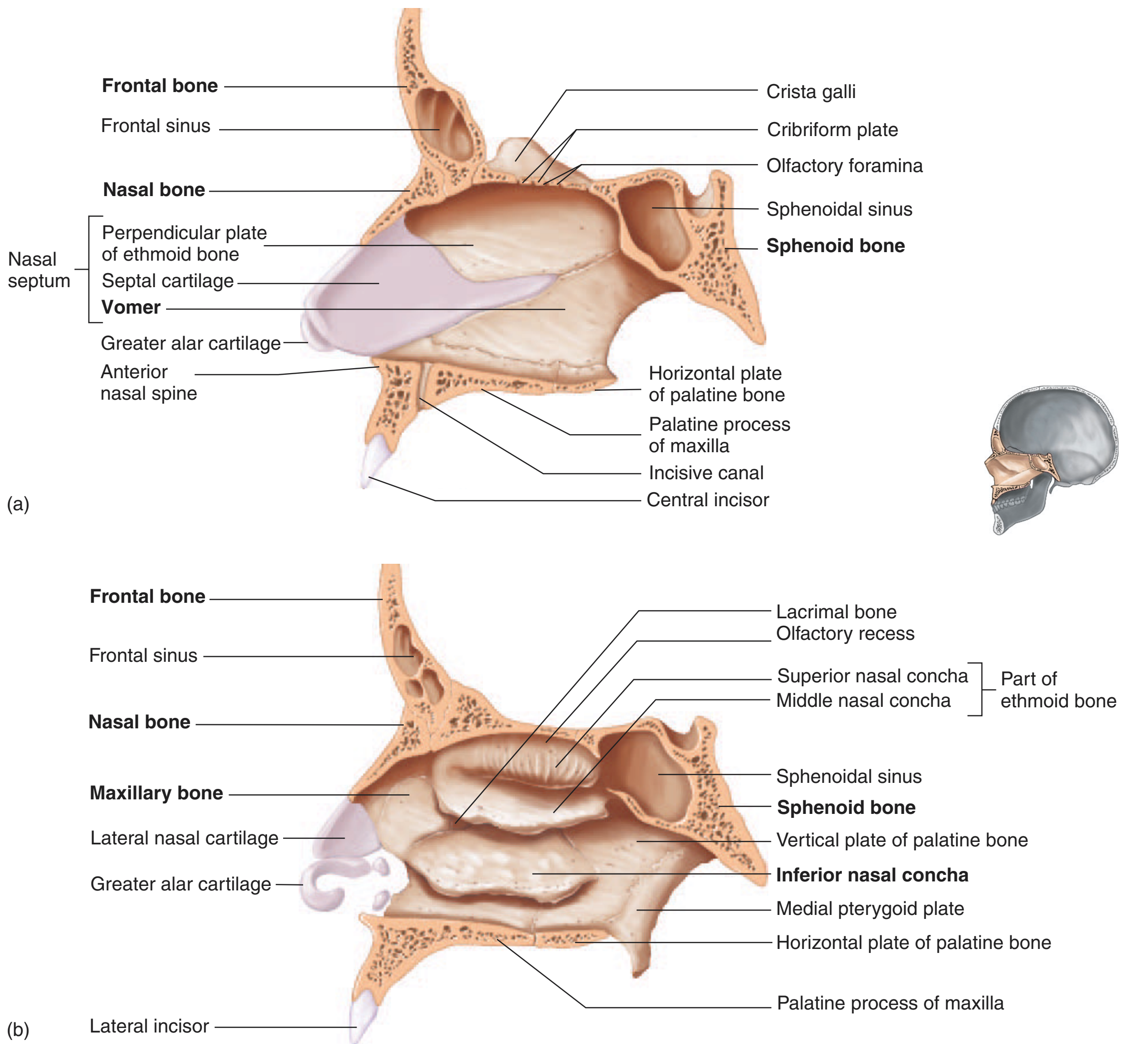


Figure 7.9 Bones of the Nasal Cavity

(*a*) Nasal septum as seen from the left nasal cavity. (*b*) Right lateral nasal wall as seen from inside the nasal cavity (nasal septum removed).

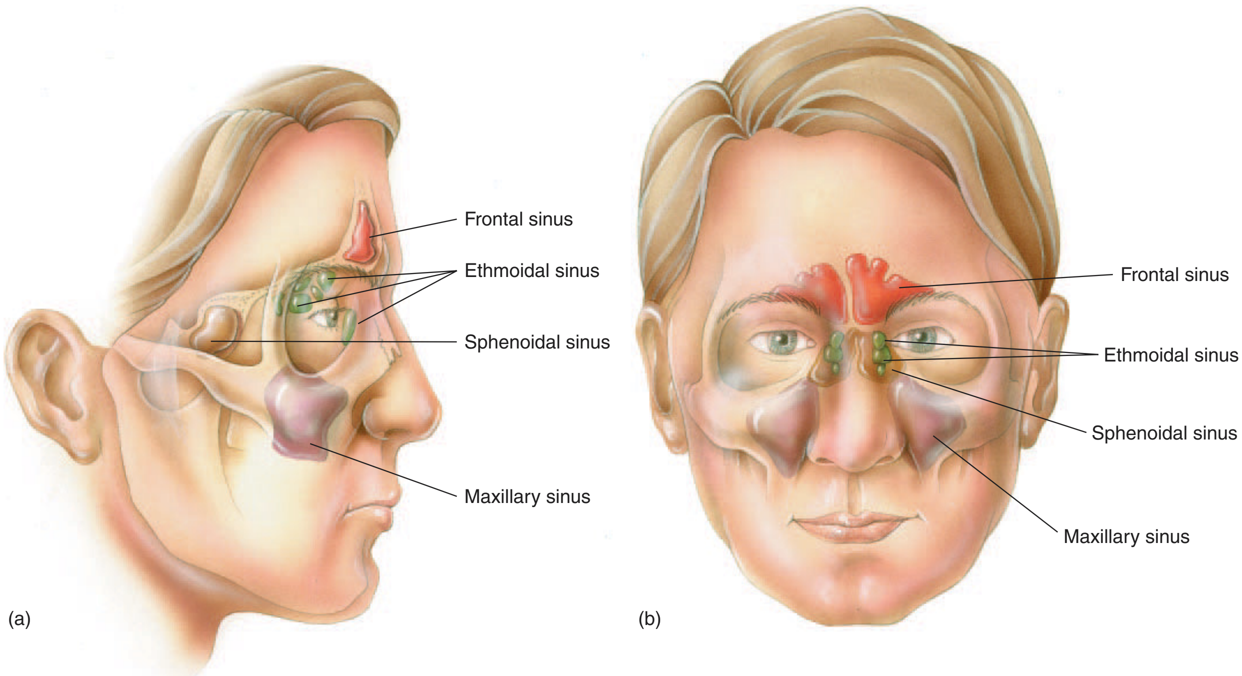
increase the surface area in the nasal cavity, thereby facilitating moistening, removal of particles, and warming of the air inhaled through the nose.

Several of the bones associated with the nasal cavity have large cavities within them called the **paranasal sinuses,** which open into the nasal cavity (figure 7.10). The sinuses decrease the weight of the skull and act as resonating chambers during voice production. Compare the normal voice to the voice of a person who has a cold and whose sinuses are "stopped up." The sinuses are named for the bones in which they are located and include the frontal, maxillary, ethmoidal, and sphenoidal sinuses.

Interior of the Cranial Cavity

The **cranial cavity** is the cavity in the skull occupied by the brain. The cranial cavity can be exposed by cutting away the **calvaria** (kal-vā′rē-ă), the upper dome-like portion of the skull. With the calvaria removed, the floor of the cranial cavity can be seen (figure 7.11). That floor can be divided roughly into anterior, middle, and posterior fossae, which are formed as the developing neurocranium conforms to the shape of the brain.

A prominent ridge, the **crista galli** (kris′tă găl′ē; rooster's comb), is located in the center of the anterior fossa. The crista galli



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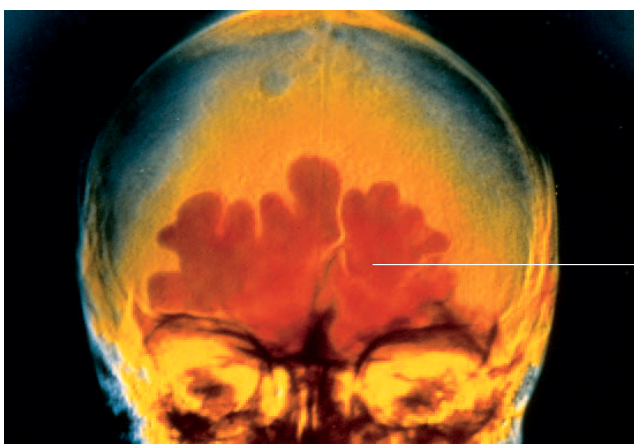


Figure 7.10 Paranasal Sinuses

(*a*) Viewed from the side. (*b*) Viewed from in front. (*c*) False-color x ray of the frontal sinus.

is a point of attachment for one of the **meninges** (mĕ-nin′jēz), a thick connective tissue membrane that supports and protects the brain (see chapter 13). On either side of the crista galli is an olfactory fossa. An olfactory bulb rests in each fossa and receives the olfactory nerves for the sense of smell. The **cribriform** (krib′ri-fōrm; sievelike) **plate** of the ethmoid bone forms the floor of each olfactory fossa. The olfactory nerves extend from the cranial cavity into the roof of the nasal cavity through sievelike perforations in the cribriform plate called **olfactory foramina** (see figure 7.9*a* and chapter 15).

Fracture of the Cribriform Plate

The cribriform plate may be fractured in an automobile accident involving a car without air bags, if the driver's nose strikes the steering wheel. Cerebrospinal (ser′ĕ-brō-spī-năl, sĕ-rē′brō-spī-năl) fluid from the cranial cavity may leak through the fracture into the nose. This leakage is a dangerous sign and requires immediate medical attention because risk of infection is very high.

The body of the sphenoid bone forms a central prominence located within the floor of the cranial cavity. This prominence is

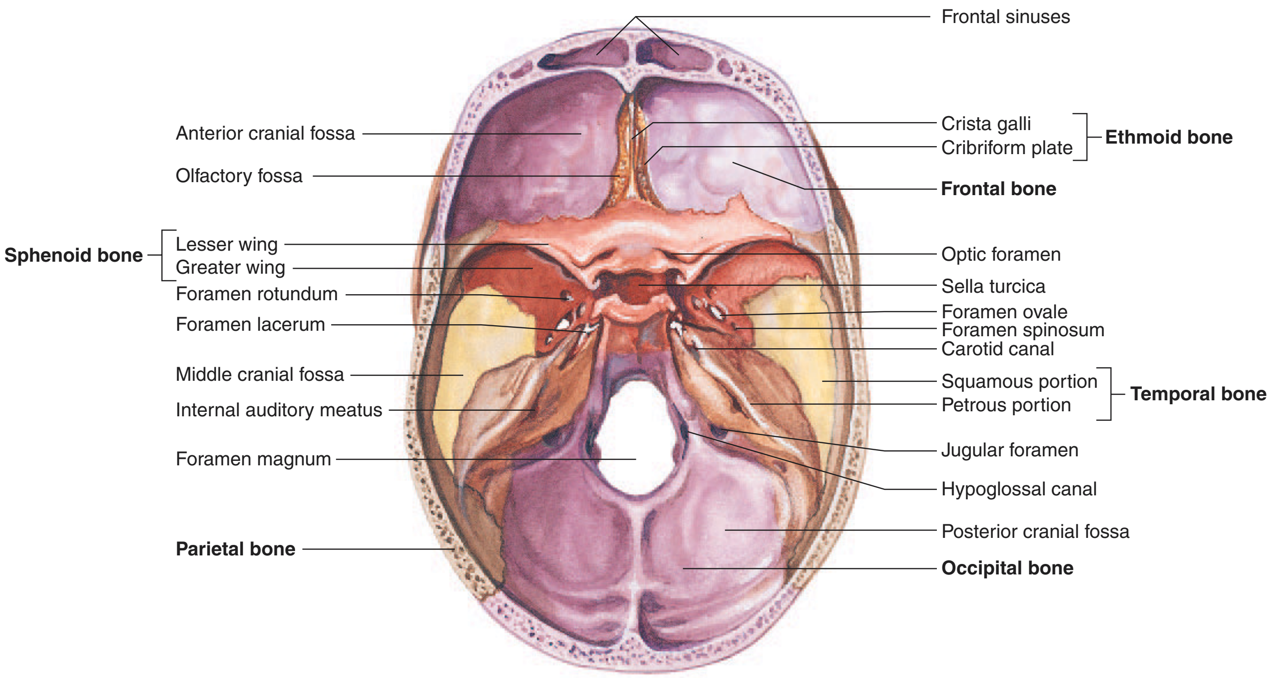


Figure 7.11 Floor of the Cranial Cavity

The roof of the skull has been removed, and the floor is viewed from above.

modified into a structure resembling a saddle, the **sella turcica** (sel′ă tŭr′si-kă; Turkish saddle), which is occupied by the pituitary gland. The petrous (rocky) part of the temporal bone is on each side of and slightly posterior to the sella turcica. This thick bony ridge is hollow and contains the middle and inner ears.

The prominent **foramen magnum,** through which the spinal cord and brain are connected, is located in the posterior fossa. The other foramina of the skull and the structures passing through them are listed in table 7.6.

Inferior View of the Skull

Seen from below with the mandible removed, the base of the skull is complex, with a number of foramina and specialized surfaces (figure 7.12). The foramen magnum passes through the occipital bone just slightly posterior to the center of the skull base. **Occipital condyles,** the smooth points of articulation between the skull and the vertebral column, are located on the lateral and anterior margins of the foramen magnum.

The major entry and exit points for blood vessels that supply the brain can be seen from this view. Blood reaches the brain through the internal carotid arteries, which pass through the **carotid** (ka-rot′id; put to sleep) **canals,** and the vertebral arteries, which pass through the foramen magnum. Immediately after the internal carotid artery enters the carotid canal, it turns medially almost 90 degrees, continues through the carotid canal, again turns almost 90 degrees, and enters the cranial cavity through the superior part of the **foramen lacerum** (lă-ser′um). A thin plate of bone separates the carotid canal from the middle ear, therefore, making it possible for a person to hear his or her own heartbeat, for example, when frightened or after running. Most blood leaves the brain through the internal jugular veins, which exit through the **jugular** (jŭg′ū-lar; throat) **foramina** located lateral to the occipital condyles.

Two long, pointed **styloid** (stī′loyd; stylus- or pen-shaped) **processes** project from the floor of the temporal bone (see figures 7.4 and 7.12). Three muscles involved in movement of the tongue, hyoid bone, and pharynx attach to each process. The **mandibular fossa,** where the mandible articulates with the rest of the skull, is anterior to the mastoid process at the base of the zygomatic arch.

The posterior opening of the nasal cavity is bounded on each side by the vertical bony plates of the sphenoid bone: the **medial pterygoid** (ter′i-goyd; wing-shaped) **plate** and the **lateral pterygoid plate.** The medial and lateral pterygoid muscles, which help move the mandible, attach to the lateral plate (see chapter 10). The **vomer** forms the posterior portion of the nasal septum and can be seen between the medial pterygoid plates in the center of the nasal cavity.

The **hard palate,** or **bony palate,** forms the floor of the nasal cavity. Sutures join four bones to form the hard palate; the palatine processes of the two maxillary bones form the anterior two-thirds of the palate, and the horizontal plates of the two palatine bones form the posterior one-third of the palate. The tissues of the soft palate extend posteriorly from the hard palate. The hard and soft palates separate the nasal cavity from the mouth and enable humans to eat and breathe at the same time.

Table 7.6 Skull Foramina, Fissures, and Canals (see figures 7.11 and 7.12)

Opening	Bone Containing the Opening	Structures Passing Through Openings
Carotid canal	Temporal	Carotid artery and carotid sympathetic nerve plexus
Ethmoid foramina, anterior and posterior	Between frontal and ethmoid	Anterior and posterior ethmoid nerves
External auditory meatus	Temporal	Sound waves enroute to the eardrum
Foramen lacerum	Between temporal, occipital, and sphenoid	The foramen is filled with cartilage during life; the carotid canal and pterygoid canal cross its superior part but do not actually pass through it
Foramen magnum	Occipital	Spinal cord, accessory nerves, and vertebral arteries
Foramen ovale	Sphenoid	Mandibular division of trigeminal nerve
Foramen rotundum	Sphenoid	Maxillary division of trigeminal nerve
Foramen spinosum	Sphenoid	Middle meningeal artery
Hypoglossal canal	Occipital	Hypoglossal nerve
Incisive foramen (canal)	Between maxillae	Incisive nerve
Inferior orbital fissure	Between sphenoid and maxilla	Infraorbital nerve and blood vessels and zygomatic nerve
Infraorbital foramen	Maxilla	Infraorbital nerve
Internal auditory meatus	Temporal	Facial nerve and vestibulocochlear nerve
Jugular foramen	Between temporal and occipital	Internal jugular vein, glossopharyngeal nerve, vagus nerve, and accessory nerve
Mandibular foramen	Mandible	Inferior alveolar nerve to the mandibular teeth
Mental foramen	Mandible	Mental nerve
Nasolacrimal canal	Between lacrimal and maxilla	Nasolacrimal (tear) duct
Olfactory foramina	Ethmoid	Olfactory nerves
Optic foramen	Sphenoid	Optic nerve and ophthalmic artery
Palatine foramina, anterior and posterior	Palatine	Palatine nerves
Pterygoid canal	Sphenoid	Sympathetic and parasympathetic nerves to the face
Sphenopalatine foramen	Between palatine and sphenoid	Nasopalatine nerve and sphenopalatine blood vessels
Stylomastoid foramen	Temporal	Facial nerve
Superior orbital fissures	Sphenoid	Oculomotor nerve, trochlear nerve, ophthalmic division of trigeminal nerve, abducens nerve, and ophthalmic veins
Supraorbital foramen or notch	Frontal	Supraorbital nerve and vessels
Zygomaticofacial foramen	Zygomatic	Zygomaticofacial nerve
Zygomaticotemporal foramen	Zygomatic	Zygomaticotemporal nerve

Cleft Lip or Palate

During development, the facial bones sometimes fail to fuse with one another. A **cleft lip** results if the maxillae don't form normally, and a **cleft palate** occurs when the palatine processes of the maxillae don't fuse with one another. A cleft palate produces an opening between the nasal and oral cavities, making it difficult to eat or drink or to speak distinctly. An artificial palate may be inserted into a newborn's mouth until the palate can be repaired. A cleft lip occurs approximately once in every 1000 births and is more common in males than in females. A cleft palate occurs approximately once in every 2500 births and is more common in females than in males. A cleft lip and cleft palate may also occur in the same person.

3. *List the parts of the axial skeleton and its functions.*
4. *List the seven bones that form the orbit of the eye.*
5. *Describe the bones and cartilage found in the nasal septum.*
6. *What is a sinus? What are the functions of sinuses? Give the location of the paranasal sinuses.*
7. *Name the bones that form the hard palate. What is the function of the hard palate?*
8. *Through what foramen does the brainstem connect to the spinal cord? Name the foramina that contain nerves for the senses of vision (optic nerve), smell (olfactory nerves), and hearing (vestibulocochlear nerve)?*
9. *Name the foramina through which the major blood vessels enter and exit the skull.*

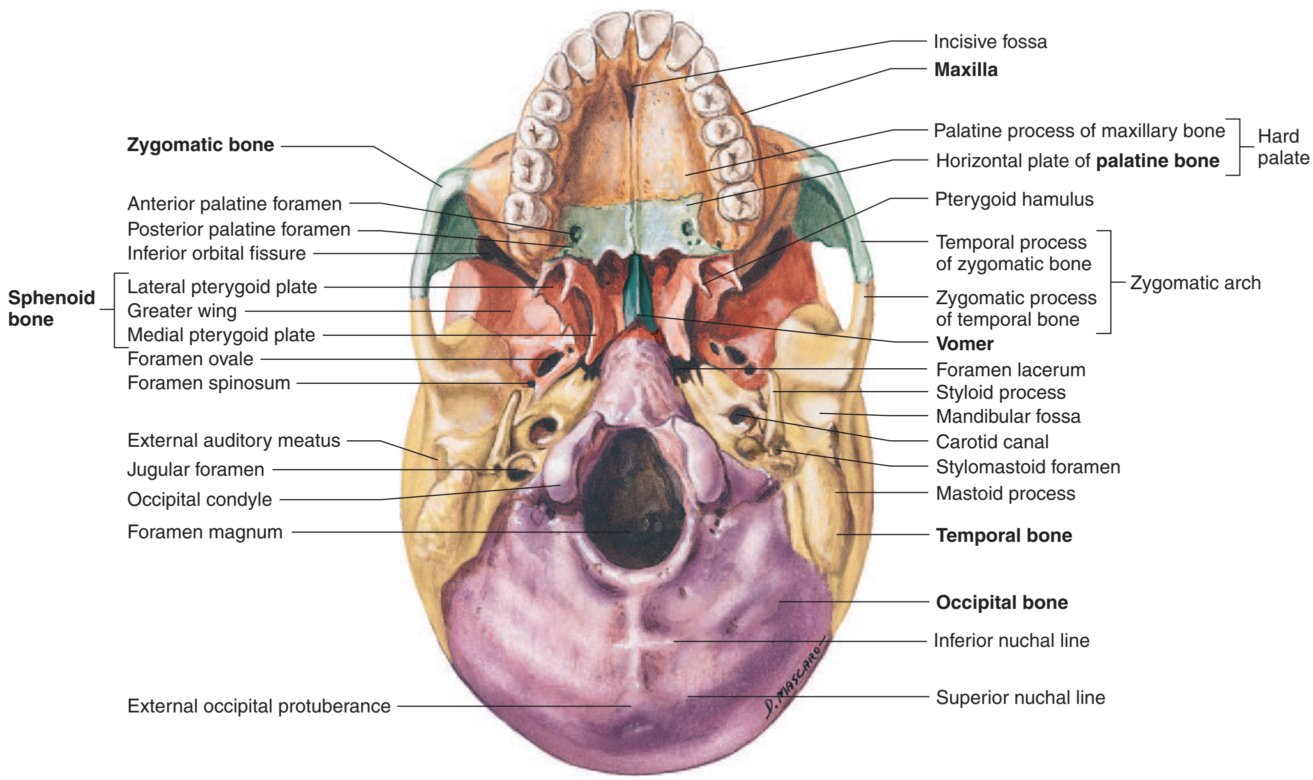


Figure 7.12 Inferior View of the Skull

10. ***List the places where these muscles attach to the skull: neck muscles, throat muscles, muscles of mastication, muscles of facial expression, and muscles that move the eyeballs.***
11. ***Name the bones of the neurocranium and viscerocranium. What functions are accomplished by each group?***

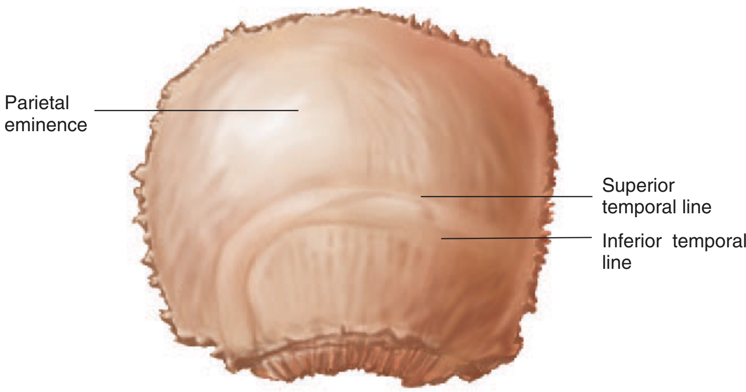
Bones of the Skull

The skull, or cranium, is composed of 22 separate bones (see table 7.1 and figure 7.13). In addition, the skull contains six **auditory ossicles,** which function in hearing (see chapter 15). Each temporal bone holds one set of auditory ossicles, which consists of the malleus, incus, and stapes. These bones cannot be observed unless the temporal bones are cut open.

The 22 bones of the skull are divided into two portions: the neurocranium and the viscerocranium. The **neurocranium,** or **braincase,** consists of eight bones that immediately surround and protect the brain. They include the paired parietal and temporal bones and the unpaired frontal, occipital, sphenoid, and ethmoid bones.

The 14 bones of the **viscerocranium,** or **facial bones,** form the structure of the face in the anterior skull. They are the maxilla (two), zygomatic (two), palatine (two), lacrimal (two), nasal (two), inferior nasal concha (two), mandible (one), and vomer (one) bones. The frontal and ethmoid bones, which are part of the neurocranium, also contribute to the face. The mandible is often listed as a facial bone, even though it is not part of the intact skull.

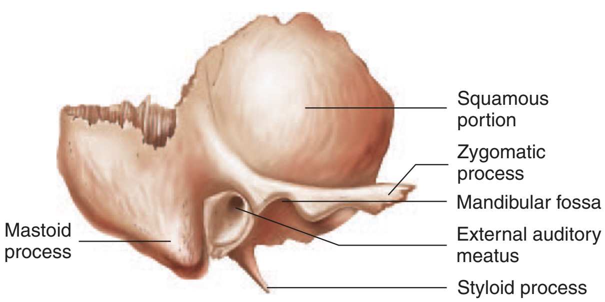
The facial bones protect the major sensory organs located in the face: the eyes, nose, and tongue. The bones of the face also provide attachment points for muscles involved in **mastication** (mas-ti-kā′shŭn; chewing), facial expression, and eye movement. The jaws (mandible and maxillae) possess **alveolar** (al-vē′ō-lăr) **processes** with sockets for the attachment of the teeth. The bones of the face and their associated soft tissues determine the unique facial features of each individual.



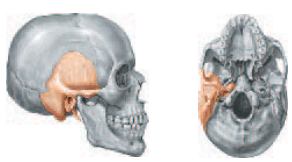
(a) Right **parietal bone** (viewed from the lateral side)

Landmarks seen on this figure:
- **Superior and inferior temporal lines:** attachment point for temporalis muscle.
- **Parietal eminence:** the widest part of the head is from one parietal eminence to the other.

Special feature: Forms lateral wall of skull.



Right **temporal bone** (viewed from the lateral side)

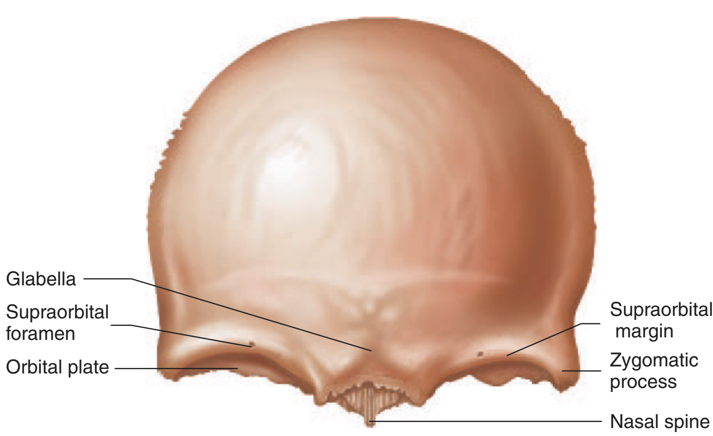


(b)

Landmarks seen on this figure:
- **External auditory meatus:** external canal of the ear; carries sound to the ear.
- **Mandibular fossa:** articulation point between the mandible and skull.
- **Mastoid process:** attachment point for muscles moving the head and for a hyoid muscle.
- **Squamous portion:** flat, lateral portion of the temporal bone.
- **Styloid process:** attachment for muscles of the tongue, throat, and hyoid bone.
- **Zygomatic process:** helps form the bony bridge from the cheek to just anterior to the ear; attachment for a muscle moving the mandible.

Landmarks seen in other figures:
- **Carotid canal:** canal through which the internal carotid artery enters the cranial cavity (figures 7.11 and 7.12).
  - **Internal auditory meatus:** opening through which the facial (cranial nerve VII) and vestibulocochlear (cranial nerve VIII) nerves enter the petrous portion of the temporal bone (figure 7.11).
- **Jugular foramen:** foramen through which the internal jugular vein exits the cranial cavity (figures 7.11 and 7.12).
- **Middle cranial fossa:** depression in the floor of the cranial cavity formed by the temporal lobes of the brain (figure 7.11).
- **Petrous portion:** thick, "rocky" portion of the temporal bone (figure 7.11).
- **Stylomastoid foramen:** foramen through which the facial nerve (cranial nerve VII) exits the skull (figure 7.12).

Special features: Contains the middle and inner ear, and the mastoid air cells; place where the mandible articulates with the rest of the skull.



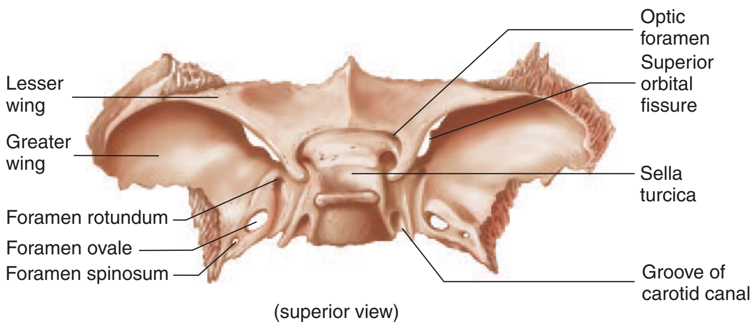
(c) **Frontal bone** (viewed from in front and slightly above)

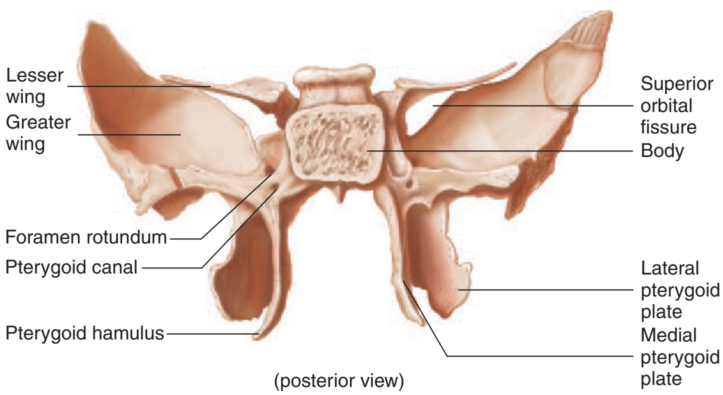
Landmarks seen on this figure:
- **Glabella:** area between the supraorbital margins.
- **Nasal spine:** superior part of the nasal bridge.
- **Orbital plate:** roof of the orbit.
- **Supraorbital foramen:** opening through which nerves and vessels exit the skull to the skin of the forehead.
- **Supraorbital margin:** ridge forming the anterior superior border of the orbit.
- **Zygomatic process:** connects to the zygomatic bone; helps form the lateral margin of the orbit.

Special features: Forms the forehead and roof of the orbit; contains the frontal sinus.

Figure 7.13 Skull Bones

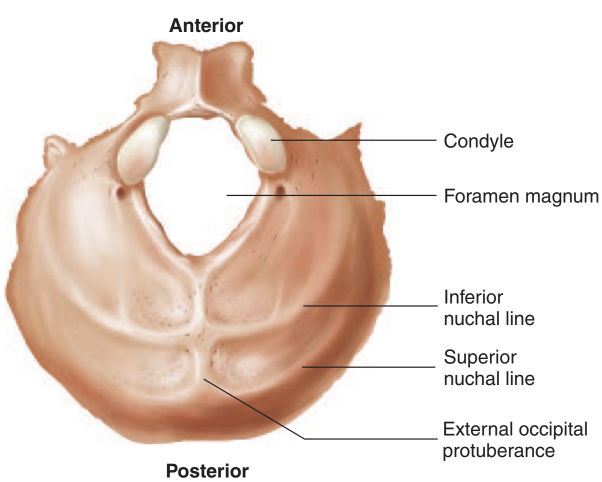
(*a*) Right **parietal bone** viewed from the lateral side. (*b*) Right **temporal bone** viewed from the lateral side. (*c*) **Frontal bone** viewed from in front and slightly above.





(d) **Sphenoid bone**

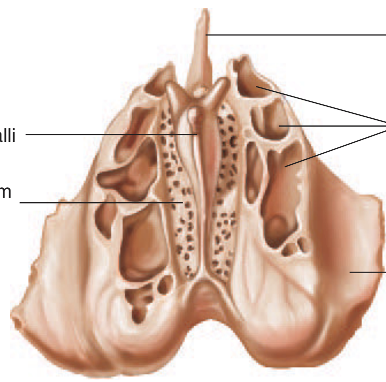
Landmarks seen on this figure:
Body: thickest part of the bone.
Foramen ovale: opening through which a branch of the trigeminal nerve (cranial nerve V) exits the cranial cavity.
Foramen rotundum: opening through which a branch of the trigeminal nerve (cranial nerve V) exits the cranial cavity.
Foramen spinosum: opening through which a major artery to the meninges (membranes around the brain) enters the cranial cavity.
Greater wing: forms the floor of the middle cranial fossa; several foramina pass through this wing.
Lateral pterygoid plate: attachment point for muscles of mastication (chewing).
Lesser wing: superior border of the superior orbital fissure.
Medial pterygoid plate: posterolateral walls of the nasal cavity.
Optic foramen: opening through which the optic nerve (cranial nerve II) passes from the orbit to the cranial cavity.
Pterygoid canal: opening through which nerves and vessels exit the cranial cavity.
Pterygoid hamulus: process around which the tendon from a muscle to the soft palate passes.
Sella turcica: fossa containing the pituitary gland.
Superior orbital fissure: opening through which nerves and vessels enter the orbit from the cranial cavity.
Special feature: Contains the sphenoidal sinus.



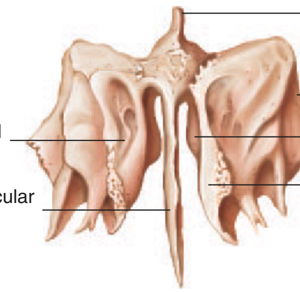
(e) **Occipital bone**
(viewed from below)

Landmarks seen on this figure:
Condyle: articulation point between the skull and first vertebra.
External occipital protuberance: attachment point for a strong ligament (nuchal ligament) in back of the neck.
Foramen magnum: opening around the point where the brain and spinal cord connect.
Inferior nuchal line: attachment point for neck muscles.
Superior nuchal line: attachment point for neck muscles.
Landmarks seen in other figures:
Hypoglossal canal: opening through which the hypoglossal nerve (cranial nerve XII) passes (figure 7.11).
Posterior cranial fossa: depression in the posterior of the cranial cavity formed by the cerebellum (figure 7.11).
Special features: Forms the base of the skull.

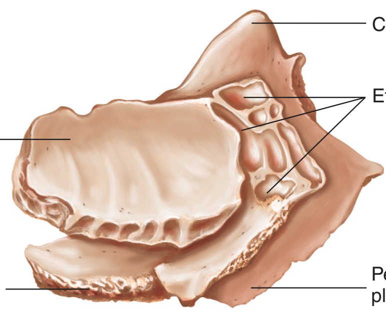
Figure 7.13 *(continued)*
(*d*) **Sphenoid bone,** superior and posterior views. (*e*) **Occipital bone** viewed from below.



(superior view)



(anterior view)



(lateral view)

(f) **Ethmoid bone**

Landmarks seen on this figure:

Cribriform plate: contains numerous openings through which branches of the olfactory nerve (cranial nerve I) enter the cranial cavity from the nasal cavity.

Crista galli: attachment for meninges (membrane around brain).

Ethmoidal sinus: spaces in the bone; help lighten the skull.

Middle nasal concha: ridge extending into the nasal cavity; increases surface area, helps warm and moisten air in the cavity.

Orbital plate: forms the medial wall of the orbit.

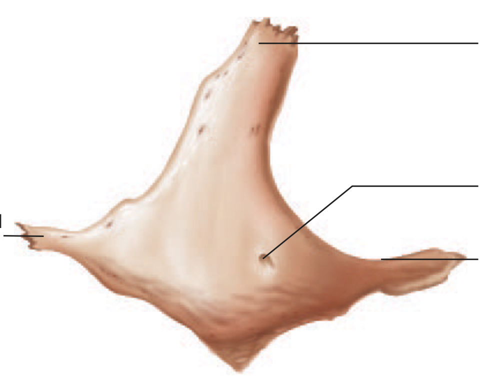
Perpendicular plate: forms part of the nasal septum.

Superior nasal concha: ridge extending into the nasal cavity; increases surface area, helps warm and moisten air in the cavity.

Landmarks seen in other figures:

Ethmoid foramina: openings through which nerves and vessels pass from the orbit to the nasal cavity (figure 7.8).

Special features: Forms part of the nasal septum and part of the lateral walls and roof of the nasal cavity; contains the ethmoidal sinus, or ethmoidal air cells.



(g) Right **zygomatic bone**
(lateral view)

Landmarks seen on this figure:

Frontal process: connection to the frontal bone; helps form the lateral margin of the orbit.

Infraorbital margin: ridge forming the inferior border of the orbit.

Temporal process: helps form the bony bridge from the cheek to just anterior to the ear.

Zygomaticofacial foramen: opening through which a nerve and vessels exit the orbit to the face.

Special features: Forms the prominence of the cheek; forms the anterolateral wall of the orbit.

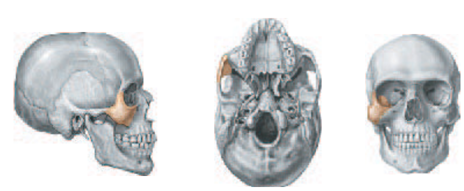
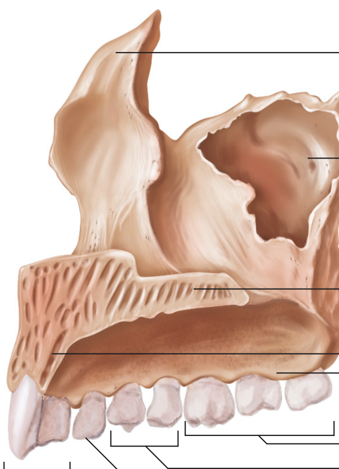
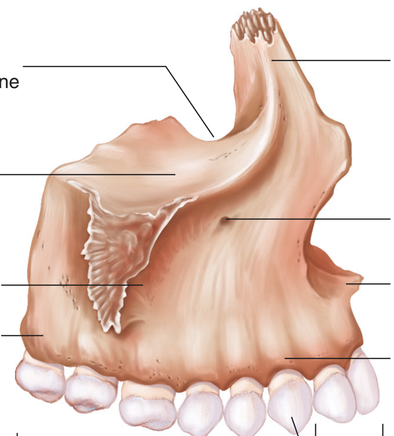


Figure 7.13 *(continued)*

(*f*) **Ethmoid bone,** superior, lateral, and anterior views. (*g*) Right **zygomatic bone,** lateral view.



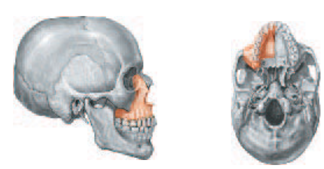
(h) (medial view)

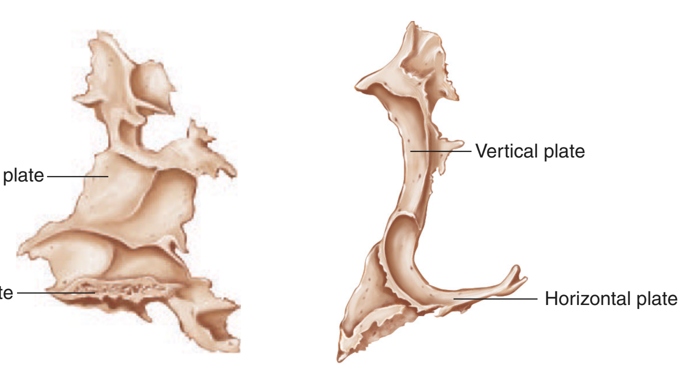


(lateral view)

Right maxilla

Landmarks seen on this figure:
- **Alveolar process:** ridge containing the teeth.
- **Anterior nasal spine:** forms part of the nasal septum.
- **Frontal process:** forms the sides of the nasal bridge.
- **Incisive canal:** opening through which a nerve exits the nasal cavity to the roof of the oral cavity.
- **Infraorbital foramen:** opening through which a nerve and vessels exit the orbit to the face.
- **Maxillary sinus:** cavity in the bone, which helps lighten the skull.
- **Orbital surface:** forms the floor of the orbit.
- **Palatine process:** forms the anterior two-thirds of the hard palate.
- **Tuberosity:** lump posterior to the last maxillary molar tooth.
- **Zygomatic process:** connection to the zygomatic bone; helps form the interior margin of the orbit.
- **Special feature:** Contains the maxillary sinus and maxillary teeth.





(medial view) (anterior view)

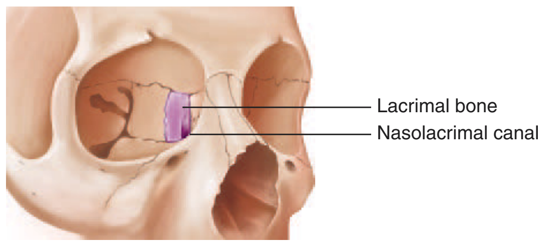
(i) Right **palatine bone**

Landmarks seen on this figure:
- **Horizontal plate:** forms the posterior one-third of the hard palate.
- **Vertical plate:** forms part of the lateral nasal wall.

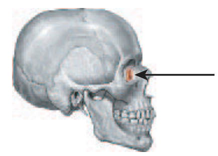
Special features: Helps form part of the hard palate and a small part of the wall of the orbit.

Figure 7.13 *(continued)*

(*h*) **Right maxilla,** medial and lateral views. (*i*) Right **palatine bone,** medial and anterior views.

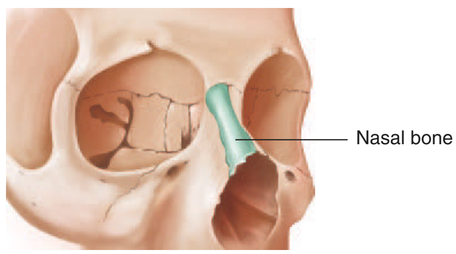


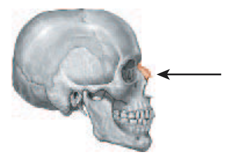
Special feature: Forms a small portion of the orbital wall.



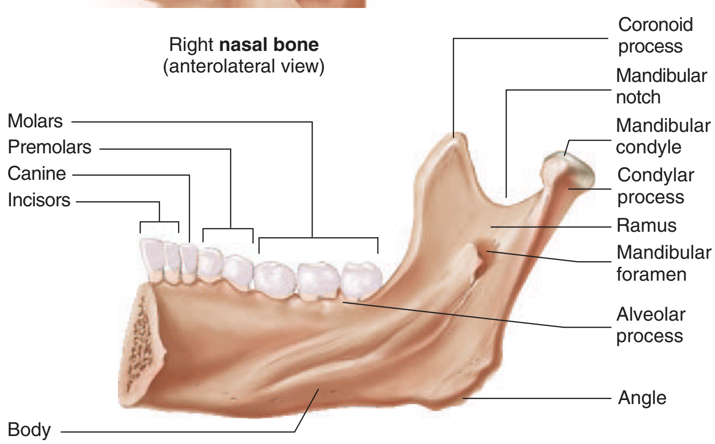
(j) Right **lacrimal bone** (anterolateral view)

Special feature: Forms the bridge of the nose.





(k) Right **nasal bone** (anterolateral view)

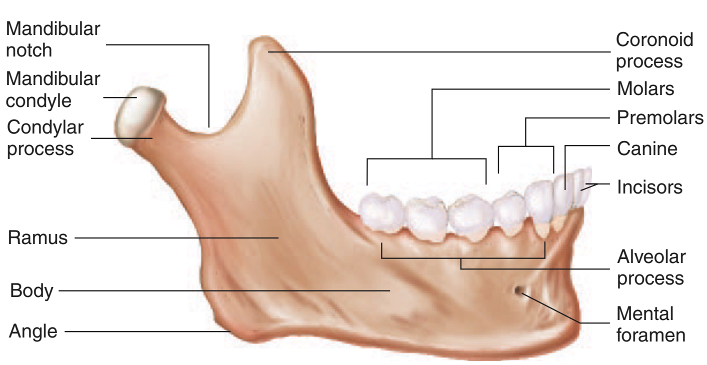


(medial view)

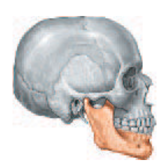
Landmarks seen on this figure:

Alveolar process: ridge containing the teeth.
Angle: corner between the body and ramus.
Body: major, horizontal portion of the bone.
Condylar process: extension containing the mandibular condyle.
Coronoid process: attachment for a muscle of mastication.
Mandibular condyle: point of articulation between the mandible and the rest of the skull.
Mandibular foramen: opening through which nerves and vessels to the mandibular teeth enter the bone.
Mandibular notch: depression between the condylar process and the coronoid process.
Mental foramen: opening through which a nerve and vessels exit the mandible to the skin of the chin.
Ramus: major, nearly vertical portion of the bone.

Special features: The only bone in this figure that is freely movable relative to the rest of the skull bones; holds the lower teeth.



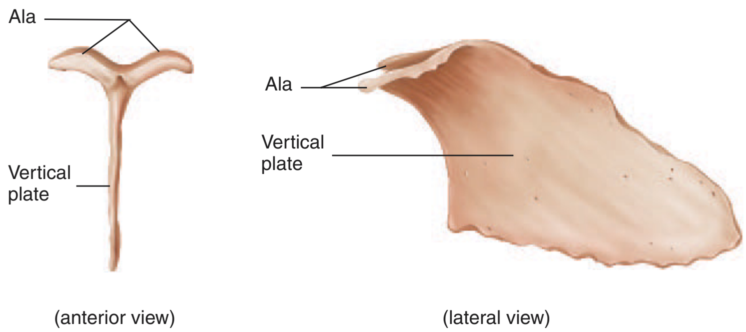
(lateral view)



(l) Right half of the **mandible**

Figure 7.13 *(continued)*

(*j*) Right **lacrimal bone,** lateral view. (*k*) Right **nasal bone,** lateral view. (*l*) Right half of the **mandible**, medial and lateral views.



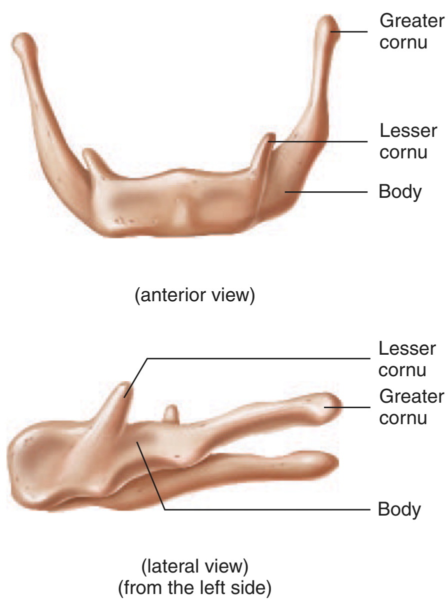
Landmarks seen on this figure:
- **Ala:** attachment point between the vomer and sphenoid.
- **Vertical plate:** forms part of the nasal septum.

Special feature: Forms most of the posterior nasal septum.

(m) **Vomer**

Figure 7.13 *(continued)*

(*m*) **Vomer**, anterior and lateral views.



Landmarks seen on this figure:
- **Body:** major portion of the bone.
- **Greater cornu:** attachment point for muscles and ligaments.
- **Lesser cornu:** attachment point for muscles and ligaments.
- **Special features:** One of the few bones of the body that does not articulate with another bone; it is attached to the skull by muscles and ligaments.

Hyoid bone

Figure 7.14 Hyoid Bone

Anterior and lateral views, from the left side.

Hyoid

The **hyoid bone** (figure 7.14), which is unpaired, is often listed as part of the viscerocranium because it has a common developmental origin with the bones of the face. It is not, however, part of the adult skull (see table 7.1). The hyoid bone has no direct bony attachment to the skull but, rather, muscles and ligaments attach it to the skull and the hyoid "floats" in the superior aspect of the neck just below the mandible. The hyoid bone provides an attachment for some tongue muscles, and it's also an attachment point for important neck muscles that elevate the larynx during speech or swallowing.

12. Where is the hyoid bone located and what does it do?

Vertebral Column

Objectives

- ***Describe the development of the four major curvatures of the vertebral column.***
- ***List the features that characterize the vertebrae of the cervical, thoracic, lumbar, and sacral regions.***

The **vertebral column** usually consists of 26 bones, which can be divided into five regions (figure 7.15). Seven **cervical vertebrae** (ver′tĕ-brē), 12 **thoracic vertebrae,** five **lumbar vertebrae,** one **sacral bone,** and one **coccygeal** (kok-sij′ē-ăl) bone make up the vertebral column. The developing embryo has about 34 vertebrae, but the five sacral vertebrae fuse to form one bone, and the four or five coccygeal bones usually fuse to form one bone.

The five regions of the adult vertebral column have four major curvatures (see figure 7.15). Two of the curves appear during embryonic development and reflect the C-shaped curve of the embryo and fetus within the uterus. When the infant raises its head in the first few months after birth, a secondary curve, which is convex anteriorly, develops in the neck. Later, when the infant learns to sit and then walk, the lumbar portion of the column also becomes convex anteriorly. Thus in the adult vertebral column, the cervical region is convex anteriorly, the thoracic region is concave anteriorly, the lumbar region is convex anteriorly, and the sacral and coccygeal regions are, together, concave anteriorly.

Abnormal Spinal Curvatures

Lordosis (lōr-dō′sis; hollow back) is an exaggeration of the convex curve of the lumbar region. **Kyphosis** (kī-fō′sis; hump back) is an exaggeration of the concave curve of the thoracic region. **Scoliosis** (skō′lē-ō′sis) is an abnormal bending of the spine to the side, which is often accompanied by secondary abnormal curvatures, such as kyphosis (figure 7.16).

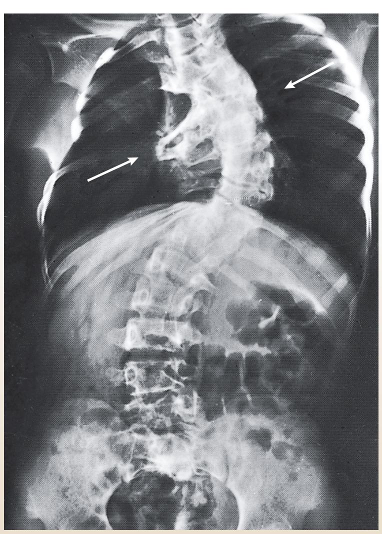


Figure 7.16 **Scoliosis**

Scoliosis is an abnormal lateral curvature of the spine. The abnormality is indicated by the *arrows*.

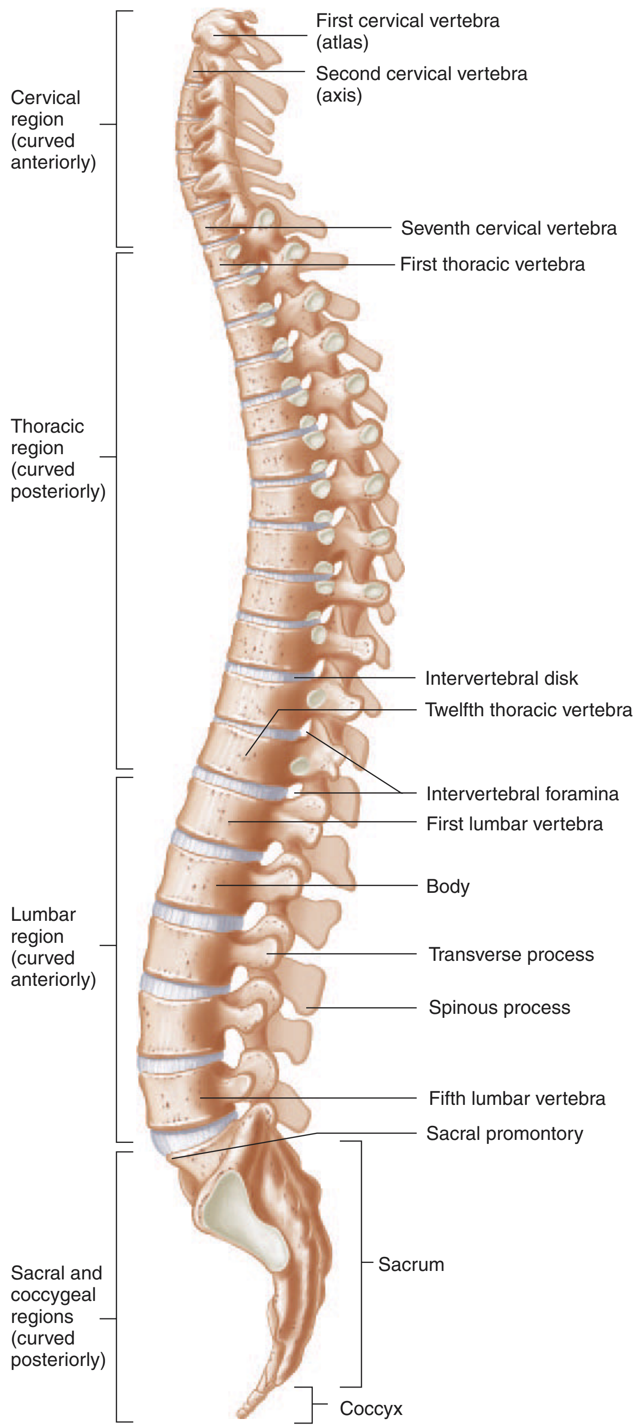


Figure 7.15 **Vertebral Column**

Complete column viewed from the left side.

Intervertebral Disks

During life, **intervertebral disks** of fibrocartilage, which are located between the bodies of adjacent vertebrae (see figures 7.15 and 7.17), provide additional support and prevent the vertebral bodies from rubbing against each other. The intervertebral disks consist of an external **annulus fibrosus** (an′ū-lŭs fī-brō′sŭs; fibrous ring) and an internal gelatinous **nucleus pulposus** (pŭl-pō′sŭs; pulp). The disk becomes more compressed with increasing age so that the distance between vertebrae and therefore the overall height of the individual decreases. The annulus fibrosus also becomes weaker with age and more susceptible to herniation.

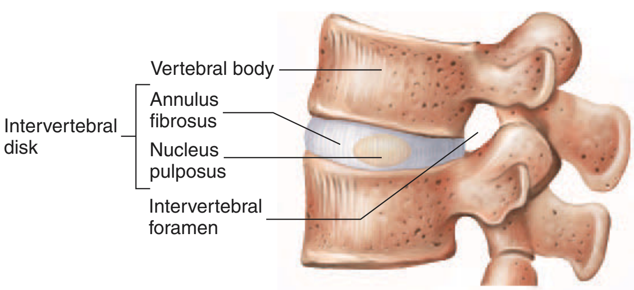


Figure 7.17 Intervertebral Disk

Herniated or Ruptured Intervertebral Disk

A **herniated,** or **ruptured, disk** results from the breakage or ballooning of the annulus fibrosus with a partial or complete release of the nucleus pulposus (figure 7.18). The herniated part of the disk may push against the spinal cord or spinal nerves, compromising their normal function and producing pain. Herniation of the inferior lumbar intervertebral disks is most common, but herniation of the inferior cervical disks is almost as common.

Herniated or ruptured disks can be repaired in one of several ways. One procedure uses prolonged bed rest and is based on the tendency for the herniated part of the disk to recede and the annulus fibrosus to repair itself. In many cases, however, surgery is required, and the damaged disk is removed. To enhance the stability of the vertebral column, a piece of hipbone is sometimes inserted into the space previously occupied by the disk, and the adjacent vertebrae become fused by bone across the gap.

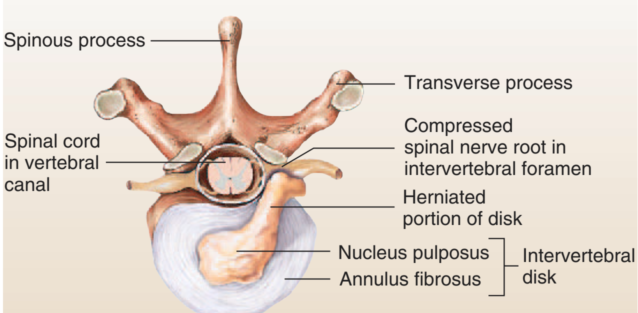


Figure 7.18 Herniated Disk

Part of the annulus fibrosus has been removed to reveal the nucleus pulposus in the center of the disk.

General Plan of the Vertebrae

The vertebral column performs five major functions: (1) it supports the weight of the head and trunk, (2) it protects the spinal cord, (3) it allows spinal nerves to exit the spinal cord, (4) it provides a site for muscle attachment, and (5) it permits movement of the head and trunk. The general structure of a vertebra is outlined in table 7.7. Each vertebra consists of a body, an arch, and various processes (figure 7.19). The weight-bearing portion of the vertebra is a bony disk called the **body.**

The **vertebral arch** projects posteriorly from the body. The arch is divided into left and right halves, and each half has two parts: the **pedicle** (ped′i-kl; foot), which is attached to the body, and the **lamina** (lam′i-na; thin plate), which joins the lamina from the opposite half of the arch. The vertebral arch and the posterior part of the body surround a large opening called the **vertebral foramen.** The vertebral foramina of adjacent vertebrae combine to form the **vertebral canal,** which contains the spinal cord. The vertebral arches and bodies protect the spinal cord.

Laminectomy and Spina Bifida

In some surgical procedures, such as removal of an intervertebral disk, the vertebrae are in the way and prevent access to the intervertebral disk. This problem can be solved by removing a lamina, a procedure called a **laminectomy.**

Sometimes vertebral laminae may partly or completely fail to fuse (or even fail to form) during fetal development, resulting in a condition called **spina bifida** (spī′nă bif′i-dă; split spine). This defect is most common in the lumbar region. If the defect is severe and involves the spinal cord (figure 7.20), it may interfere with normal nerve function below the point of the defect.

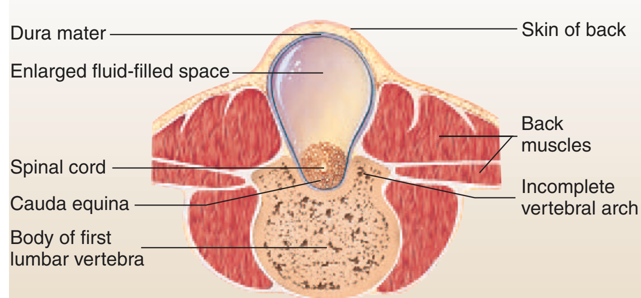


Figure 7.20 Spina Bifida

This developmental malformation occurs when two vertebral laminae fail to fuse.

Table 7.7 General Structure of a Vertebra (see figure 7.19 *b* and *c*)

Feature	Description
Body	Disk-shaped; usually the largest part with flat surfaces directed superiorly and inferiorly; forms the anterior wall of the vertebral foramen; intervertebral disks are located between the bodies
Vertebral foramen	Hole in each vertebra through which the spinal cord passes; adjacent vertebral foramina form the vertebral canal
Vertebral arch	Forms the lateral and posterior walls of the vertebral foramen; possesses several processes and articular surfaces
Pedicle	Foot of the arch with one on each side; forms the lateral walls of the vertebral foramen
Lamina	Posterior part of the arch; forms the posterior wall of the vertebral foramen
Transverse process	Process projecting laterally from the junction of the lamina and pedicle; a site of muscle attachment
Spinous process	Process projecting posteriorly at the point where the two laminae join; a site of muscle attachment; strengthens the vertebral column and allows for movement
Articular processes	Superior and inferior projections containing articular facets where vertebrae articulate with each other; strengthen the vertebral column and allow for movement
Intervertebral foramen	Lateral opening between two adjacent vertebrae through which spinal nerves exit the vertebral canal

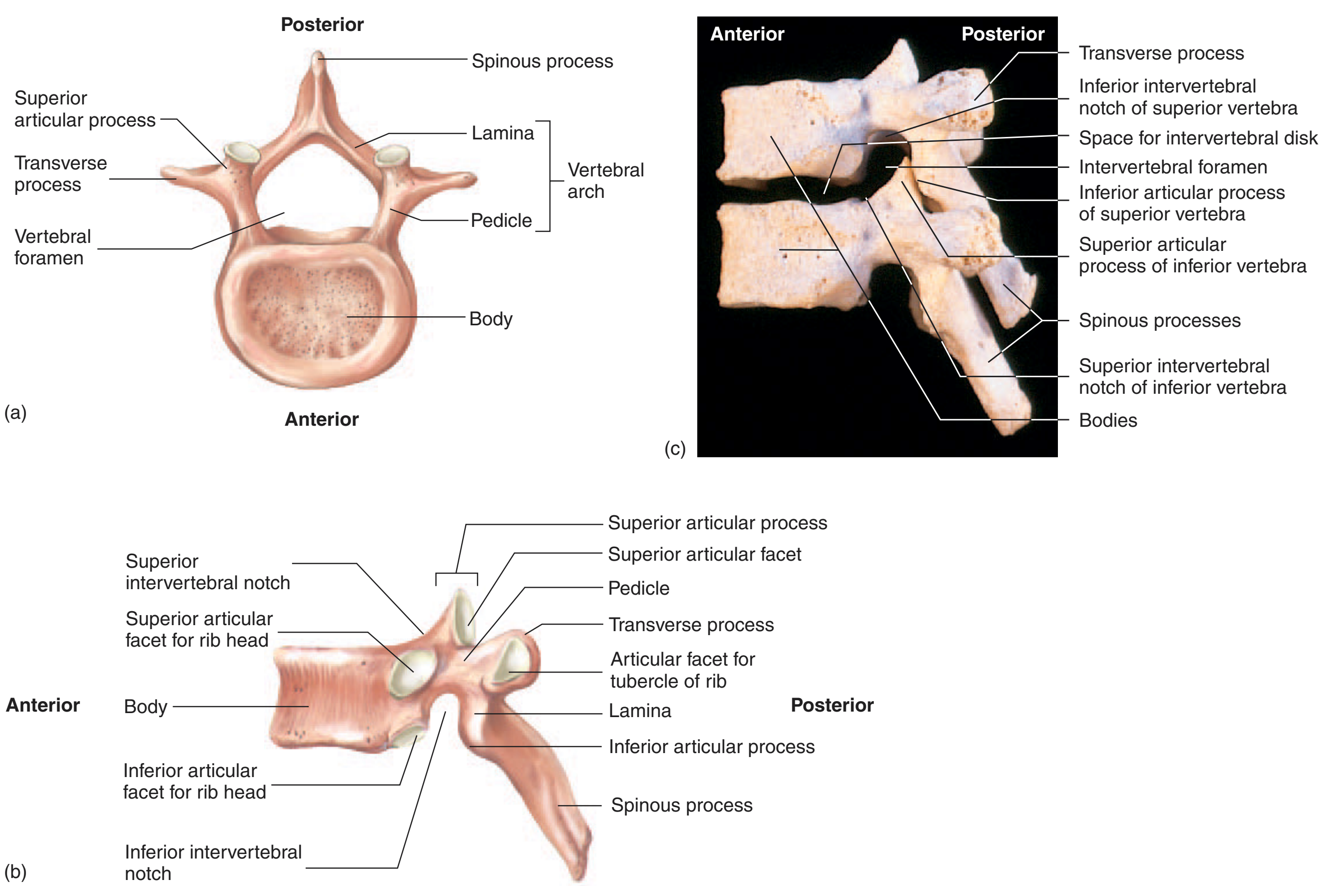


Figure 7.19 Vertebra

(*a*) Superior view. (*b*) Lateral view of a thoracic vertebra. (*c*) Photograph of two stacked thoracic vertebrae from a lateral view. The relationship between the inferior articular process of one vertebra and the superior articular process of the next inferior vertebra can be seen. The intervertebral foramen and the space for the intervertebral disk also can be seen.

A **transverse process** extends laterally from each side of the arch between the lamina and pedicle, and a single **spinous process** is present at the point of junction between the two laminae. The spinous processes can be seen and felt as a series of lumps down the midline of the back (figure 7.21). Much vertebral movement is accomplished by the contraction of skeletal muscles that are attached to the transverse and spinous processes (see chapter 10).

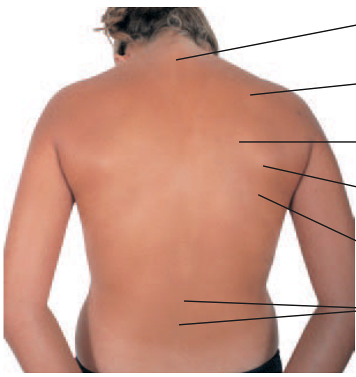


Figure 7.21 A Person's Back Showing the Scapula and Vertebral Spinous Processes

Spinal nerves exit the spinal cord through the **intervertebral foramina** (see figures 7.15 and 7.19*c*). Each intervertebral foramen is formed by notches in the pedicles of adjacent vertebrae.

Movement and additional support of the vertebral column are made possible by the vertebral processes. Each vertebra has a **superior** and an **inferior articular process,** with the superior process of one vertebra articulating with the inferior process of the next superior vertebra. Overlap of these processes increases the rigidity of the vertebral column. The region of overlap and articulation between the superior and inferior articular processes creates a smooth **articular facet** (fas′et, little face), on each articular process.

Regional Differences in Vertebrae

The vertebrae of each region of the vertebral column have specific characteristics that tend to blend at the boundaries between regions. The **cervical vertebrae** (see figures 7.15 and 7.22*a–d*) have very small bodies, partly **bifid** (bī′fid; split) **spinous processes,** and a **transverse foramen** in each transverse process through which the vertebral arteries extend toward the head. Only cervical vertebrae have transverse foramina.

The first cervical vertebra is called the **atlas** (see figure 7.22*a*) because it holds up the head, just as Atlas in classical

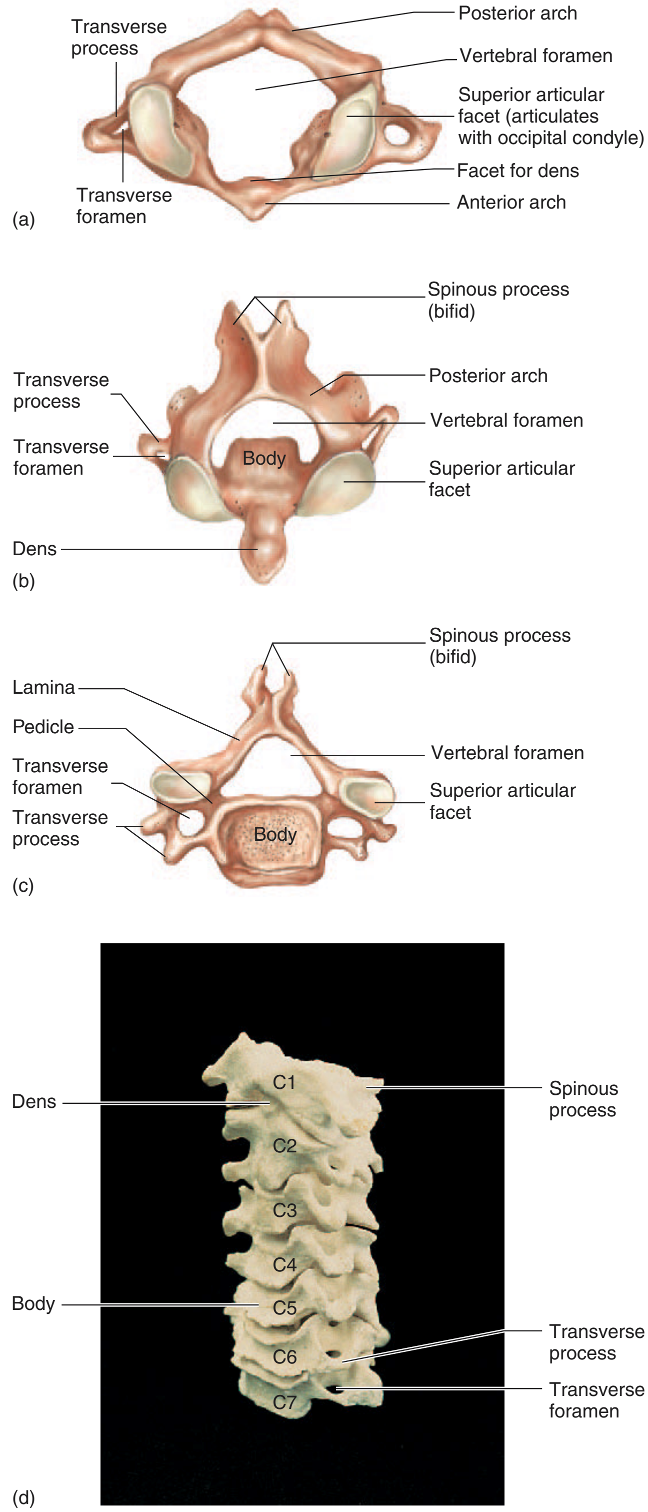


Figure 7.22 Cervical Vertebrae

(*a*) Atlas (first cervical vertebra), superior view. (*b*) Axis (second cervical vertebra), slightly posterior and superior view. (*c*) Fifth cervical vertebra, superior view. (*d*) Cervical vertebrae together from a lateral view.

mythology held up the world. The atlas vertebra has no body and no spinous process, but it has large superior articular facets, where it joins the occipital condyles on the base of the skull. This joint allows the head to move in a yes motion or to tilt from side to side. The second cervical vertebra is called the **axis** (figure 7.22*b*) because a considerable amount of rotation occurs at this vertebra to produce a no motion of the head. The axis has a highly modified process on the superior side of its small body called the **dens,** or **odontoid** (ō-don′toyd; tooth-shaped) **process** (both dens and odontoid mean tooth-shaped). The dens fits into the enlarged vertebral foramen of the atlas, and the latter rotates around this process. The spinous process of the seventh cervical vertebra, which is not bifid, is quite pronounced and often can be seen and felt as a lump between the shoulders (see figure 7.21). The most prominent spinous process in this area is called the **vertebral prominens.** This is usually the spinous process of the seventh cervical vertebra, but may be that of the sixth cervical vertebra or even the first thoracic.

Whiplash

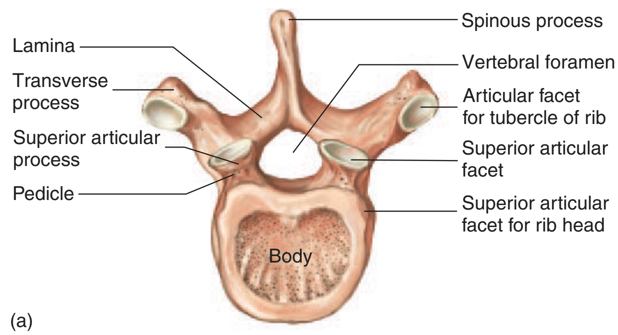
Whiplash is a traumatic hyperextension of the cervical vertebrae. The head is a heavy object at the end of a flexible column, and it may become hyperextended when the head "snaps back" as a result of a sudden acceleration of the body. This commonly occurs in "rear-end" automobile accidents, or athletic injuries, in which the body is quickly forced forward while the head remains stationary. Common injuries resulting from whiplash are fracture of the spinous processes of the cervical vertebrae and herniated disks, with an anterior tear of the annulus fibrosus. These injuries can cause posterior pressure on the spinal cord or spinal nerves and strained or torn muscles, tendons, and ligaments.

The **thoracic vertebrae** (see figures 7.15 and 7.23) possess long, thin spinous processes, which are directed inferiorly, and they have relatively long transverse processes. The first 10 thoracic vertebrae have articular facets on their transverse processes, where they articulate with the tubercles of the ribs. Additional articular facets are on the superior and inferior margins of the body where the heads of the ribs articulate. The head of most ribs articulates with the inferior articular facet of one vertebra and the superior articular facet for the rib head on the next vertebra down.

The **lumbar vertebrae** (see figures 7.15 and 7.24) have large, thick bodies and heavy, rectangular transverse and spinous processes. The superior articular processes face medially, and the inferior articular processes face laterally. When the superior articular surface of one lumbar vertebra joins the inferior articulating surface of another lumbar vertebra, the resulting arrangement adds strength to the inferior portion of the vertebral column and limits rotation of the lumbar vertebrae.

P R E D I C T 3

Why are the lumbar vertebrae more massive than the cervical vertebrae?



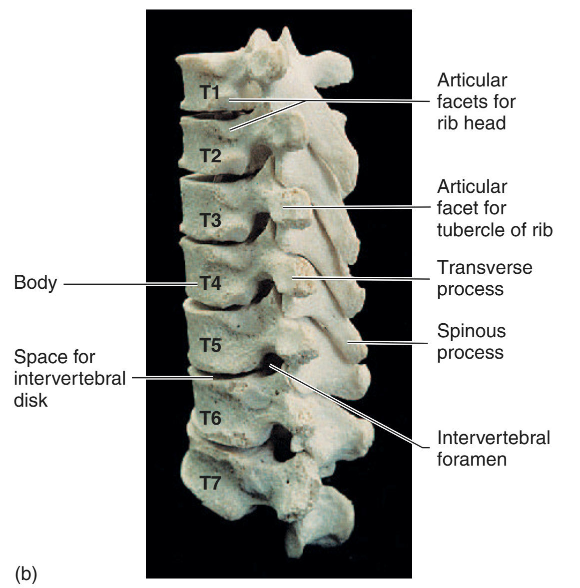


Figure 7.23 Thoracic Vertebrae
(*a*) Thoracic vertebra, superior view. (*b*) Thoracic vertebrae together from a lateral view.

The **sacral** (sā′krăl) **vertebrae** (see figures 7.15 and 7.25) are highly modified compared to the others. These five vertebrae are fused into a single bone called the **sacrum** (sā′krŭm).

Variation in Lumbar Vertebrae

The fifth lumbar vertebra or first coccygeal vertebra may become fused into the sacrum. Conversely, the first sacral vertebra may fail to fuse with the rest of the sacrum, resulting in six lumbar vertebrae.

The transverse processes of the sacral vertebrae fuse to form the **alae** (ā′lē; wings), which join the sacrum to the pelvic bones. The spinous processes of the first four sacral vertebrae partially fuse to form projections, called the **median sacral crest,** along the dorsal surface of the sacrum. The spinous process of the fifth vertebra does not form, thereby leaving a **sacral hiatus** (hī-ā′tŭs) at the inferior end of the sacrum, which is often the site of anesthetic injections. The intervertebral foramina are divided into dorsal and ventral foramina, called the **sacral foramina,** which are lateral to the midline. The anterior edge of the body of the first sacral vertebra bulges to form the **sacral promontory** (see figure 7.15), a landmark that separates the abdominal cavity from the pelvic cavity. The sacral promontory can be felt during a vaginal examination, and it's used as a reference point during measurement of the pelvic inlet.

The **coccyx** (kok′siks; shaped like a cuckoo's bill; see figures 7.15 and 7.25), or tailbone, is the most inferior portion of the vertebral column and usually consists of three to five more-or-less fused vertebrae that form a triangle, with the apex directed inferiorly. The coccygeal vertebrae are greatly reduced in size relative to the other vertebrae and have neither vertebral foramina nor well-developed processes.

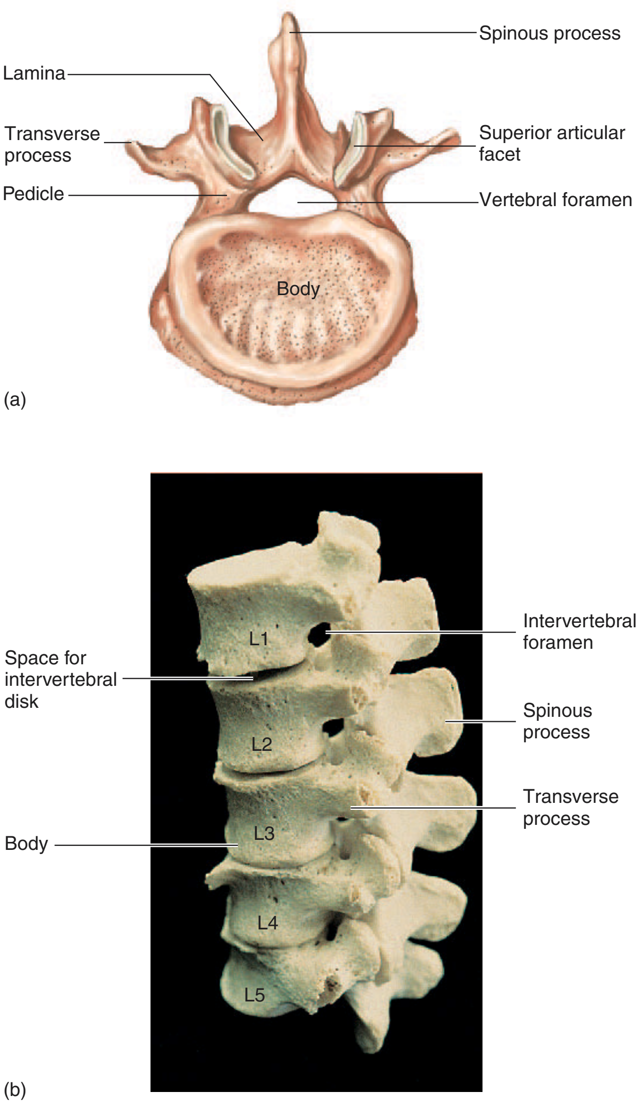


Figure 7.24 Lumbar Vertebrae

(*a*) Lumbar vertebra, superior view. (*b*) Lumbar vertebrae together from a lateral view.

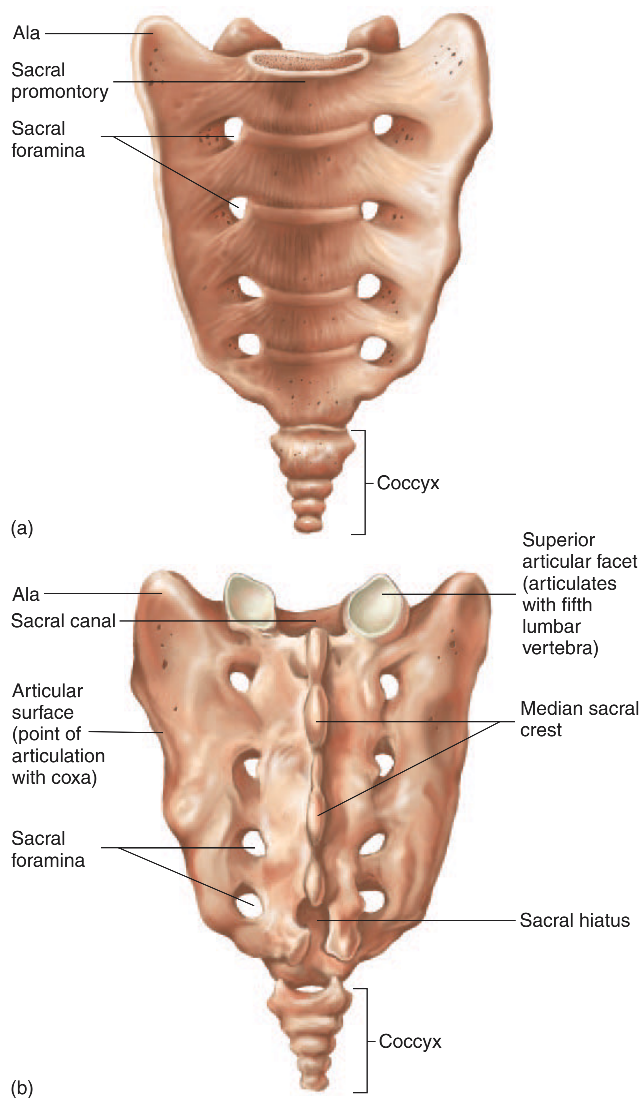


Figure 7.25 Sacrum

(*a*) Anterior view. (*b*) Posterior view.

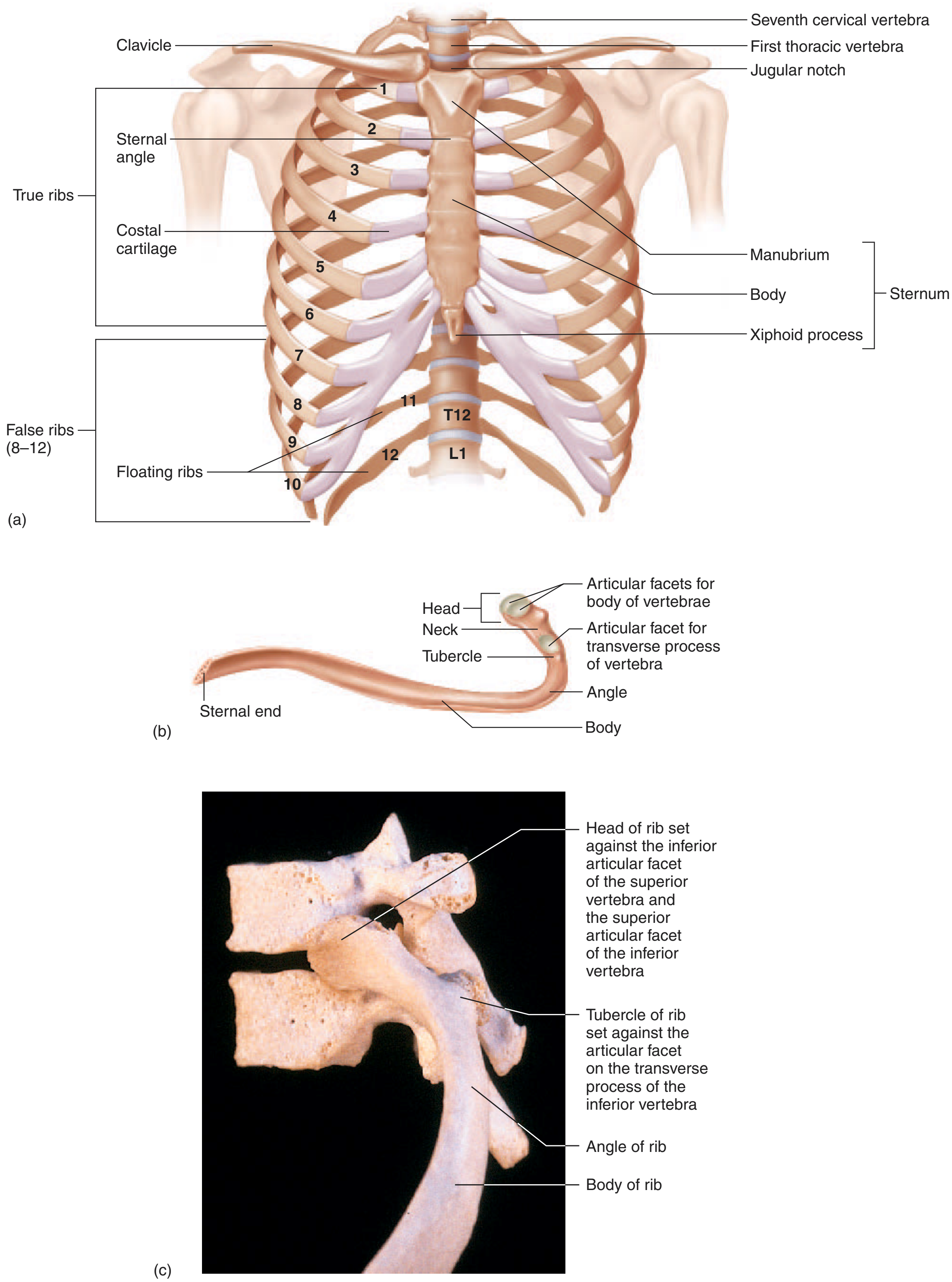


Figure 7.26 Thoracic Cage

(*a*) Entire thoracic cage as seen from in front. (*b*) Typical rib. (*c*) Photograph of two thoracic vertebrae and the proximal end of a rib, as seen from the left side, showing the relationship between the vertebra and the head and tubercle of the rib.

Vertebral Column Injuries

Because the cervical vertebrae are rather delicate and have small bodies, dislocations and fractures are more common in this area than in other regions of the column. Because the lumbar vertebrae have massive bodies and carry a large amount of weight, fractures are less common, but ruptured intervertebral disks are more common in this area than in other regions of the column. The coccyx is easily broken in a fall in which a person sits down hard on a solid surface.

13. *Describe the four major curvatures of the vertebral column, explain what causes them, and when they develop. Define the terms scoliosis, kyphosis, and lordosis.*
14. *Describe the structures forming the vertebral foramen. Where do spinal nerves exit the vertebral column?*
15. *Describe how superior and inferior articular processes help support and allow movement of the vertebral column.*
16. *Name and give the number of each type of vertebra. Describe the characteristics that distinguish the different types of vertebrae.*

Thoracic Cage

Objectives

- *Describe the parts of the thoracic (rib) cage, and explain their function.*

The **thoracic cage,** or **rib cage,** protects the vital organs within the thorax and forms a semi-rigid chamber that can increase and decrease in volume during respiration. It consists of the thoracic vertebrae, the ribs with their associated costal (rib) cartilages, and the sternum (figure 7.26*a*).

Ribs and Costal Cartilages

The 12 pairs of **ribs** are classified as either true or false ribs. The superior seven pairs are called **true ribs,** or **vertebrosternal** (ver′tĕ′brō-ster′năl) **ribs,** and articulate with the thoracic vertebrae and attach directly through their **costal cartilages** to the sternum. The inferior five pairs, or **false ribs,** articulate with the thoracic vertebrae but do not attach directly to the sternum. The false ribs consist of two groups. The eighth, ninth, and tenth ribs, the **vertebrochondral** (ver′tĕ-brō-kon′drăl) **ribs,** are joined by a common cartilage to the costal cartilage of the seventh rib, which, in turn, is attached to the sternum. Two of the false ribs, the eleventh and twelfth ribs, are also called **floating,** or **vertebral, ribs** because they do not attach to the sternum. The costal cartilages are flexible and permit the thoracic cage to expand during respiration.

Most ribs have two points of articulation with the thoracic vertebrae (figure 7.26*b* and *c*). First, the **head** articulates with the bodies of two adjacent vertebrae and the intervertebral disk between them. The head of each rib articulates with the inferior articular facet of the superior vertebra and the superior articular facet of the inferior vertebra. Second, the **tubercle** articulates with the transverse process of one vertebra. The **neck** is between the head and tubercle, and the **body,** or shaft, is the main part of the rib. The **angle** of the rib is located just lateral to the tubercle and is the point of greatest curvature.

Rib Defects

A **separated rib** is a dislocation between a rib and its costal cartilage. As a result of the dislocation, the rib can move, override adjacent ribs, and cause pain. Separation of the tenth rib is the most common.

The angle is the weakest part of the rib and may be fractured in a crushing accident, such as an automobile accident.

The transverse processes of the seventh cervical vertebra may form separate bones called **cervical ribs.** These ribs may be just tiny pieces of bone or may be long enough to reach the sternum. The first lumbar vertebra may develop lumbar ribs.

Sternum

The **sternum,** or breastbone, has been described as being sword-shaped and has three parts (see figure 7.26*a*). The **manubrium** (mă-noo′brē-ŭm; handle) is the sword handle, the **body** is the blade, and the **xiphoid** (zi′foyd; sword) **process** is the sword tip. The superior margin of the manubrium has a **jugular** (neck) **notch** in the midline, which can be easily felt at the anterior base of the neck (figure 7.27). The first rib and the clavicle articulate with the manubrium. The point at which the manubrium joins the body of the sternum can be felt as a prominence on the anterior thorax called the **sternal angle** (see figure 7.26). The cartilage of the second rib attaches to the sternum at the sternal angle, the third through seventh ribs attach to the body of the sternum, and no ribs attach to the xiphoid process.

Sternal Angle and Thoracic Landmarks

The sternal angle is important clinically because the second rib is found lateral to it and can be used as a starting point for counting the other ribs. Counting ribs is important because they are landmarks used to locate structures in the thorax, such as areas of the heart. The sternum often is used as a site for taking red bone marrow samples because it is readily accessible. Because the xiphoid process of the sternum is attached only at its superior end, it may be broken during cardiopulmonary resuscitation (CPR) and then may lacerate the liver.

17. *What is the function of the thoracic (rib) cage? Distinguish between true, false, and floating ribs, and give the number of each type.*
18. *Describe the articulation of the ribs with thoracic vertebrae.*
19. *Describe the different parts of the sternum. Name the structures that attach to, or articulate with, the sternum.*

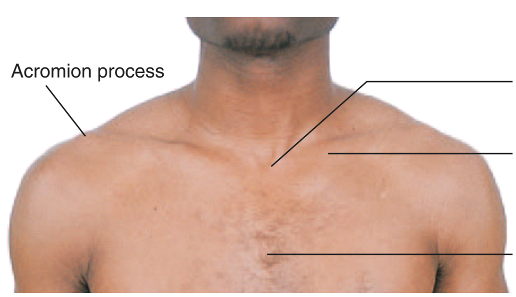


Figure 7.27 Surface Anatomy Showing Bones of the Upper Thorax

Appendicular Skeleton

Objectives

- *Name and describe the bones of the pectoral girdle and upper limb.*
- *Name the major features of these bones and describe their functions.*
- *Name and describe the bones of the pelvic girdle and lower limb.*
- *Name the major features of these bones and describe their functions.*

The appendicular skeleton (see figure 7.1) consists of the bones of the **upper** and **lower limbs** and the **girdles** by which they are attached to the body. The term *girdle* means a belt or a zone and refers to the two zones, pectoral and pelvic, where the limbs are attached to the body.

Pectoral Girdle and Upper Limb

The human upper limb (figure 7.28) is extremely mobile. It is capable of a wide range of movements, including lifting, grasping, pulling, and touching. Many structural characteristics of the upper limb reflect these functions. The upper limb and its girdle are attached rather loosely by muscles to the rest of the body, an arrangement that allows considerable freedom of movement of this extremity. This freedom of movement allows placement of the hand in a wide range of positions to accomplish its functions.

Pectoral Girdle

The **pectoral** (pek′tō-răl), or **shoulder, girdle** consists of two pairs of bones that attach the upper limb to the body: each pair is composed of a **scapula** (skap′ū-lă), or shoulder blade (figure 7.29), and a **clavicle** (klav′i-kl), or collarbone (see figures 7.26, 7.28, and 7.29*c*). The scapula is a flat, triangular bone that can easily be seen and felt in a living person (see figure 7.21). The base of the triangle, the superior border, faces superiorly; and the apex, the inferior angle, is directed inferiorly.

The large **acromion** (ă-krō′mē-on; shoulder tip) **process** of the scapula, which can be felt at the tip of the shoulder, has three functions: (1) to form a protective cover for the shoulder joint, (2) to form the attachment site for the clavicle, and (3) to provide attachment points for some of the shoulder muscles. The **scapular spine** extends from the acromion process across the posterior surface of the scapula and divides that surface into a small **supraspinous fossa** superior to the spine and a larger **infraspinous fossa** inferior to the spine. The deep, anterior surface of the scapula constitutes the **subscapular fossa.** The smaller **coracoid** (meaning shaped like a crow's beak) **process** provides attachments for some shoulder and arm muscles. A **glenoid** (glē′noyd, glen′oyd) **cavity,** located in the superior lateral portion of the bone, articulates with the head of the humerus.

The clavicle (see figures 7.26, 7.28, and 7.29*c*) is a long bone with a slight sigmoid (S-shaped) curve and is easily seen and felt in the living human (see figure 7.27). The lateral end of the clavicle articulates with the acromion process, and its medial end articulates with the manubrium of the sternum. These articulations form the only bony connections between the pectoral girdle and the axial skeleton. Because the clavicle holds the upper limb away from the body it facilitates the mobility of the limb.

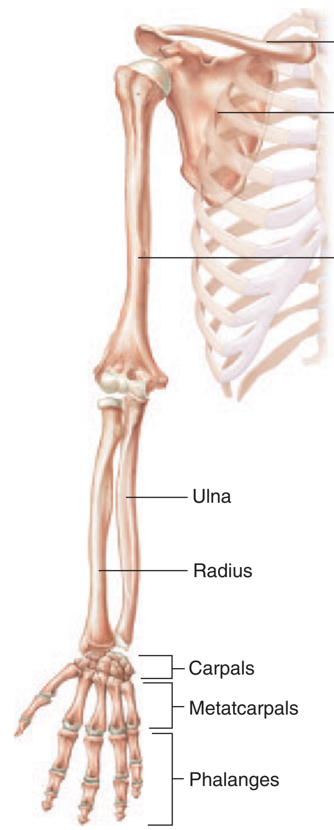


Figure 7.28 Bones of the Pectoral Girdle and Right Upper Limb

20. *Name the bones that make up the pectoral girdle. Describe their functions.*
21. *What are the functions of the acromion process and the coracoid process of the scapula?*

P R E D I C T 4

A broken clavicle changes the position of the upper limb in what way?

Arm

The arm, the part of the upper limb from the shoulder to the elbow, contains only one bone, the **humerus** (figure 7.30). The humeral **head** articulates with the glenoid cavity of the scapula. The **anatomical neck,** immediately distal to the head, is almost nonexistent; thus a surgical neck has been designated. The **surgical neck** is so named because it's a common fracture site that often requires surgical repair. If it becomes necessary to remove the humeral head because of disease or injury, it's removed down to the surgical neck. The **greater tubercle** is located on the lateral surface and the **lesser tubercle** is located on the anterior surface of the proximal end of the humerus, where they function as sites of muscle attachment. The groove between the two tubercles contains one tendon of the biceps brachii muscle and is called the

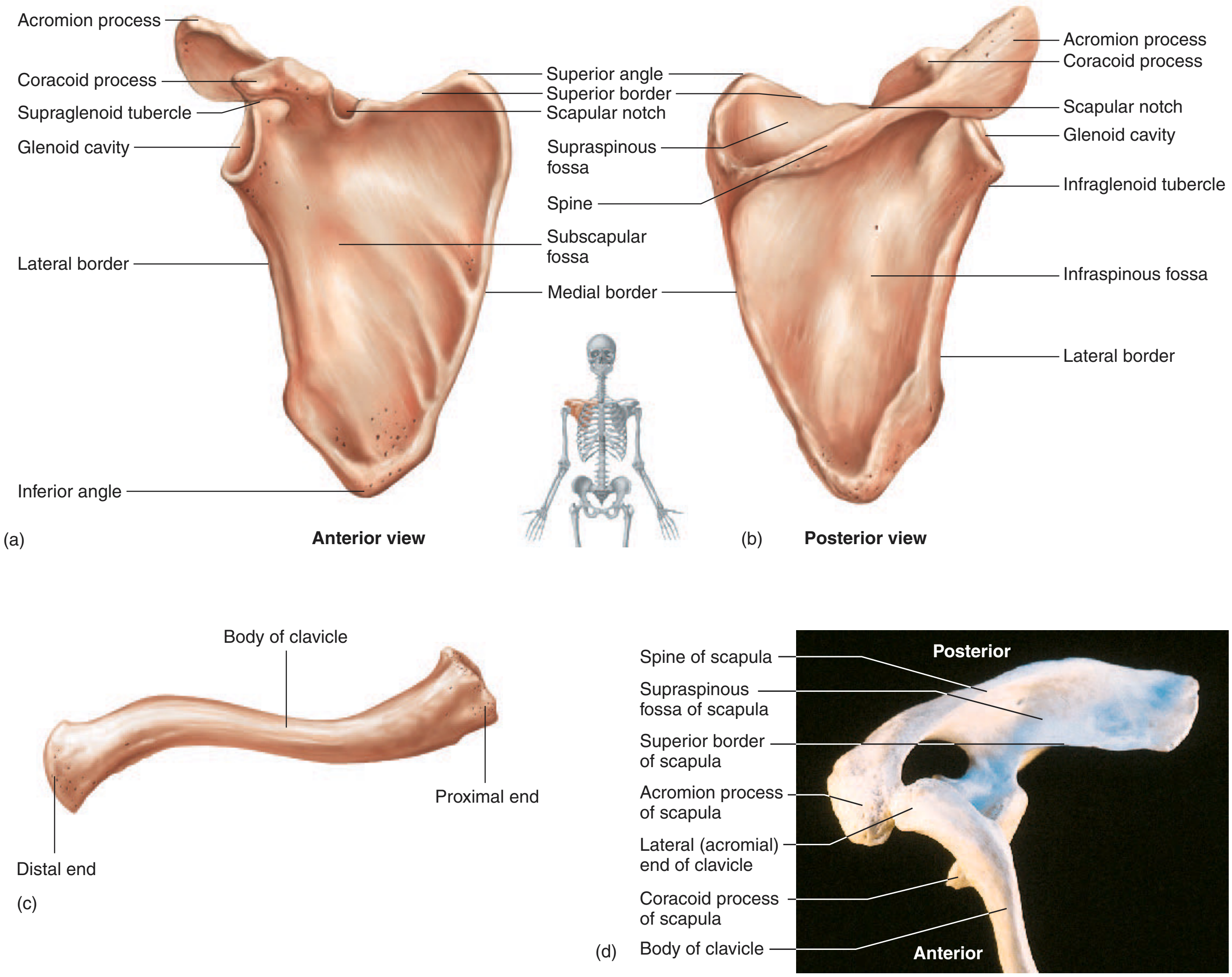


Figure 7.29 Right Scapula and Clavicle

(*a*) Right scapula, anterior view. (*b*) Right scapula, posterior view. (*c*) Right clavicle, anterior view. (*d*) Photograph of the right scapula and clavicle from a superior view, showing the relationship between the distal end of the clavicle and the acromion process of the scapula.

intertubercular, or **bicipital** (bī-sip′i-tăl), **groove.** The **deltoid tuberosity** is located on the lateral surface of the humerus a little more than a third of the way along its length and is the attachment site for the deltoid muscle.

The articular surfaces of the distal end of the humerus exhibit unusual features where the humerus articulates with the two forearm bones. The lateral portion of the articular surface is very rounded, articulates with the radius, and is called the **capitulum** (kă-pit′ū-lŭm; head-shaped). The medial portion somewhat resembles a spool or pulley, articulates with the ulna, and is called the **trochlea** (trok′lē-ă; spool). Proximal to the capitulum and the trochlea are the **medial** and **lateral epicondyles,** which function as points of muscle attachment for the muscles of the forearm.

Forearm

The forearm has two bones. The **ulna** is on the medial side of the forearm, the side with the little finger. The **radius** is on the lateral, or thumb side, of the forearm (figure 7.31).

The proximal end of the ulna has a C-shaped articular surface, called the **trochlear,** or **semilunar, notch** that fits over the trochlea of the humerus. The trochlear notch is bounded by two processes. The larger, posterior process is the **olecranon**

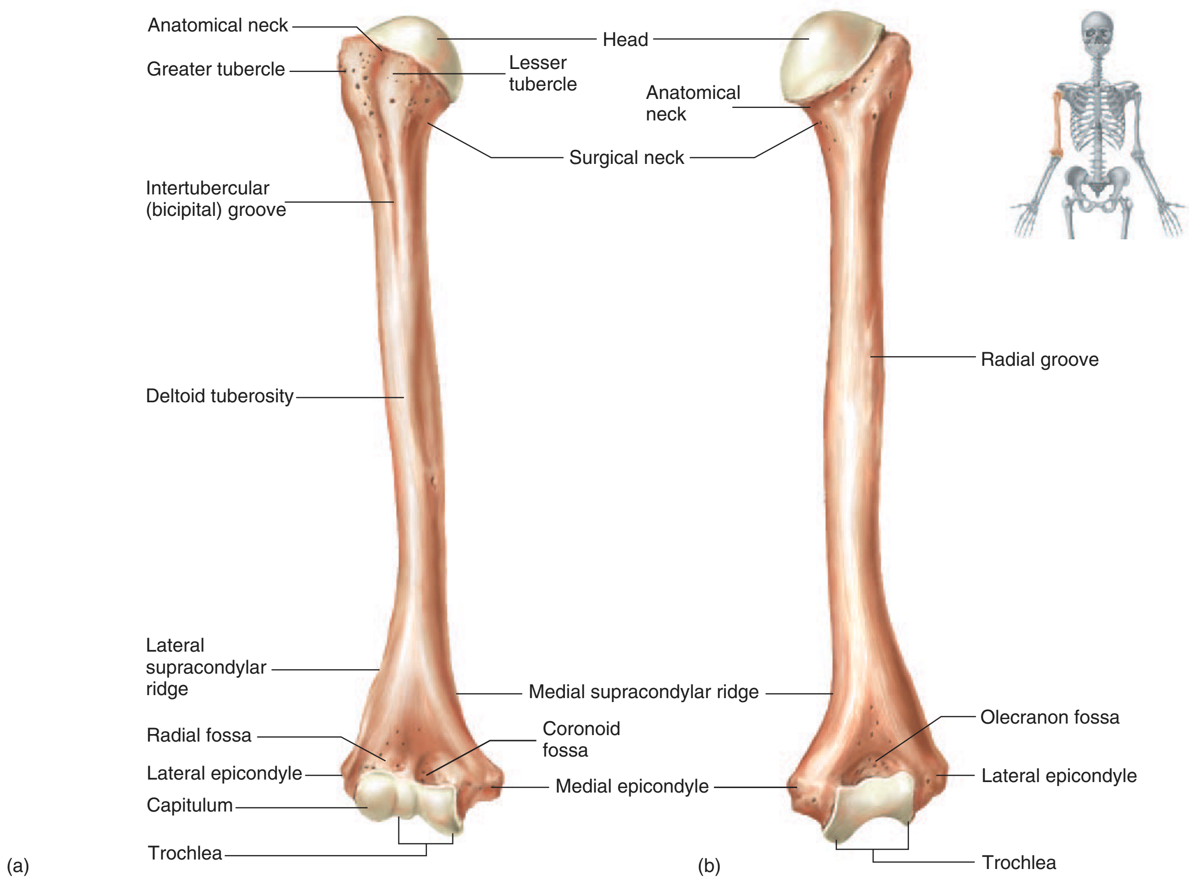


Figure 7.30 Right Humerus

(*a*) Anterior view. (*b*) Posterior view.

(ō-lek′ră-non; the point of the elbow) **process.** It can easily be felt and is commonly referred to as "the elbow" (see figure 7.33). Posterior arm muscles attach to the olecranon process. The smaller, anterior process is the **coronoid** (kōr′ŏ-noyd; crow's beak) **process.**

P R E D I C T 5

Explain the function of the olecranon and coronoid fossae on the distal humerus (see figure 7.30).

The distal end of the ulna has a small **head,** which articulates with both the radius and the wrist bones (see figures 7.31 and 7.33). The head can be seen on the posterior, medial (ulnar) side of the distal forearm. The posteromedial side of the head has a small **styloid** (stī′loyd; shaped like a stylus or writing instrument) **process** to which ligaments of the wrist are attached.

The proximal end of the radius is the **head.** It is concave and articulates with the capitulum of the humerus. The lateral surfaces of the head constitute a smooth cylinder, where the radius rotates against the **radial notch** of the ulna. As the forearm rotates (supination and pronation; see chapter 8), the proximal end of the ulna stays in place, and the radius rotates. The **radial tuberosity** is the point at which a major anterior arm muscle, the biceps brachii, attaches.

The distal end of the radius, which articulates with the ulna and the carpals, is somewhat broadened, and a **styloid process** to which wrist ligaments are attached is located on the lateral side of the distal radius.

Radius Fractures

The radius is the most commonly fractured bone in people over 50 years old. It is often fractured as the result of a fall on an outstretched hand. The most common site of fracture is 2.5 cm proximal to the wrist, and the fracture is often comminuted, or impacted.

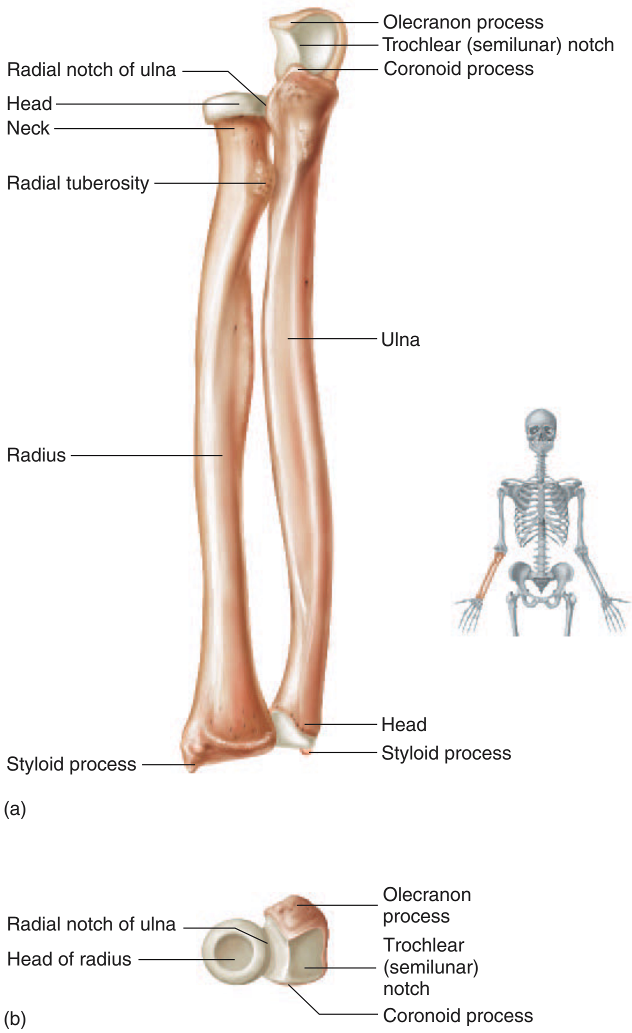


Figure 7.31 Right Ulna and Radius

(*a*) Anterior view of right ulna and radius. (*b*) Proximal ends of the right ulna and radius.

Wrist

The wrist is a relatively short region between the forearm and hand and is composed of eight **carpal** (kar′păl) **bones** arranged into two rows of four each (figure 7.32). The eight carpals, taken together, are convex posteriorly and concave anteriorly. The anterior concavity of the carpals is accentuated by the tubercle of the trapezium at the base of the thumb and the hook of the hamate at the base of the little finger. A ligament stretches across the wrist from the tubercle of the trapezium to the hook of the hamate to form a tunnel on the anterior surface of the wrist called the **carpal tunnel.** Tendons, nerves, and blood vessels pass through this tunnel to enter the hand.

Carpal Tunnel Syndrome

The bones and ligaments that form the walls of the carpal tunnel do not stretch. Edema (fluid buildup) or connective tissue deposition may occur within the carpal tunnel as the result of trauma or some other problem. The edema or connective tissue may apply pressure against the nerve and vessels passing through the tunnel. This pressure causes carpal tunnel syndrome, which consists of tingling, burning, and numbness in the hand. Carpal tunnel syndrome occurs more frequently in people who use their hands a lot. The number of cases has increased in recent decades among people who perform repetitive tasks such as computer keyboarding.

Hand

Five **metacarpals** are attached to the carpal bones and constitute the bony framework of the hand (see figure 7.32). The metacarpals form a curve so that, in the resting position, the palm of the hand is concave. The distal ends of the metacarpals help form the knuckles of the hand (figure 7.33). The spaces between the metacarpals are occupied by soft tissue.

The five **digits** of each hand include one thumb and four fingers. Each digit consists of small long bones called **phalanges** (fă-lan′jēz; the singular term *phalanx* refers to the Greek word, meaning a line or wedge of soldiers holding their spears, tips outward, in front of them). The thumb has two phalanges, and each finger has three. One or two **sesamoid** (ses′ă-moyd; resembling a sesame seed) **bones** (not illustrated) often form near the junction between the proximal phalanx and the metacarpal of the thumb. Sesamoid bones are small bones located within tendons.

P R E D I C T 6

Explain why the dried, articulated skeleton appears to have much longer "fingers" than are seen in the hand with the soft tissue intact.

22. *Name the important sites of muscle attachment on the humerus.*
23. *Give the points of articulation between the scapula, humerus, radius, ulna, and wrist bones.*
24. *What is the function of the radial tuberosity? Of the styloid processes? Name the part of the ulna commonly referred to as "the elbow."*
25. *List the eight carpal bones. What is the carpal tunnel?*
26. *What bones form the hand? The knuckles? How many phalanges are in each finger and in the thumb?*

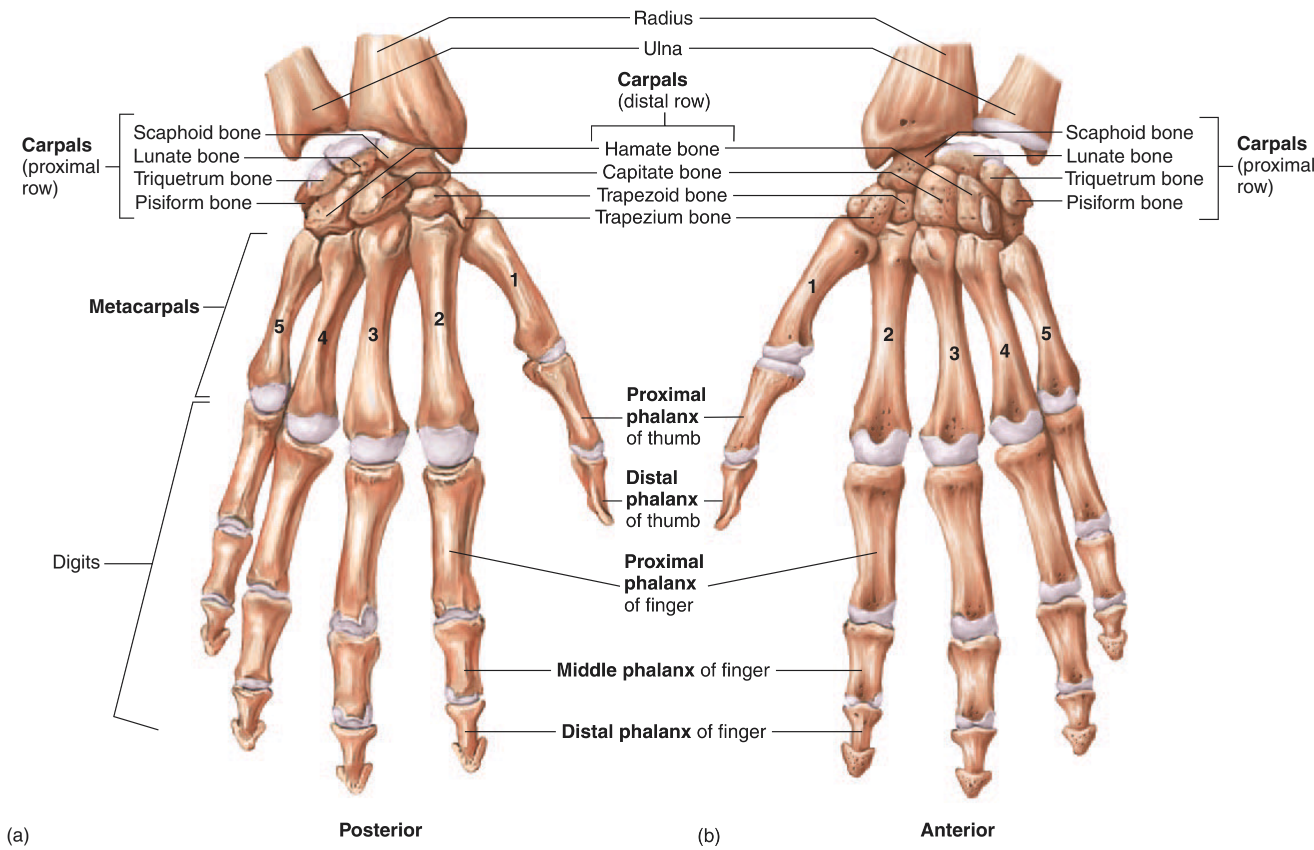


Figure 7.32 Bones of the Right Wrist and Hand

(*a*) Posterior view. (*b*) Anterior view.

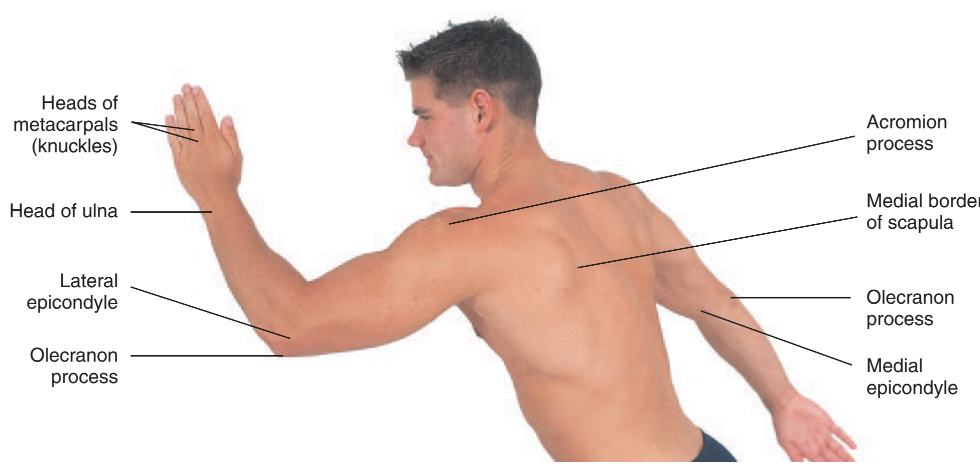


Figure 7.33 Surface Anatomy Showing Bones of the Pectoral Girdle and Upper Limb

Pelvic Girdle and Lower Limb

The lower limbs support the body and are essential for normal standing, walking, and running. The general pattern of the lower limb (figure 7.34) is very similar to that of the upper limb, except that the pelvic girdle is attached much more firmly to the body than is the pectoral girdle, and the bones in general are thicker, heavier, and longer than those of the upper limb. These structures reflect the function of the lower limb in support and movement of the body.

Pelvic Girdle

The **pelvic girdle** consists of the right and left **coxae** (kok′sē), or hipbones. The coxae join each other anteriorly and with the sacrum posteriorly to form a ring of bone called the **pelvis** (pel′vis, basin) (figure 7.35). Each coxa consists of a large, concave bony plate superiorly, a slightly narrower region in the center, and an expanded bony ring inferiorly, which surrounds a large **obturator** (ob′too-rā-tŏr; to occlude or close up, indicating that the foramen is occluded by soft tissue) **foramen.** A fossa called the **acetabulum** (as-ĕ-tab′ū-lŭm; a shallow vinegar cup—a common household item in ancient times) is located on the lateral surface of each coxa and is the point of articulation of the lower limb with the girdle. The articular surface of the acetabulum is crescent-shaped and occupies only the superior and lateral aspects of the fossa. The pelvic girdle is the place of attachment for the lower limbs, supports the weight of the body, and protects internal organs. Because the pelvis is a complete bony ring, it provides more stable support but less mobility than the incomplete ring of the pectoral girdle. In addition, the pelvis in a woman protects the developing fetus and forms a passageway through which the fetus passes during delivery.

Each coxa is formed by the fusion of three bones during development: the **ilium** (il′ē-ŭm; groin), the **ischium** (is′kē-ŭm; hip), and the **pubis** (pū′bis; refers to the genital hair). All three bones join near the center of the acetabulum (figure 7.36*a*). The superior portion of the ilium is called the **iliac crest** (figure 7.36*b* and *c*). The crest ends anteriorly as the **anterior superior iliac spine** and posteriorly as the **posterior superior iliac spine.** The crest and anterior spine can be felt and even seen in thin individuals (figure 7.37). The anterior superior iliac spine is an important anatomic landmark that is used, for example, to find the correct location for giving injections in the hip muscle. A dimple overlies the posterior superior iliac spine just superior to the buttocks. The **greater ischiadic** (is-kē-ad′ik; formerly called sciatic) **notch** is on the posterior side of the ilium, just inferior to the inferior posterior iliac spine. The ischiadic nerve passes through the greater ischiadic notch. The **articular surface** of the ilium joins the sacrum to form the **sacroiliac joint** (see figure 7.35). The medial side of the ilium consists of a large depression called the **iliac fossa.**

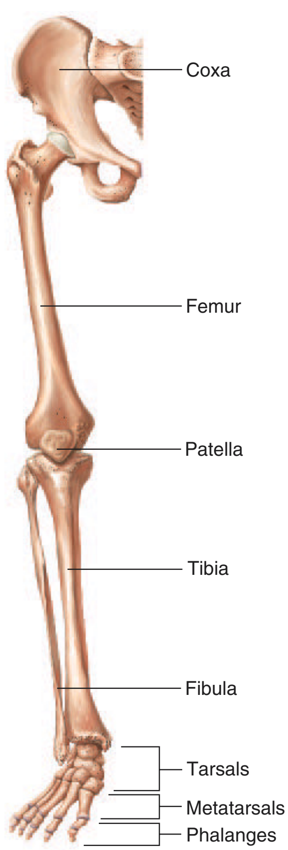


Figure 7.34 **Bones of the Pelvic Girdle and Right Lower Limb**

The Sacroiliac Joint

The sacroiliac joint receives most of the weight of the upper body and is strongly supported by ligaments. Excessive strain on the joint, however, can cause slight joint movement and can stretch connective tissue and associated nerve endings in the area and cause pain. Thus is derived the expression, "My aching sacroiliac!" This problem sometimes develops in pregnant women because of the forward weight distribution of the fetus.

The ischium possesses a heavy **ischial** (is′kē-ăl) **tuberosity,** where posterior thigh muscles attach and on which a person sits (see figure 7.36*b*). The pubis possesses a **pubic crest,** where abdominal muscles attach (see figure 7.36*c*). The pubic crest can be felt anteriorly. Just inferior to the pubic crest is the point of junction, the **symphysis** (sim′fi-sis; a coming together) **pubis,** or **pubic symphysis,** between the two coxae (see figure 7.35).

The pelvis can be thought of as having two parts divided by an imaginary plane passing from the sacral promontory along the **iliopectineal lines** of the ilium to the pubic crest (figure 7.38). The bony boundary of this plane is the **pelvic brim.** The **false,** or **greater, pelvis** is superior to the pelvic brim and is partially surrounded by bone on the posterior and lateral sides. During life, the abdominal muscles form the anterior wall of the false pelvis. The **true pelvis** is inferior to the pelvic brim and is completely surrounded by bone. The superior opening of the true pelvis, at the level of the pelvic brim, is the **pelvic inlet.** The inferior opening of the true pelvis, bordered by the inferior margin of the pubis, the ischial spines and tuberosities, and the coccyx, is the **pelvic outlet** (see figure 7.38*c*).

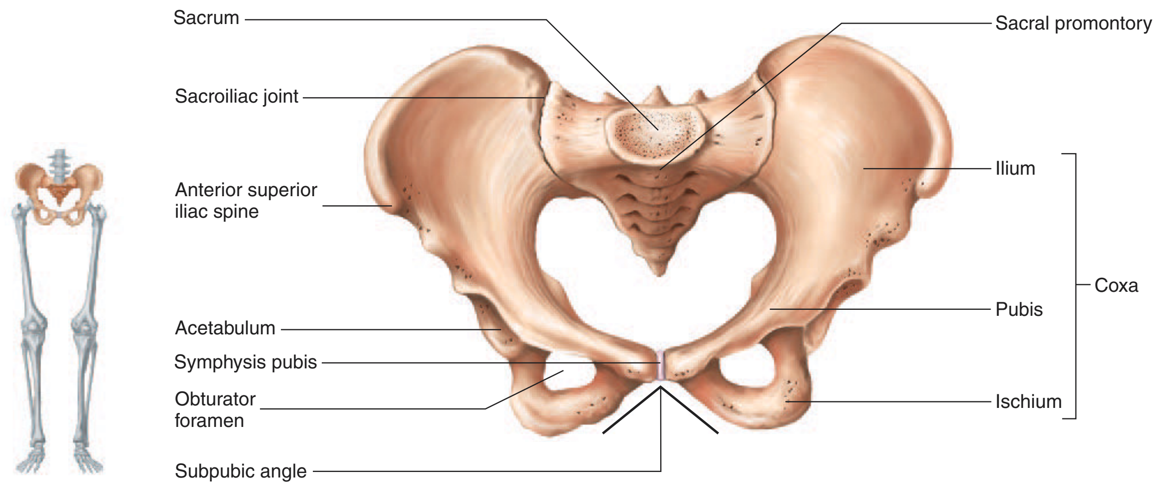
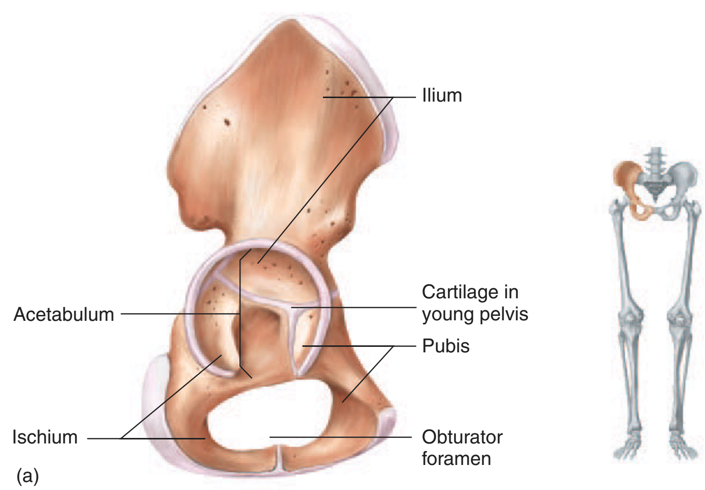
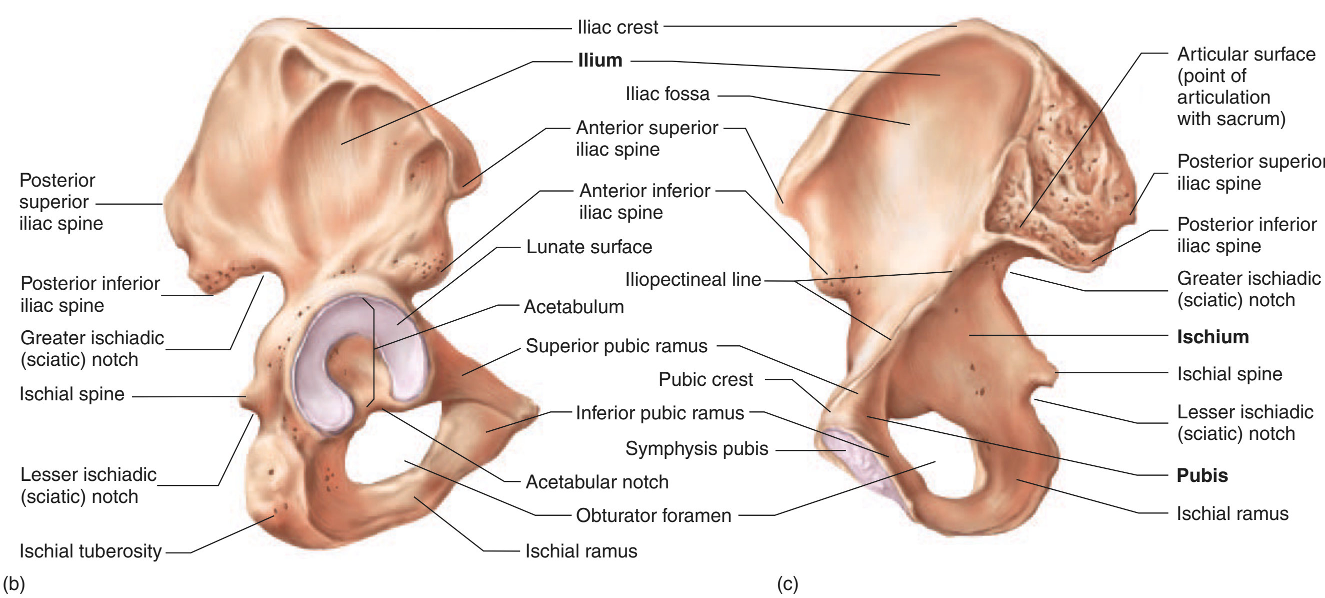


Figure 7.35 Anterior View of the Pelvis

Figure 7.36 Coxa

(*a*) Right coxa of a growing child. Each coxa is formed by fusion of the ilium, ischium, and pubis. The three bones can be seen joining near the center of the acetabulum, separated by lines of cartilage. (*b*) Right coxa, lateral view. (*c*) Right coxa, medial view.





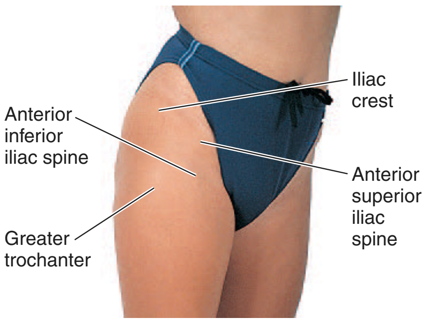


Figure 7.37 Surface Anatomy Showing an Anterior View of the Hipbones

Comparison of the Male and Female Pelvis

The male pelvis usually is more massive than the female pelvis as a result of the greater weight and size of the male, and the female pelvis is broader and has a larger, more rounded pelvic inlet and outlet (see figure 7.38*a* and *b*), consistent with the need to allow the fetus to pass through these openings in the female pelvis during delivery. Table 7.8 lists additional differences between the male and female pelvis.

Pelvic Outlet and Birth

A wide circular pelvic inlet and a pelvic outlet with widely spaced ischial spines are ideal for delivery. Variation from this ideal can cause problems during delivery; thus the size of the pelvic inlet and outlet is routinely measured during prenatal pelvic examinations of pregnant women. If the pelvic outlet is too small for normal delivery, delivery can be accomplished by **cesarean section,** which is the surgical removal of the fetus through the abdominal wall.

27. ***Define the terms pelvic girdle and pelvis. What bones fuse to form each coxa? Where and with what bones do the coxae articulate?***
28. ***Name the important sites of muscle attachment on the pelvis.***
29. ***Distinguish between the true pelvis and the false pelvis.***
30. ***Describe the differences between a male and a female pelvis.***

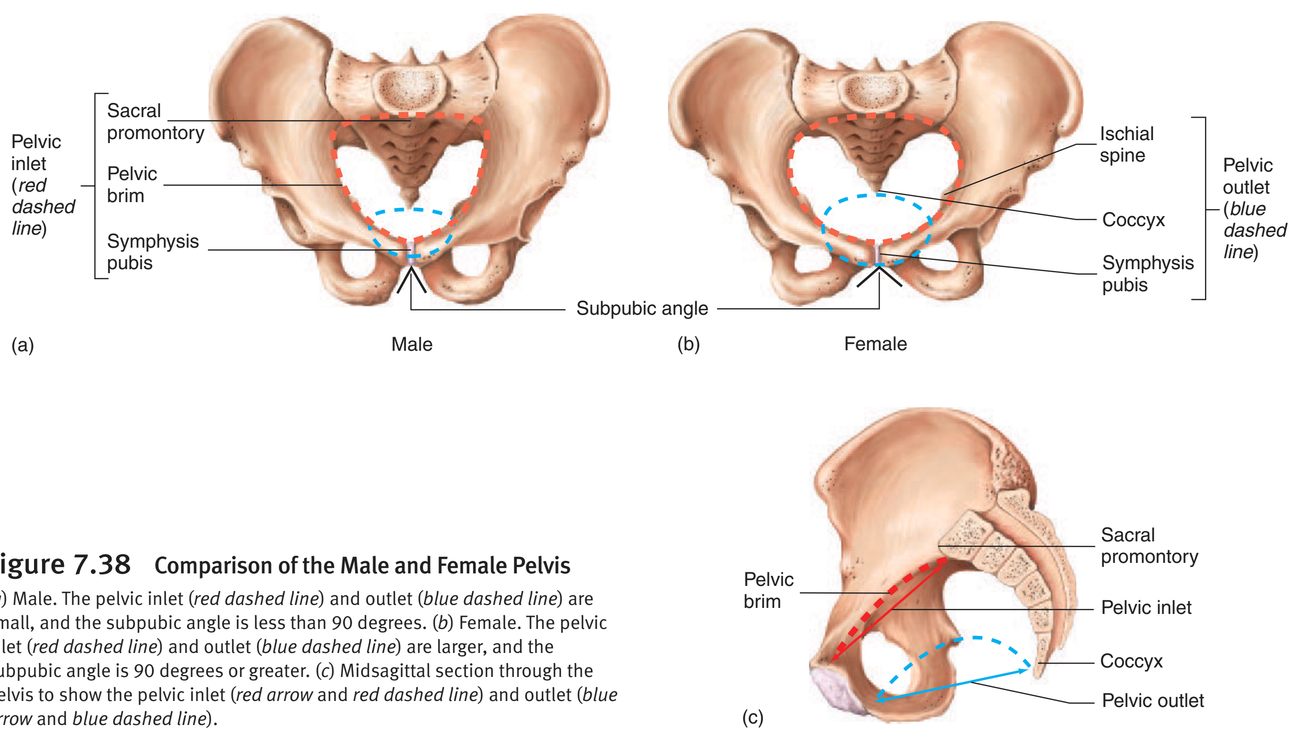


Figure 7.38 Comparison of the Male and Female Pelvis

(*a*) Male. The pelvic inlet (*red dashed line*) and outlet (*blue dashed line*) are small, and the subpubic angle is less than 90 degrees. (*b*) Female. The pelvic inlet (*red dashed line*) and outlet (*blue dashed line*) are larger, and the subpubic angle is 90 degrees or greater. (*c*) Midsagittal section through the pelvis to show the pelvic inlet (*red arrow* and *red dashed line*) and outlet (*blue arrow* and *blue dashed line*).

Table 7.8 Differences Between the Male and Female Pelvis (see figure 7.38)

Area	Description
General	The female pelvis is somewhat lighter in weight and wider laterally but shorter superiorly to inferiorly and less funnel-shaped; less obvious muscle attachment points exist in females than in males
Sacrum	Broader in females with the inferior part directed more posteriorly; the sacral promontory does not project as far anteriorly in the female
Pelvic inlet	Heart-shaped in males; oval in females
Pelvic outlet	Broader and more shallow in females
Subpubic angle	Less than 90 degrees in males; 90 degrees or more in females
Ilium	More shallow and flared laterally in females
Ischial spines	Farther apart in females
Ischial tuberosities	Turned laterally in females and medially in males

Thigh

The thigh, like the arm, contains a single bone, which is called the **femur.** The femur has a prominent rounded **head,** where it articulates with the acetabulum, and a well-defined **neck;** both are located at an oblique angle to the shaft of the femur (figure 7.39). The proximal shaft exhibits two tuberosities: a **greater trochanter** (trō-kan′ter; runner) lateral to the neck and a smaller, or **lesser, trochanter** inferior and posterior to the neck. Both trochanters are attachment sites for muscles that fasten the hip to the thigh. The greater trochanter and its attached muscles form a bulge that can be seen as the widest part of the hips (see figure 7.37). The distal end of the femur has **medial** and **lateral condyles,** smooth, rounded surfaces that articulate with the tibia. Located proximally to the condyles are the **medial** and **lateral epicondyles,** important sites of ligament attachment.

P R E D I C T 7

Compare the following in terms of structure and function for the upper and lower limbs: depth of sockets, size of bones, and size of tubercles and trochanters. What is the significance of these differences?

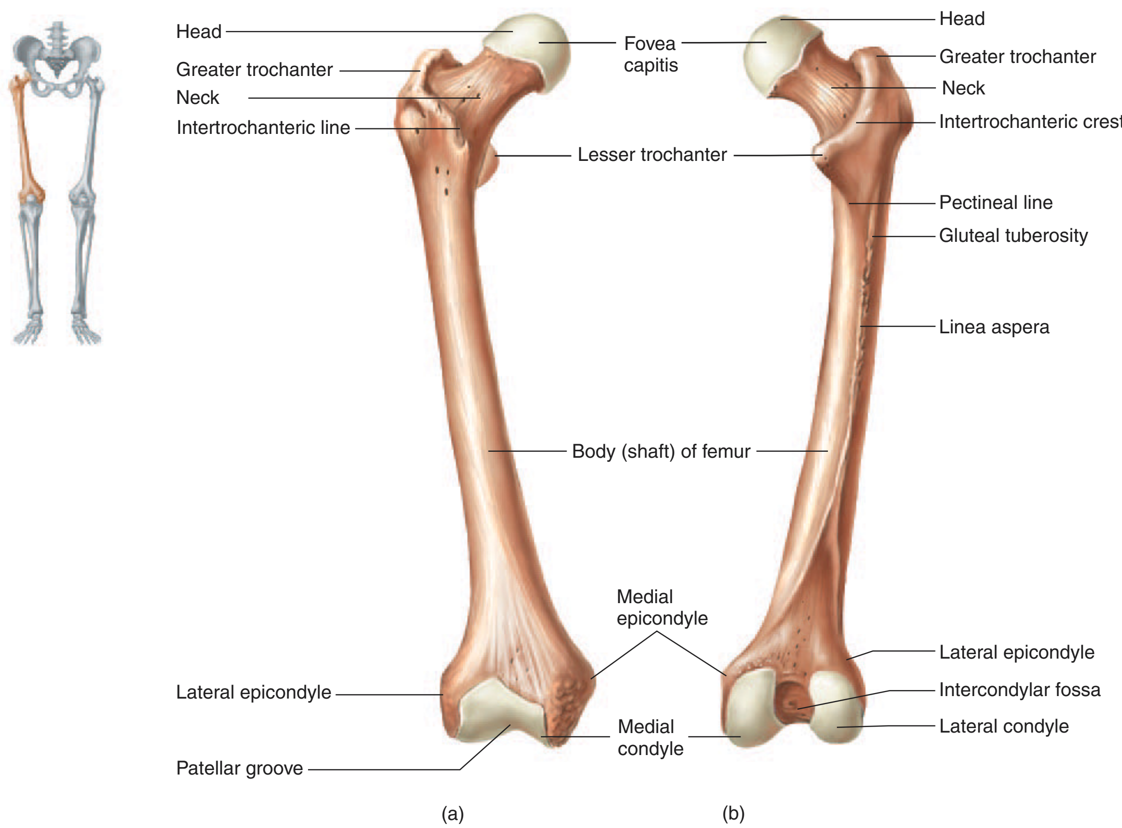


Figure 7.39 Right Femur

(*a*) Anterior view. (*b*) Posterior view.

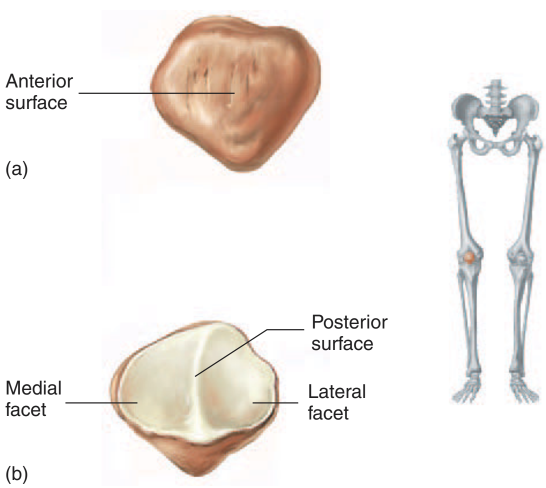


Figure 7.40 Right Patella

(*a*) Anterior view. (*b*) Posterior view.

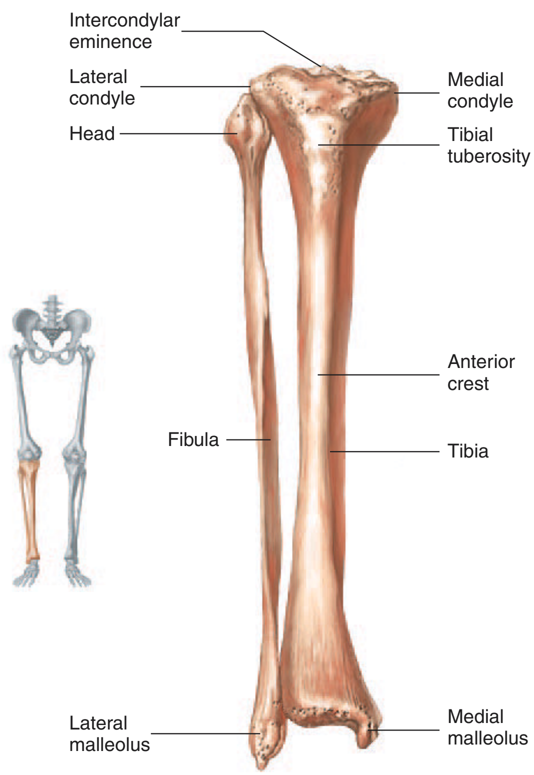


Figure 7.41 Right Tibia and Fibula, Anterior View

The **patella,** or kneecap, is a large sesamoid bone located within the tendon of the quadriceps femoris muscle group, which is the major muscle group of the anterior thigh (figure 7.40). The patella articulates with the patellar groove of the femur to create a smooth articular surface over the anterior distal end of the femur. The patella holds the tendon away from the distal end of the femur and therefore changes the angle of the tendon between the quadriceps femoris muscle and the tibia, where the tendon attaches. This change in angle increases the force that can be applied from the muscle to the tibia. As the result of this increase in applied force, less muscle contraction force is required to move the tibia.

Patellar Defects

If the patella is severely fractured, the tendon from the quadriceps femoris muscle group may be torn, resulting in a severe decrease in muscle function. In extreme cases, it may be necessary to remove the patella to repair the tendon. Removal of the patella results in a decrease in the amount of power the quadriceps femoris muscle can generate at the tibia.

The patella normally tracks in the patellar groove on the anterodistal end of the femur. Abnormal tracking of the patella can become a problem in some teenagers, especially females. As the young woman's hips widen during puberty, the angles at the joints between the hips and the tibia may change considerably. As the knee becomes located more medially relative to the hip, the patella may be forced to track more laterally than normal. This lateral tracking may result in pain in the knees of some young athletes.

Leg

The leg is the part of the lower limb between the knee and the ankle. Like the forearm, it consists of two bones: the **tibia** (tib′ē-ă; or shinbone) and the **fibula** (fib′ū-lă; resembling a clasp or buckle; figure 7.41). The tibia is by far the larger of the two and supports most of the weight of the leg. A **tibial tuberosity,** which is the attachment point for the quadriceps femoris muscle group, can easily be seen and felt just inferior to the patella (figure 7.42). The **anterior crest** forms the shin. The proximal end of the tibia has flat **medial** and **lateral condyles,** which articulate with the condyles of the femur. Located between the condyles is the **intercondylar eminence,** which is a ridge between the two articular surfaces of the proximal tibia. The distal end of the tibia is enlarged to form the **medial malleolus** (ma-lē′ō-lŭs; mallet-shaped), which helps form the medial side of the ankle joint.

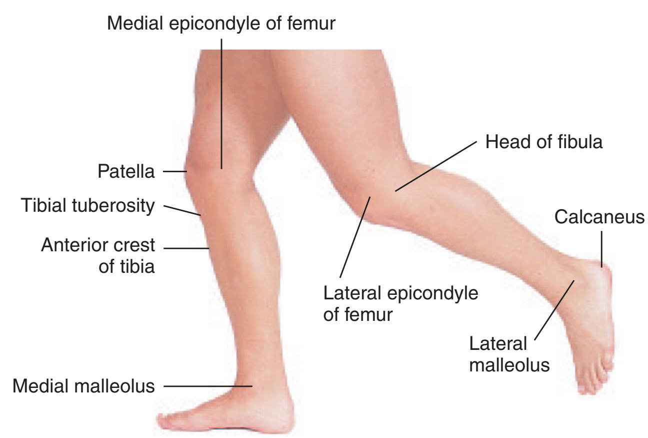


Figure 7.42 Surface Anatomy Showing Bones of the Lower Limb

The fibula does not articulate with the femur but has a small proximal head where it articulates with the tibia. The distal end of the fibula is slightly enlarged as the **lateral malleolus** to create the lateral wall of the ankle joint. The lateral and medial malleoli can be felt and seen as prominent lumps on either side of the ankle (see figure 7.42). The thinnest, weakest portion of the fibula is just proximal to the lateral malleolus.

P R E D I C T 8

Explain why modern ski boots are designed with high tops that extend partway up the leg.

Foot

The proximal portion of the foot consists of seven **tarsal** (tar′săl; the sole of the foot) **bones,** which are depicted and named in figure 7.43. The **talus** (tā′lŭs; ankle bone), or ankle bone, articulates with the tibia and the fibula to form the ankle joint. The **calcaneus** (kal-kā′nē-us; heel) is located inferior to the talus and supports that bone. The calcaneus protrudes posteriorly where the calf muscles attach to it and where it can be easily felt as the heel of the foot. The proximal foot is relatively much larger than the wrist.

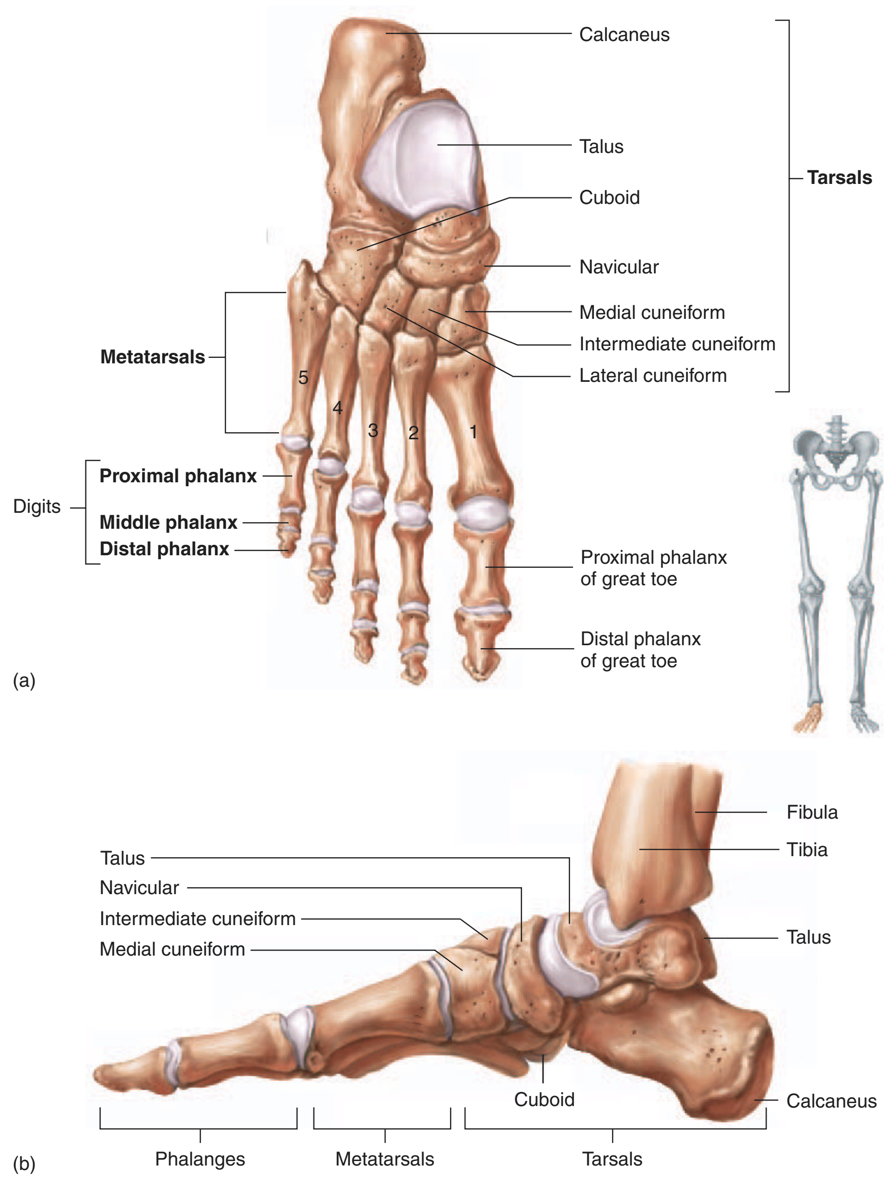


Figure 7.43 **Bones of the Right Foot**

(*a*) Dorsal view. (*b*) Medial view.

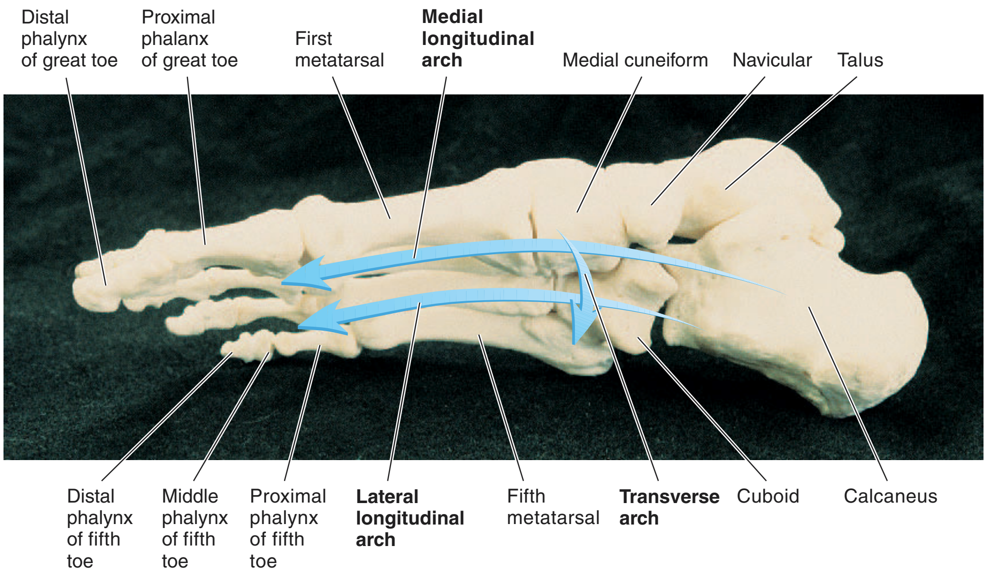


Figure 7.44 Arches (*arrows*) of the Right Foot

The medial longitudinal arch is formed by the calcaneus, talus, navicular, cuneiforms, and three medial metatarsals. The lateral longitudinal arch is formed by the calcaneus, cuboid, and two lateral metatarsals. The transverse arch is formed by the cuboid and cuneiforms.

The **metatarsals** and **phalanges** of the foot are arranged in a manner very similar to that of the metacarpals and phalanges of the hand, with the great toe analogous to the thumb (see figure 7.43*a*). Small sesamoid bones often form in the tendons of muscles attached to the great toe. The ball of the foot is the junction between the metatarsals and phalanges. The foot as a unit is convex dorsally and concave ventrally to form the arches of the foot (described more fully in chapter 8).

PREDICT 9

A decubitus ulcer is a chronic ulcer that appears in pressure areas of skin overlying a bony prominence in bedridden or otherwise immobilized patients. Where are likely sites for decubitus ulcers to occur?

Arches of the Foot

The foot has three major **arches** that distribute the weight of the body between the heel and the ball of the foot during standing and walking (figure 7.44). As the foot is placed on the ground, weight is transferred from the tibia and the fibula to the talus. From there, the weight is distributed first to the heel (calcaneus) and then through the arch system along the lateral side of the foot to the ball of the foot (head of the metatarsals). This effect can be observed when a person with wet, bare feet walks across a dry surface; the print of the heel, the lateral border of the foot, and the ball of the foot can be seen, but the middle of the plantar surface and the medial border leave no impression. The medial side leaves no mark because the arches on this side of the foot are higher than those on the lateral side. The shape of the arches is maintained by the configuration of the bones, the ligaments connecting them, and the muscles acting on the foot.

31. ***What is the function of the greater trochanter and the lesser trochanter?***
32. ***Describe the function of the patella.***
33. ***Name the bones of the leg.***
34. ***Give the points of articulation between the pelvis, femur, leg, and ankle.***
35. ***What is the function of the tibial tuberosity?***
36. ***Name the seven tarsal bones. Which bones form the ankle joint? What bone forms the heel?***
37. ***Describe the bones of the foot. How many phalanges are in each toe?***

SUMMARY

The gross anatomy of the skeletal system considers the features of bone, cartilage, tendons, and ligaments that can be seen without the use of a microscope. Dried, prepared bones display the major features of bone but obscure the relationship between bone and soft tissue.

General Considerations (p. 198)

Bones have processes, smooth surfaces, and holes that are associated with ligaments, muscles, joints, nerves, and blood vessels.

Axial Skeleton (p. 200)

The axial skeleton consists of the skull, hyoid bone, vertebral column, and thoracic cage.

Skull

1. The skull, or cranium, can be thought of as a single unit.
2. The parietal bones are joined at the midline by the sagittal suture; they are joined to the frontal bone by the coronal suture, to the occipital bone by the lambdoid suture, and to the temporal bone by the squamous suture.
3. Nuchal lines are the points of attachment for neck muscles.
4. Several skull features are seen from a lateral view.
   - The external auditory meatus transmits sound waves toward the eardrum.
   - Important neck muscles attach to the mastoid process.
   - The temporal lines are attachment points of the temporalis muscle.
   - The zygomatic arch, from the temporal and zygomatic bones, forms a bridge across the side of the skull.
5. Several skull features are seen from a frontal view.
   - The orbits contain the eyes.
   - The nasal cavity is divided by the nasal septum, and the hard palate separates the nasal cavity from the oral cavity.
   - Sinuses within bone are air-filled cavities. The paranasal sinuses, which connect to the nasal cavity, are the frontal, ethmoidal, sphenoidal, and maxillary sinuses.
   - The mandible articulates with the temporal bone.
6. Several skull features are seen inside the cranial cavity.
   - The crista galli is a point of attachment for one of the meninges.
   - The olfactory nerves extend into the roof of the nasal cavity through the cribriform plate.
   - The sella turcica is occupied by the pituitary gland.
   - The spinal cord and brain are connected through the foramen magnum.
7. Several features are seen on the inferior surface of the skull.
   - Occipital condyles are points of articulation between the skull and the vertebral column.
   - Blood reaches the brain through the internal carotid arteries, which pass through the carotid canals, and the vertebral arteries, which pass through the foramen magnum.
   - Most blood leaves the brain through the internal jugular veins, which exit through the jugular foramina.
   - Styloid processes provide attachment points for three muscles involved in movement of the tongue, hyoid bone, and pharynx.
   - The hard palate forms the floor of the nasal cavity.
8. The skull is composed of 22 bones.
   - The auditory ossicles, which function in hearing, are located inside the temporal bones.
   - The braincase protects the brain.
   - The facial bones protect the sensory organs of the head and function as muscle attachment sites (mastication, facial expression, and eye muscles).
   - The mandible and maxillae possess alveolar processes with sockets for the attachment of the teeth.

Hyoid

The hyoid bone, which "floats" in the neck, is the attachment site for throat and tongue muscles.

Vertebral Column

1. The vertebral column provides flexible support and protects the spinal cord.
2. The vertebral column has four major curvatures: cervical, thoracic, lumbar, and sacral/coccygeal. Abnormal curvatures are lordosis (lumbar), kyphosis (thoracic), and scoliosis (lateral).
3. Adjacent bodies are separated by intervertebral disks. The disk has a fibrous outer covering (annulus fibrosus) surrounding a gelatinous interior (nucleus pulposus).
4. A typical vertebra consists of a body, a vertebral arch, and various processes.
   - Part of the body and the vertebral arch (pedicle and lamina) form the vertebral foramen, which contains and protects the spinal cord.
   - Spinal nerves exit through the intervertebral foramina.
   - The transverse and spinous processes serve as points of muscle and ligament attachment.
   - Vertebrae articulate with one another through the superior and inferior articular processes.
5. Several types of vertebrae can be distinguished.
   - All seven cervical vertebrae have transverse foramina, and most have bifid spinous processes.
   - The 12 thoracic vertebrae are characterized by long, downward-pointing spinous processes and demifacets.
   - The five lumbar vertebrae have thick, heavy bodies and processes.
   - The sacrum consists of five fused vertebrae and attaches to the coxae to form the pelvis.
   - The coccyx consists of four fused vertebrae attached to the sacrum.

Thoracic Cage

1. The thoracic cage (consisting of the ribs, their associated costal cartilages, and the sternum) functions to protect the thoracic organs and changes volume during respiration.
2. Twelve pairs of ribs attach to the thoracic vertebrae. They are divided into seven pairs of true ribs and five pairs of false ribs. Two pairs of false ribs are floating ribs.
3. The sternum is composed of the manubrium, the body, and the xiphoid process.

Appendicular Skeleton (p. 225)

The appendicular skeleton consists of the upper and lower limbs and the girdles that attach the limbs to the body.

Pectoral Girdle and Upper Limb

1. The upper limb is attached loosely and functions in grasping and manipulation.
2. The pectoral girdle consists of the scapulae and clavicles.
   - The scapula articulates with the humerus and the clavicle. It serves as an attachment site for shoulder, back, and arm muscles.
   - The clavicle holds the shoulder away from the body, permitting free movement of the arm.
3. The arm bone is the humerus.
   - The humerus articulates with the scapula (head), the radius (capitulum), and the ulna (trochlea).
   - Sites of muscle attachment are the greater and lesser tubercles, the deltoid tuberosity, and the epicondyles.

4. The forearm contains the ulna and radius.
   - The ulna and the radius articulate with each other and with the humerus and the wrist bones.
   - The wrist ligaments attach to the styloid processes of the radius and the ulna.
5. Eight carpal, or wrist, bones are arranged in two rows.
6. The hand consists of five metacarpal bones.
7. The phalanges are digital bones. Each finger has three phalanges, and the thumb has two phalanges.

Pelvic Girdle and Lower Limb

1. The lower limb is attached solidly to the coxa and functions in support and movement.
2. The pelvic girdle consists of the right and left coxae. Each coxa is formed by the fusion of the ilium, the ischium, and the pubis.
   - The coxae articulate with each other (symphysis pubis) and with the sacrum (sacroiliac joint) and the femur (acetabulum).
   - Important sites of muscle attachment are the iliac crest, the iliac spines, and the ischial tuberosity.
   - The female pelvis has a larger pelvic inlet and outlet than the male pelvis.
3. The thigh bone is the femur.
   - The femur articulates with the coxa (head), the tibia (medial and lateral condyles), and the patella (patellar groove).
   - Sites of muscle attachment are the greater and lesser trochanters.
   - Sites of ligament attachment are the lateral and medial epicondyles.
4. The leg consists of the tibia and the fibula.
   - The tibia articulates with the femur, the fibula, and the talus. The fibula articulates with the tibia and the talus.
   - Tendons from the thigh muscles attach to the tibial tuberosity.
5. Seven tarsal bones form the proximal portion of the foot.
6. The foot consists of five metatarsal bones.
7. The toes have three phalanges each, except for the big toe, which has two.
8. The bony arches transfer weight from the heels to the toes and allow the foot to conform to many different positions.

R E V I E W A N D C O M P R E H E N S I O N

1. Which of these is part of the appendicular skeleton?
   a. cranium
   b. ribs
   c. clavicle
   d. sternum
   e. vertebra
2. A knoblike lump on a bone is called a
   a. spine.
   b. facet.
   c. tuberosity.
   d. sulcus.
   e. ramus.
3. The superior and middle nasal conchae are formed by projections of the
   a. sphenoid bone.
   b. vomer bone.
   c. palatine process of maxillae.
   d. palatine bone.
   e. ethmoid bone.
4. The crista galli
   a. separates the nasal cavity into two parts.
   b. attaches the hyoid bone to the skull.
   c. holds the pituitary gland.
   d. is an attachment site for the membranes that surround the brain.
   e. is a passageway for blood vessels.
5. The perpendicular plate of the ethmoid and the ______________ form the nasal septum.
   a. palatine process of the maxilla
   b. horizontal plate of the palatine
   c. vomer
   d. nasal bone
   e. lacrimal bone
6. Which of these bones does *not* contain a paranasal sinus?
   a. ethmoid
   b. sphenoid
   c. frontal
   d. temporal
   e. maxilla
7. The mandible articulates with the skull at the
   a. styloid process.
   b. occipital condyle.
   c. mandibular fossa.
   d. zygomatic arch.
   e. medial pterygoid.
8. The nerves for the sense of smell pass through the
   a. cribriform plate.
   b. nasolacrimal canal.
   c. internal auditory meatus.
   d. optic foramen.
   e. orbital fissure.
9. The major blood supply to the brain enters through the
   a. foramen magnum.
   b. carotid canals.
   c. jugular foramina.
   d. both a and b.
   e. all of the above.
10. The site of the sella turcica is the
    a. sphenoid bone.
    b. maxillae.
    c. frontal bone.
    d. ethmoid bone.
    e. temporal bone.
11. Which of these bones is *not* in contact with the sphenoid bone?
    a. maxilla
    b. inferior nasal concha
    c. ethmoid
    d. parietal
    e. vomer
12. Which of these statements about vertebral column curvature is *not* true?
    a. The cervical curvature develops before birth.
    b. The thoracic curvature becomes exaggerated in kyphosis.
    c. The lumbar curvature becomes exaggerated in lordosis.
    d. The sacral curvature develops before birth.
    e. The lumbar curvature develops as an infant learns to sit and walk.

13. A herniated disk occurs when
    a. the annulus fibrosus ruptures.
    b. the intervertebral disk slips out of place.
    c. the spinal cord ruptures.
    d. too much fluid builds up in the nucleus pulposus.
    e. all of the above.
14. The weight-bearing portion of a vertebra is the
    a. vertebral arch.
    b. articular process.
    c. body.
    d. transverse process.
    e. spinous process.
15. Transverse foramina are found only in
    a. cervical vertebrae.
    b. thoracic vertebrae.
    c. lumbar vertebrae.
    d. the sacrum.
    e. the coccyx.
16. Articular facets on the bodies and transverse processes are found only on
    a. cervical vertebrae.
    b. thoracic vertebrae.
    c. lumbar vertebrae.
    d. the sacrum.
    e. the coccyx.
17. Medially facing, superior articular processes and laterally facing, inferior articular processes are found on
    a. cervical vertebrae.
    b. thoracic vertebrae.
    c. lumbar vertebrae.
    d. the sacrum.
    e. the coccyx.
18. Which of these statements concerning ribs is true?
    a. The true ribs attach directly to the sternum with costal cartilage.
    b. There are five pairs of floating ribs.
    c. The head of the rib attaches to the transverse process of the vertebra.
    d. Vertebrochondral ribs are classified as true ribs.
    e. Floating ribs do not attach to vertebrae.
19. The point where the scapula and clavicle connect is the
    a. coracoid process.
    b. styloid process.
    c. glenoid fossa.
    d. acromion process.
    e. capitulum.
20. The distal medial process of the humerus to which the ulna joins is the
    a. epicondyle.
    b. deltoid tuberosity.
    c. malleolus.
    d. capitulum.
    e. trochlea
21. The depression on the anterior surface of the humerus that receives part of the ulna when the forearm is flexed (bent) is the
    a. glenoid fossa.
    b. capitulum.
    c. coronoid fossa.
    d. olecranon fossa.
    e. radial fossa.
22. Which of these is *not* a point of muscle attachment on the pectoral girdle or upper limb?
    a. epicondyles
    b. mastoid process
    c. radial tuberosity
    d. spine of scapula
    e. greater tubercle
23. Which of these parts of the upper limb are *not* correctly matched with the number of bones in that part?
    a. arm: 1
    b. forearm: 2
    c. wrist: 10
    d. palm of hand: 5
    e. fingers: 14
24. The ankle bone that the tibia rests upon is the
    a. talus.
    b. calcaneus.
    c. metatarsals.
    d. navicular.
    e. phalanges.
25. A place where nerves or blood vessels pass from the trunk to the lower limb is the
    a. obturator foramen.
    b. greater ischiadic (sciatic) notch.
    c. ischial tuberosity.
    d. iliac crest.
    e. pubis symphysis.
26. A projection on the pelvic girdle that is used as a landmark for finding an injection site is the
    a. ischial tuberosity.
    b. iliac crest.
    c. anterior superior iliac spine.
    d. posterior inferior iliac spine.
    e. ischial spine.
27. When comparing the pectoral girdle to the pelvic girdle, which of these statements is true?
    a. The pectoral girdle has greater mass than the pelvic girdle.
    b. The pelvic girdle is more firmly attached to the body than the pectoral girdle.
    c. The pectoral girdle has the limbs more securely attached than the pelvic girdle.
    d. The pelvic girdle allows greater mobility than the pectoral girdle.
28. When comparing a male pelvis to a female pelvis, which of these statements is true?
    a. The pelvic inlet in males is larger and more circular.
    b. The subpubic angle in females is less than 90 degrees.
    c. The ischial spines in males are closer together.
    d. The sacrum in males is broader and less curved.
29. A site of muscle attachment on the proximal end of the femur is the
    a. greater trochanter.
    b. epicondyle.
    c. greater tubercle.
    d. intercondylar eminence.
    e. condyle.
30. A process that forms the outer ankle is the lateral
    a. malleolus.
    b. condyle.
    c. epicondyle.
    d. tuberosity.
    e. tubercle.

Answers in Appendix F

CRITICAL THINKING

1. A patient has an infection in the nasal cavity. Name seven adjacent structures to which the infection could spread.
2. A patient is unconscious. Radiographic films reveal that the superior articular process of the atlas has been fractured. Which of the following could have produced this condition: falling on the top of the head or being hit in the jaw with an uppercut? Explain.
3. If the vertebral column is forcefully rotated, what part of the vertebra is most likely to be damaged? In what area of the vertebral column is such damage most likely?
4. An asymmetric weakness of the back muscles can produce which of the following: scoliosis, kyphosis, or lordosis? Which could result from pregnancy? Explain.
5. What might be the consequences of a broken forearm involving both the ulna and radius when the ulna and radius fuse to each other during repair of the fracture?
6. Suppose you need to compare the length of one lower limb to the other in an individual. Using bony landmarks, suggest an easy way to accomplish the measurements.
7. A paraplegic individual develops decubitus ulcers (pressure sores) on the buttocks from sitting in a wheelchair for extended periods. Name the bony protuberance responsible.
8. Why are women knock-kneed more often than men?
9. On the basis of bone structure of the lower limb, explain why it's easier to turn the foot medially (sole of the foot facing toward the midline of the body) than laterally. Why is it easier to cock the wrist medially than laterally?
10. Justin Time leaped from his hotel room to avoid burning to death in a fire. If he landed on his heels, what bone was he likely to fracture? Unfortunately for Justin, a 240 lb fire fighter, Hefty Stomper, ran by and stepped heavily on the proximal part of Justin's foot (not the toes). What bones could now be broken?

Answers in Appendix G

ANSWERS TO PREDICT QUESTIONS

1. The sagittal suture is so named because it is in line with the midsagittal plane of the head. The coronal suture is so named because it is in line with the coronal plane (see chapter 1).
2. The bones most often broken in a "broken nose" are the nasals, ethmoid, vomer, and maxillae.
3. The lumbar vertebrae support a greater weight than the other vertebrae. The vertebrae are more massive because of the greater weight they support.
4. The anterior support of the scapula is lost with a broken clavicle, and the shoulder is located more inferiorly and anteriorly than normal. In addition, since the clavicle normally holds the upper limb away from the body, the upper limb moves medially and rests against the side of the body.
5. The olecranon process moves into the olecranon fossa as the elbow is straightened. The coronoid process moves into the coronoid fossa as the elbow is bent.
6. The dried skeleton seems to have longer "fingers" than the hand with soft tissue intact because the soft tissue fills in the space between the metacarpals. With the soft tissue gone, the metacarpals seem to be an extension of the fingers, which appear to extend from the most distal phalanx to the carpals.
7. The depth of the hip socket is deeper, the bone is more massive, and the tubercles are larger than similar structures in the upper limb. All of this correlates with the weight-bearing nature of the lower limb and the more massive muscles necessary for moving the lower limb compared to the upper limb.
8. The top of modern ski boots is placed high up the leg to protect the weakest point of the fibula and make it less susceptible to great strain during a fall. Modern ski boots are also designed to reduce ankle mobility, which increases comfort and performance.
9. Decubitus ulcers form over bony prominences where the bone is close to the overlying skin and where the body contacts the bed when lying down. Such sites are the back and front of the skull and the cheeks (over zygomatic bones), the acromion process, scapula, olecranon process, coccyx, greater trochanter, lateral epicondyle of femur, patella, and lateral malleolus.

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