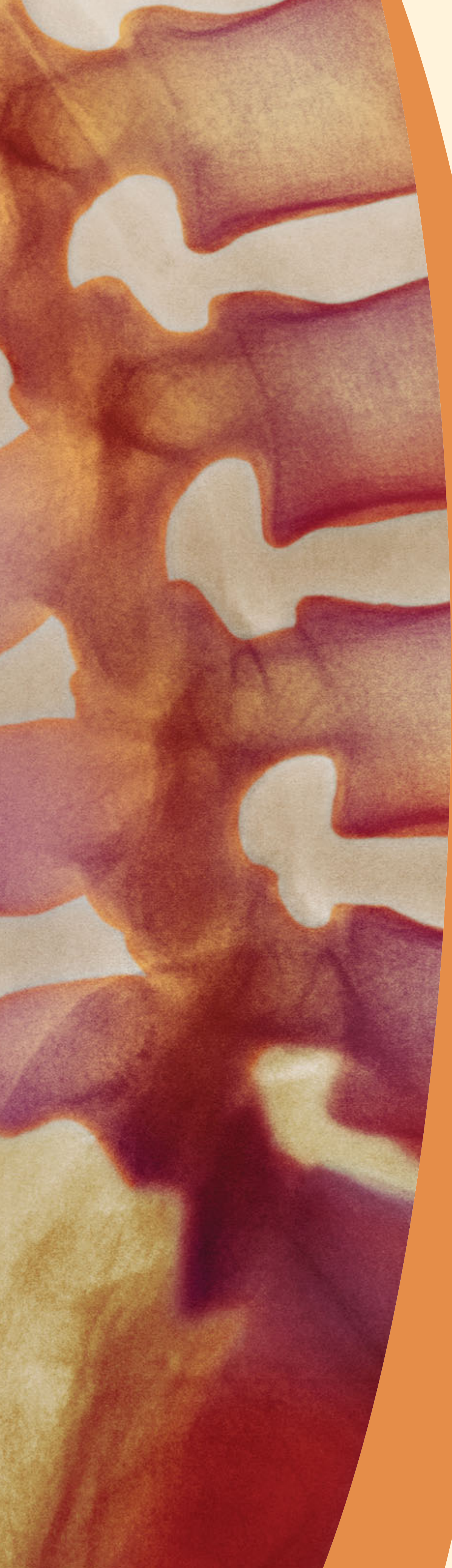


Bones, Part 1: The Axial Skeleton

7

A healthy lumbar spine, saggital view (colored X ray).

The word *skeleton* comes from a Greek word meaning "dried-up body" or "mummy," a rather disparaging description. Nonetheless, this internal framework is a greater triumph of design and engineering than any skyscraper. The skeleton is strong yet light, wonderfully adapted for the weight-bearing, locomotive, protective, and manipulative functions it performs.

The skeleton consists of **bones, cartilages, joints,** and **ligaments.** Joints, also called **articulations,** are the junctions between skeletal elements. Ligaments connect bones and reinforce most joints. Bones are described in this and the next chapter; joints and their ligaments are discussed in detail in Chapter 9.

The 206 named bones of the human skeleton are grouped into the axial and appendicular skeletons **(Figure 7.1)**. The

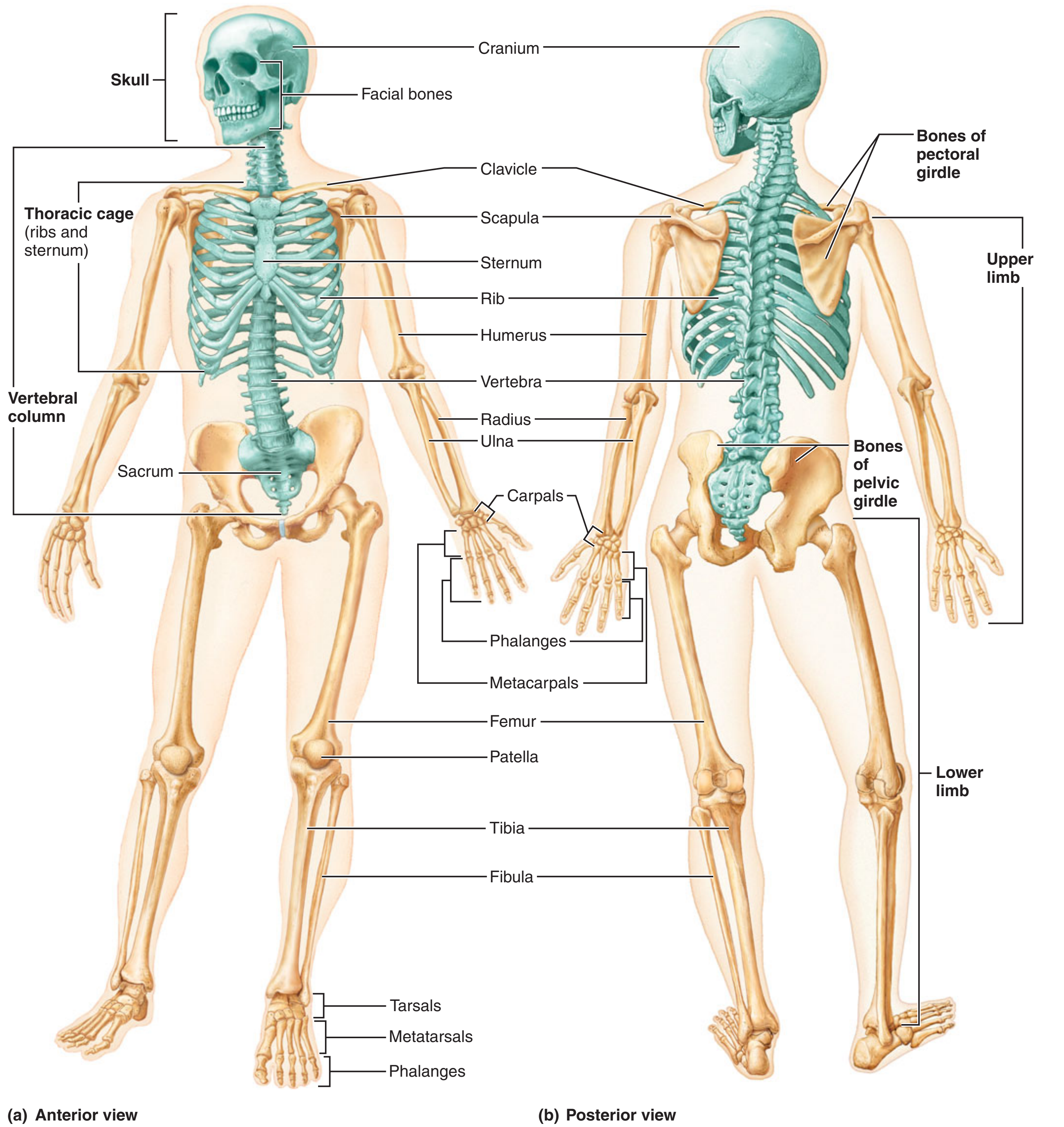


FIGURE 7.1 The human skeleton. Bones of the axial skeleton are colored green. Bones of the appendicular skeleton are tan.

appendicular (ap″en-dik′u-lar) **skeleton,** the subject of Chapter 8, consists of the bones of the upper and lower limbs, including the pectoral (shoulder) and pelvic girdles that attach the limbs to the axial skeleton.

The **axial skeleton,** which forms the long axis of the body, is the focus of this chapter. It has 80 named bones arranged into three major regions: the *skull, vertebral column,* and *thoracic cage* (see Figure 7.1). This axial division of the skeleton supports the head, neck, and trunk, and protects the brain, spinal cord, and the organs in the thorax.

THE SKULL

- Name and describe the bones of the skull. Identify their important features.
- Compare the functions of the cranial and facial bones.

The **skull** is the body's most complex bony structure. It is formed by cranial and facial bones **(Figure 7.2a)**. The *cranial bones,* or **cranium** (kra′ne-um), enclose and protect the brain and provide attachment sites for some head and neck muscles. The *facial bones* (1) form the framework of the face; (2) form cavities for the sense organs of sight, taste, and smell; (3) provide openings for the passage of air and food; (4) hold the teeth; and (5) anchor the muscles of the face.

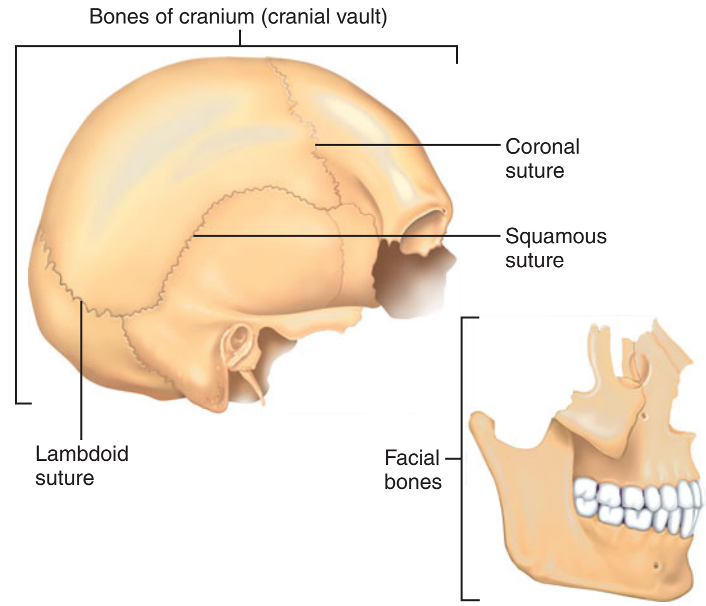
Most skull bones are flat bones and are firmly united by interlocking, immovable joints called sutures (soo′cherz; "seams"). The suture lines have an irregular, saw-toothed appearance. The longest sutures—the *coronal, sagittal, squamous,* and *lambdoid sutures*—connect the cranial bones. Most other skull sutures connect facial bones and are named according to the specific bones they connect.

Overview of Skull Geography

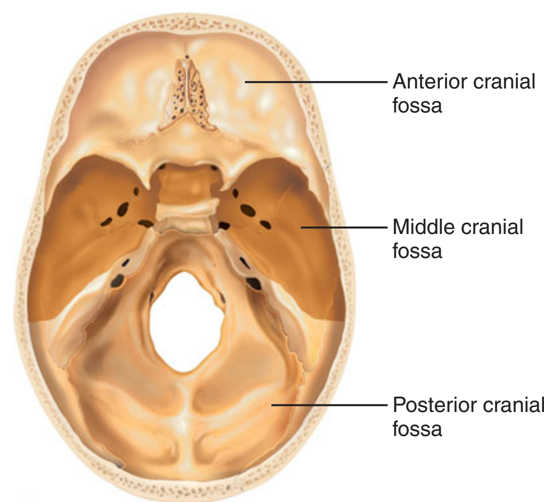
It is worth surveying basic skull "geography" before describing the individual bones. With the lower jaw removed, the skull resembles a lopsided, hollow, bony sphere. The facial bones form its anterior aspect, and the cranium forms the rest. The cranium can be divided into a vault and a base. The *cranial vault,* also called the *calvaria* (kal-va′re-ah; "bald part of skull") or skullcap, forms the superior, lateral, and posterior aspects of the skull, as well as the forehead region. The *cranial base,* or *floor,* is the inferior part. Internally, prominent bony ridges divide the cranial base into three distinct "steps," or fossae—the anterior, middle, and posterior *cranial fossae* (Figure 7.2b). The brain sits snugly in these cranial fossae and is completely enclosed by the cranial vault (Figure 7.2c). Overall, the brain is said to occupy the *cranial cavity.*

In addition to its large cranial cavity, the skull contains many smaller cavities, including the *middle ear* and *inner ear cavities* (carved into the lateral aspects of the cranial base), the *nasal cavity,* and the *orbits* **(Figure 7.3)**. The nasal cavity lies in and posterior to the nose, and the orbits house the eyeballs. Air-filled sinuses that occur in several bones around the nasal cavity are the *paranasal sinuses.*

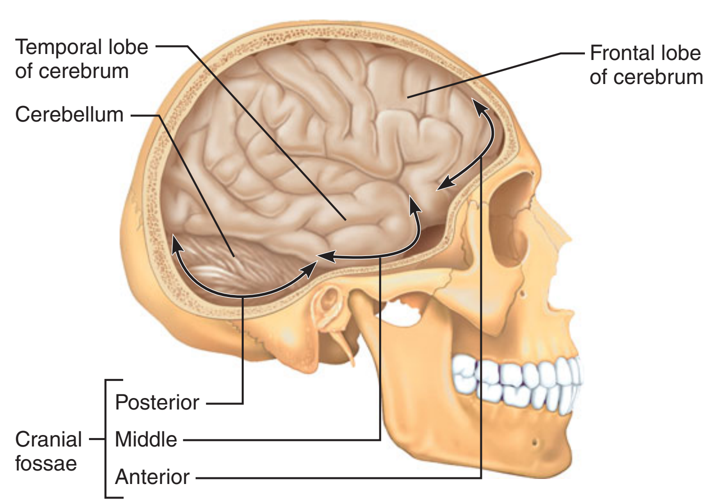
Moreover, the skull has about 85 named openings (foramina, canals, fissures). The most important of these provide passageways for the spinal cord, the major blood



(a) Cranial and facial divisions of the skull



(b) Superior view of the cranial fossae



(c) Lateral view of cranial fossae showing the contained brain regions

FIGURE 7.2 The skull: cranial and facial divisions and fossae.

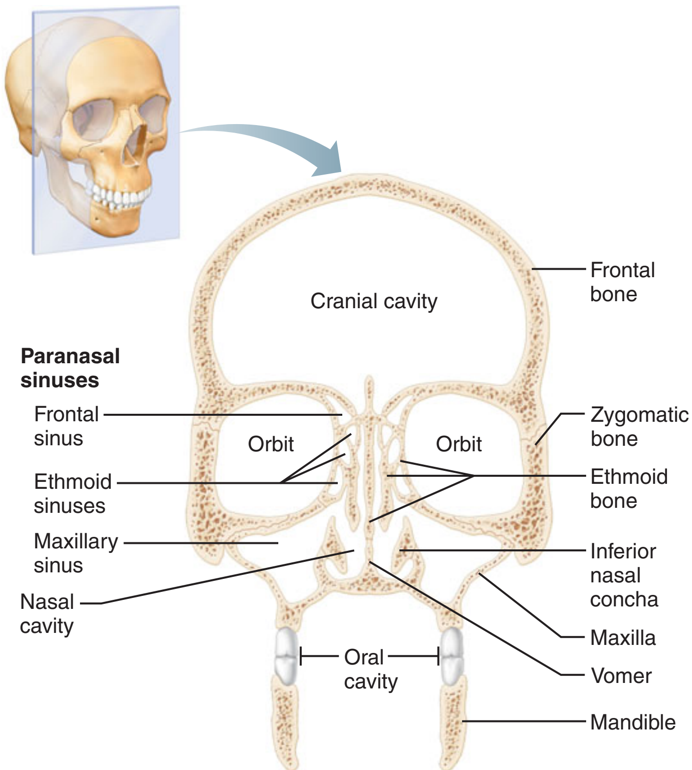


FIGURE 7.3 Major cavities of the skull, frontal section.

vessels serving the brain, and the 12 pairs of *cranial nerves,* which conduct impulses to and from the brain. Cranial nerves, which are discussed in Chapter 14, p. 431, are classified by number, using the Roman numerals I through XII.

The skull bones and their features are illustrated in Figures 7.3–7.16 and summarized in **Table 7.1** on pp. 162–163. The colored box beside each bone's name corresponds to the color of that bone in the figures.

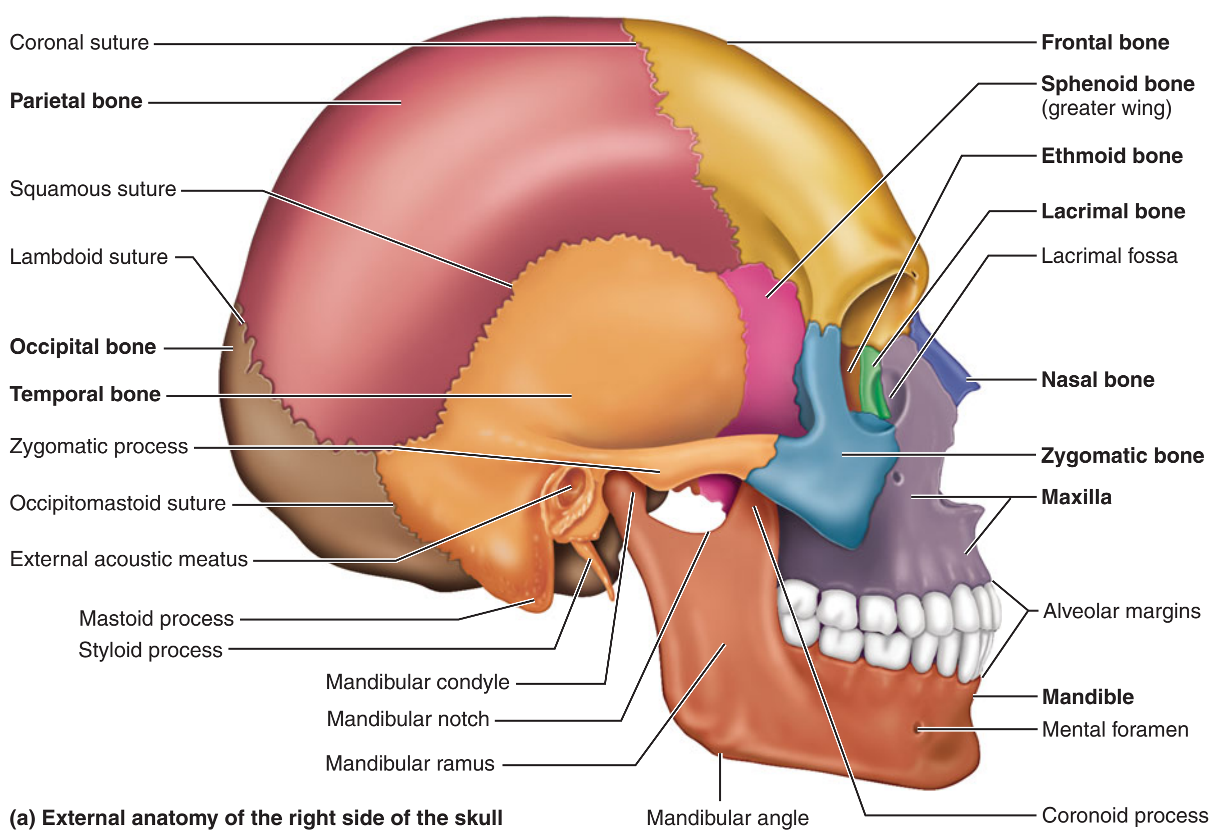
Cranial Bones

The eight large bones of the cranium are the paired parietal and temporal bones and the unpaired frontal, occipital, sphenoid, and ethmoid bones. Together these bones form the brain's protective "shell." Because its superior aspect is curved, the cranium is self-bracing. This allows the bones to be thin, and, like an eggshell, the cranium is remarkably strong for its weight.

Parietal Bones and the Major Sutures

(FIGURES 7.4 AND 7.5)

The two large **parietal bones,** shaped like curved rectangles, make up the bulk of the cranial vault; that is, they form most of the superior part of the skull, as well as its lateral walls (*parietal* = wall) **(Figure 7.4)**. The sites at which the parietal bones articulate (form a joint) with other cranial bones are the four largest sutures:



(a) External anatomy of the right side of the skull

FIGURE 7.4 Lateral aspect of the skull.

1. The **coronal suture,** running in the coronal plane, occurs anteriorly where the parietal bones meet the frontal bone.
2. A **squamous suture** occurs where each parietal bone meets a temporal bone inferiorly, on each lateral aspect of the skull.
3. The **sagittal suture** occurs where the right and left parietal bones meet superiorly in the midline of the cranium **(Figure 7.5)**.
4. The **lambdoid suture** occurs where the parietal bones meet the occipital bone posteriorly (Figures 7.4 and 7.5). This suture is so named because it resembles the Greek letter lambda (λ).

These sutures vary somewhat in appearance in different skulls. As a person ages, the sutural lines close up, making these sutures less noticeable.

Sutural Bones

Sutural bones are small bones that occur *within* the sutures, especially in the lambdoid suture (Figure 7.5). They are irregular in shape, size, and location, and not all people have them. They develop between the major cranial bones during the fetal period and persist throughout life. The significance of these bones is unknown.

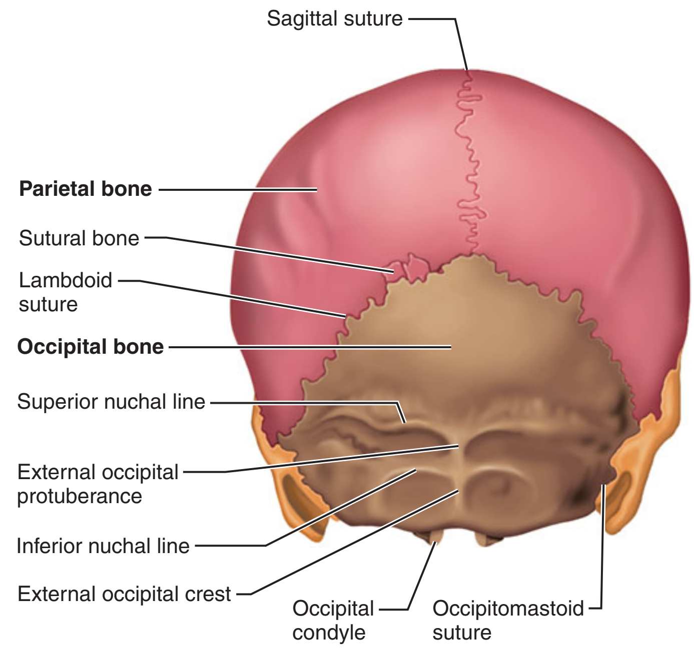
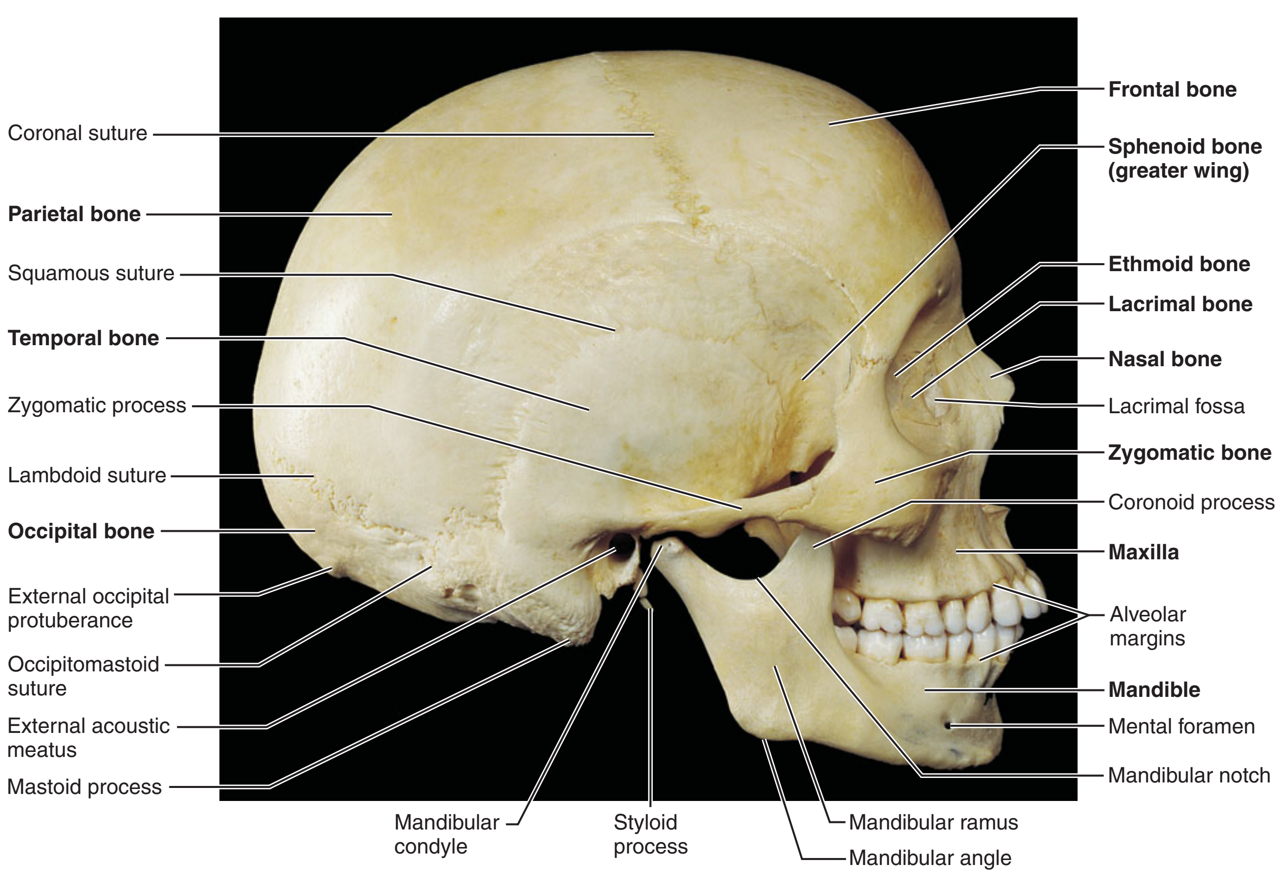


FIGURE 7.5 Posterior view of the skull.



(b) Photograph of right side of skull

FIGURE 7.4 Lateral aspect of the skull, *continued.*

Frontal Bone (FIGURE 7.6)

The **frontal bone** forms the forehead and the roofs of the orbits **(Figure 7.6)**. Just superior to the orbits, it protrudes slightly to form *superciliary* (soo″per-sil′e-a-re; "eyebrow") *arches,* which lie just deep to our eyebrows. The **supraorbital margin,** or superior margin of each orbit, is pierced by a hole or by a notch, respectively called the **supraorbital foramen** or *supraorbital notch.* This opening transmits the supraorbital nerve (a branch of cranial nerve V) and artery, which supply the forehead. The smooth part of the frontal bone between the superciliary arches in the midline is the **glabella** (glah-bel′ah; "smooth, without hair"). Just inferior to it, the frontal bone meets the nasal bones at the *frontonasal suture.* The regions of the frontal bone lateral to the glabella contain the air-filled **frontal sinuses** (see Figure 7.3).

Internally, the frontal bone contributes to the **anterior cranial fossa** (see Figures 7.2b and 7.9), which holds the large frontal lobes of the brain.

Occipital Bone (FIGURES 7.5 AND 7.7)

The **occipital bone** (ok-sip′ĭ-tal; "back of the head") makes up the posterior part of the cranium and cranial base (Figure 7.5). It articulates with the parietal bones at the lambdoid suture and with the temporal bones at the *occipitomastoid sutures* (Figure 7.4). Internally, it forms the walls of the **posterior cranial fossa,** which holds a part of the brain called the cerebellum (Figure 7.2). In the base of the occipital bone is the **foramen magnum,** literally, "large hole" **(Figure 7.7)**. Through this opening, the inferior part of the brain connects with the spinal cord. The foramen magnum is flanked laterally by two rockerlike **occipital condyles,** which articulate with the first vertebra of the vertebral column in a way that enables the head to nod "yes." Hidden medial and superior to each occipital condyle is a **hypoglossal** (hi″po-glos′al) **canal,** through which runs cranial nerve XII, the hypoglossal nerve. Anterior to the foramen magnum, the occipital bone joins the sphenoid bone via the basilar part of the occipital bone.

Several features occur on the external surface of the occipital bone (Figures 7.5 and 7.7). The **external occipital**

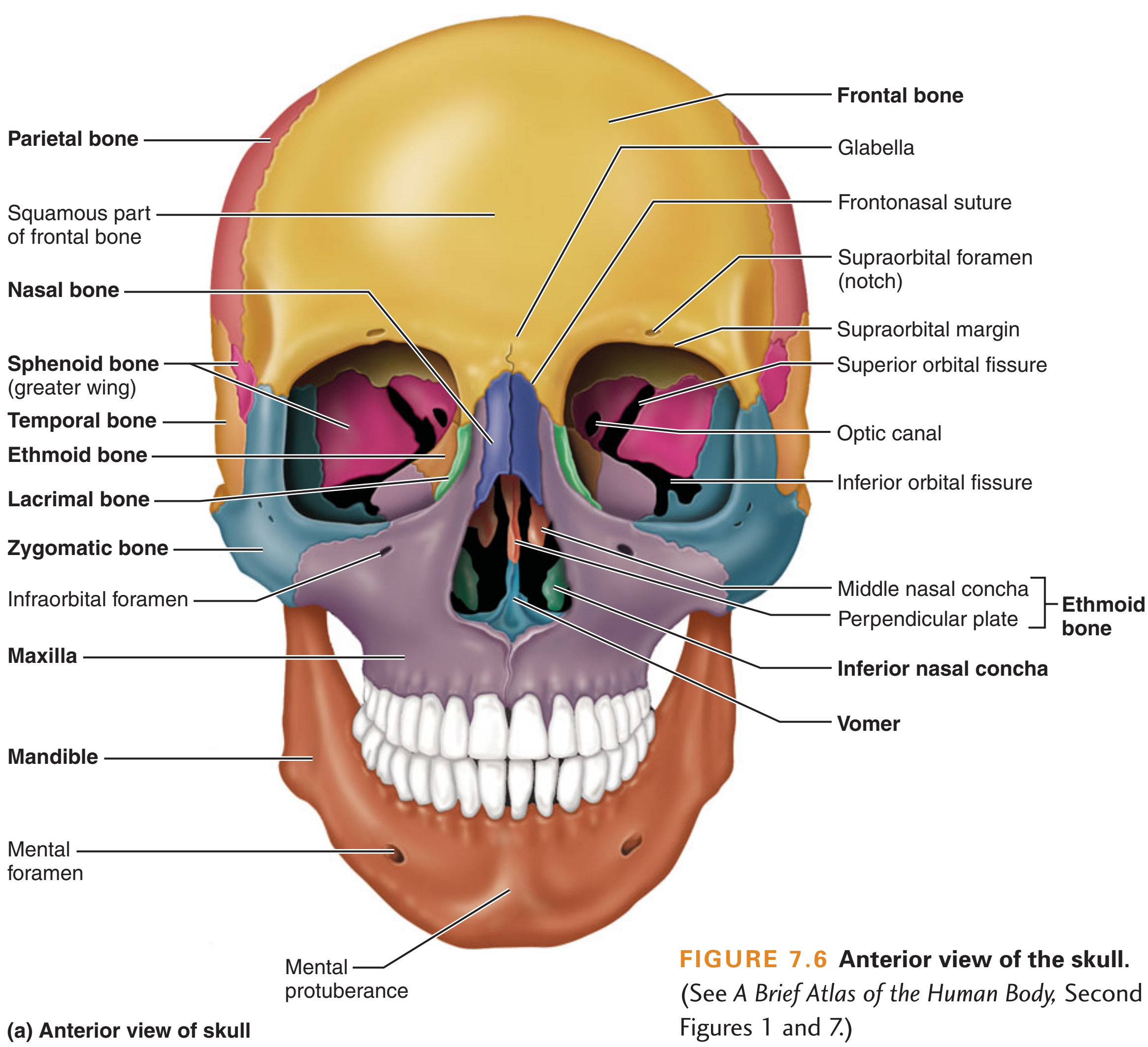


FIGURE 7.6 Anterior view of the skull. (See *A Brief Atlas of the Human Body,* Second Edition, Figures 1 and 7.)

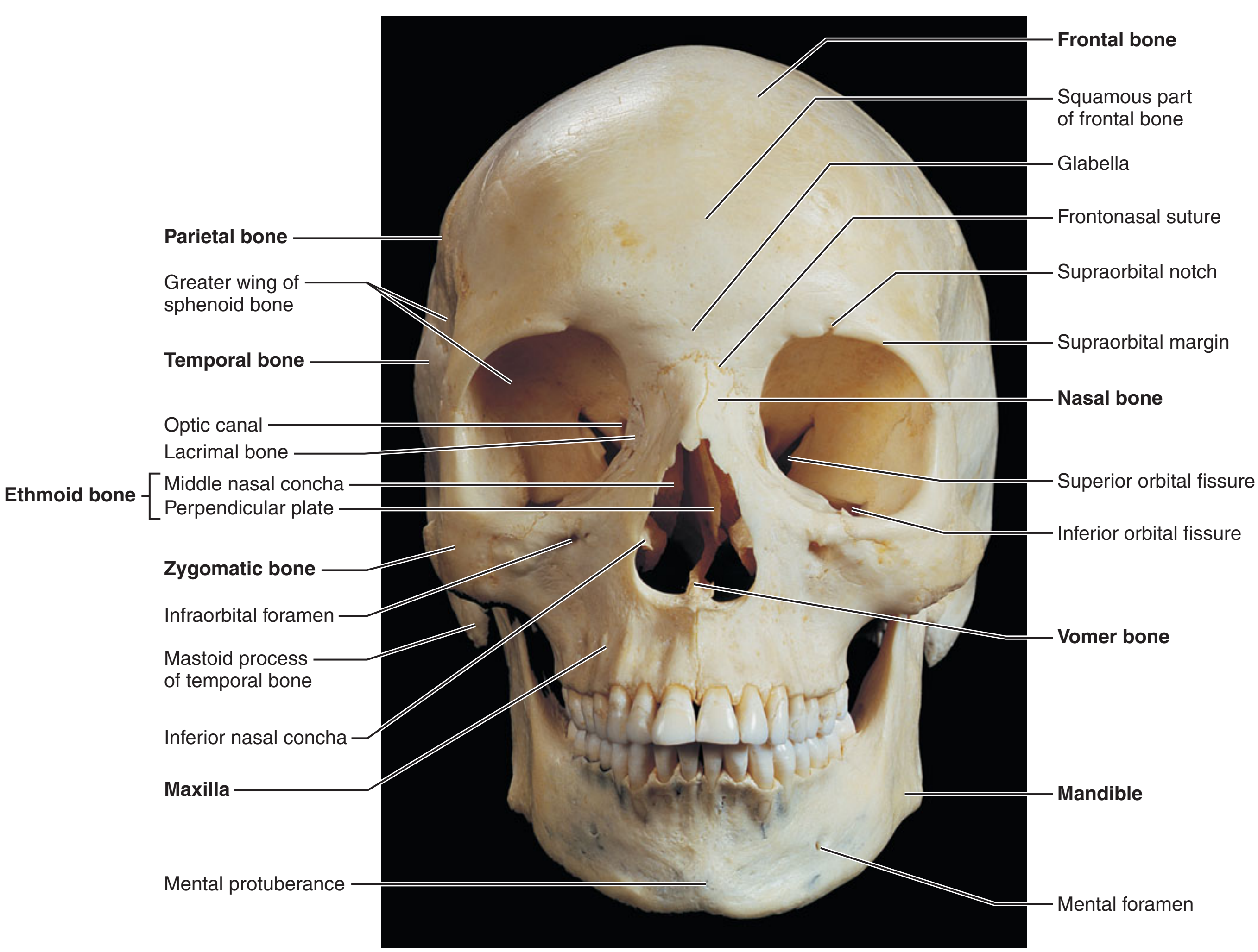
protuberance is a knob in the midline, at the junction of the base and the posterior wall of the skull. The *external occipital crest* extends anteriorly from the protuberance to the foramen magnum. This crest secures the *ligamentum nuchae* (nu′ke; "of the neck"), an elastic, sheet-shaped ligament that lies in the median plane of the posterior neck and connects the neck vertebrae to the skull. Extending laterally from the occipital protuberance are the **superior nuchal** (nu′kal) **lines,** and running laterally from a point halfway along the occipital crest are the **inferior nuchal lines.** The nuchal lines and the bony regions between them anchor many muscles of the neck and back. The superior nuchal line marks the upper limit of the neck.

Temporal Bones *(FIGURES 7.4 AND 7.8)*

The temporal bones are best viewed laterally (Figure 7.4). They lie inferior to the parietal bones and form the inferolateral region of the skull and parts of the cranial floor. The terms *temporal* and *temple,* from the Latin word for "time," refer to the fact that gray hairs, a sign of time's passage, appear first at the temples.

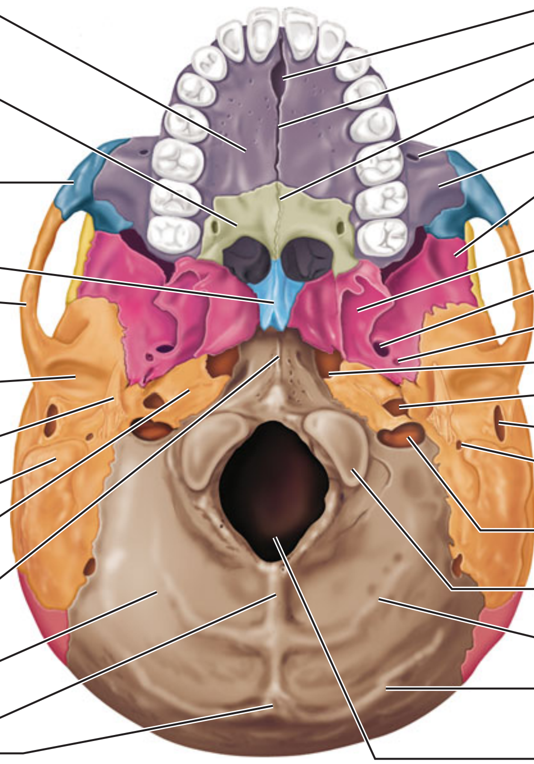
Each temporal bone has an intricate shape and is described in terms of its four major regions: the *squamous, tympanic, mastoid,* and *petrous regions.* The plate-shaped **squamous region (Figure 7.8)** abuts the squamous suture. It has a barlike **zygomatic process** (zi″go-mat′ik; "cheek") that projects anteriorly to meet the zygomatic bone of the face. Together, these two bony structures form the *zygomatic arch,* commonly called the cheek bone. The oval **mandibular** (man-dib′u-lar) **fossa** on the inferior surface of the zygomatic process receives the mandible (lower jawbone), forming the freely movable *temporomandibular joint* (jaw joint).

The **tympanic region** (tim-pan′ik; "eardrum") surrounds the **external acoustic meatus,** or external ear canal. It is through this canal that sound enters the ear. The external acoustic meatus and the tympanic membrane (eardrum) at its deep end are parts of the external ear. In a dried skull, the tympanic membrane has been removed. Thus, part of the *middle ear cavity* deep to the tympanic region may be visible through the meatus. Projecting inferiorly from the tympanic region is the needle-like **styloid process** (sti′loid; "stakelike"). This process is an attachment point for some muscles of the tongue

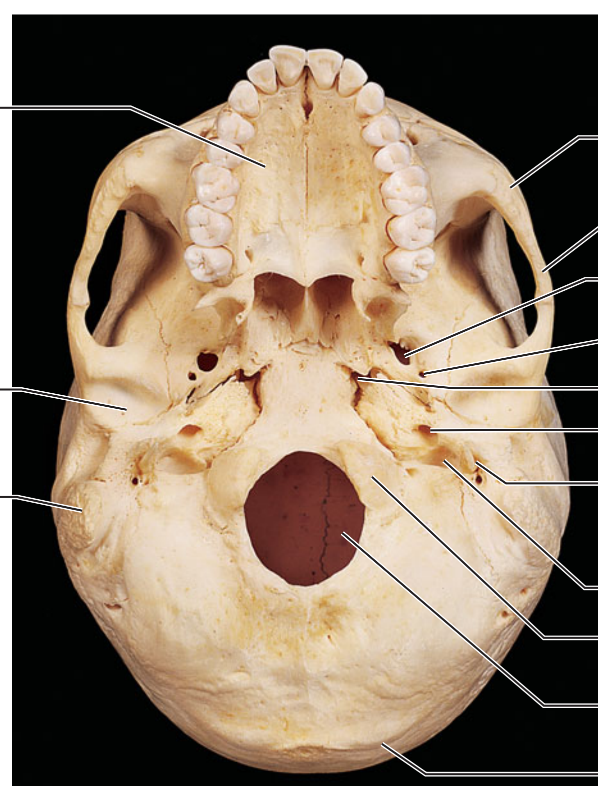


(b) Photo of anterior view of skull

FIGURE 7.6 Anterior view of the skull, *continued.*



(a) Inferior view of the skull (mandible removed)



(b) Photo of inferior view of the skull

FIGURE 7.7 Inferior aspect of the skull.

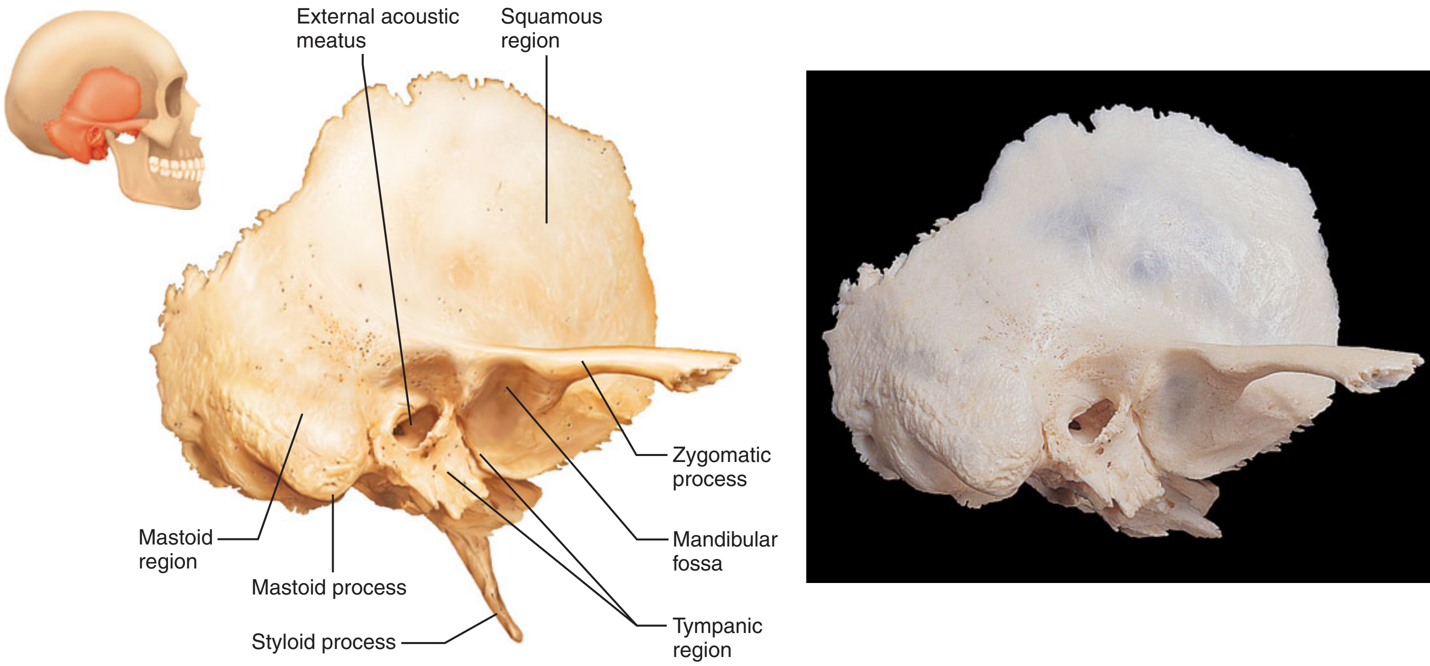


FIGURE 7.8 The temporal bone. Right lateral view. (See *A Brief Atlas of the Human Body,* Second Edition, Figures 2 and 8.)

and pharynx and for a ligament that connects the skull to the hyoid bone of the neck.

The **mastoid region** (mas′toid; "breast-shaped") has a prominent **mastoid process,** an anchoring site for some neck muscles. This process can be felt as a lump just posterior to the ear. The **stylomastoid foramen** (Figure 7.7a) is located between the styloid and mastoid processes. A branch of cranial nerve VII, the facial nerve, leaves the skull through this foramen.

The mastoid process is full of air sinuses called *mastoid air cells,* which lie just posterior to the middle ear cavity. Infections can spread from the throat to the middle ear to the mastoid cells. Such an infection, called *mastoiditis,* can even spread to the brain, from which the mastoid air cells are separated by only a thin roof of bone. This was a serious problem before the late 1940s, when antibiotics became available.

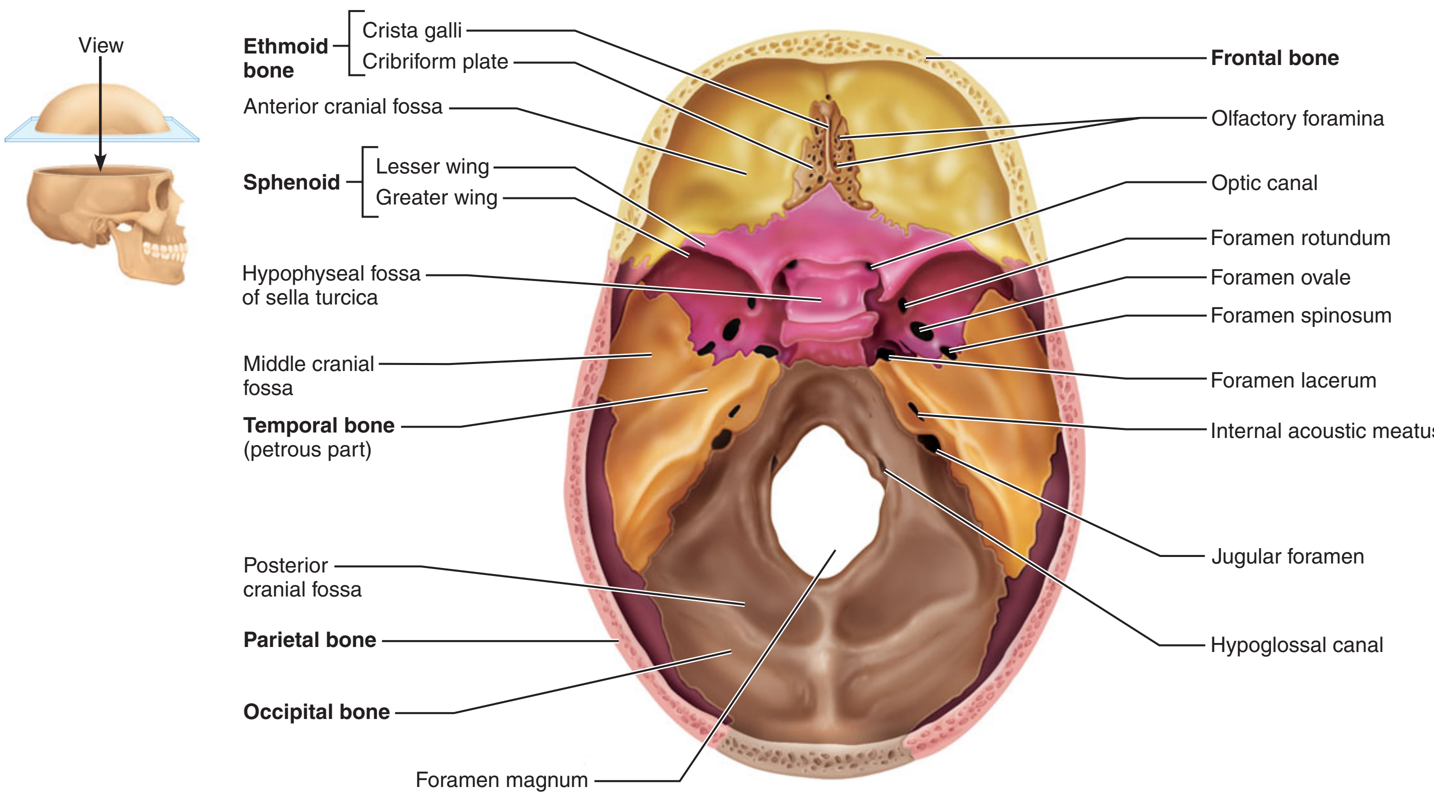
The **petrous** (pet′rus; "rocky") region of the temporal bone projects medially and contributes to the cranial base. It appears as a bony wedge between the occipital bone posteriorly and the sphenoid bone anteriorly (Figure 7.7a). From within the cranial cavity this very dense region looks like a mountain ridge **(Figure 7.9)**. The posterior slope of this ridge lies in the posterior cranial fossa, whereas the anterior slope is in the **middle cranial fossa,** the fossa that holds the temporal lobes of the brain. Housed inside the petrous region are the cavities of the middle and inner ear, which contain the sensory apparatus for hearing and balance.

Several foramina penetrate the bone of the petrous region (Figure 7.7a). The large **jugular foramen** is located where the petrous region joins the occipital bone. Through this foramen pass the largest vein of the head, the internal jugular vein, and cranial nerves IX, X, and XI. The **carotid** (ka-rot′id) **canal** opens in the petrous region on the skull's inferior aspect, just anterior to the jugular foramen. The internal carotid artery, the main artery to the brain, passes through it into the cranial cavity. The **foramen lacerum** (la′ser-um; "lacerated") is a jagged opening between the medial tip of the petrous portion of the temporal bone and the sphenoid bone. This foramen is almost completely closed by cartilage in a living person, but it is so conspicuous in a dried skull that students usually ask its name. The **internal acoustic meatus** lies in the cranial cavity on the posterior face of the petrous region (Figure 7.9). It transmits cranial nerves VII and VIII, the facial and vestibulocochlear nerves.

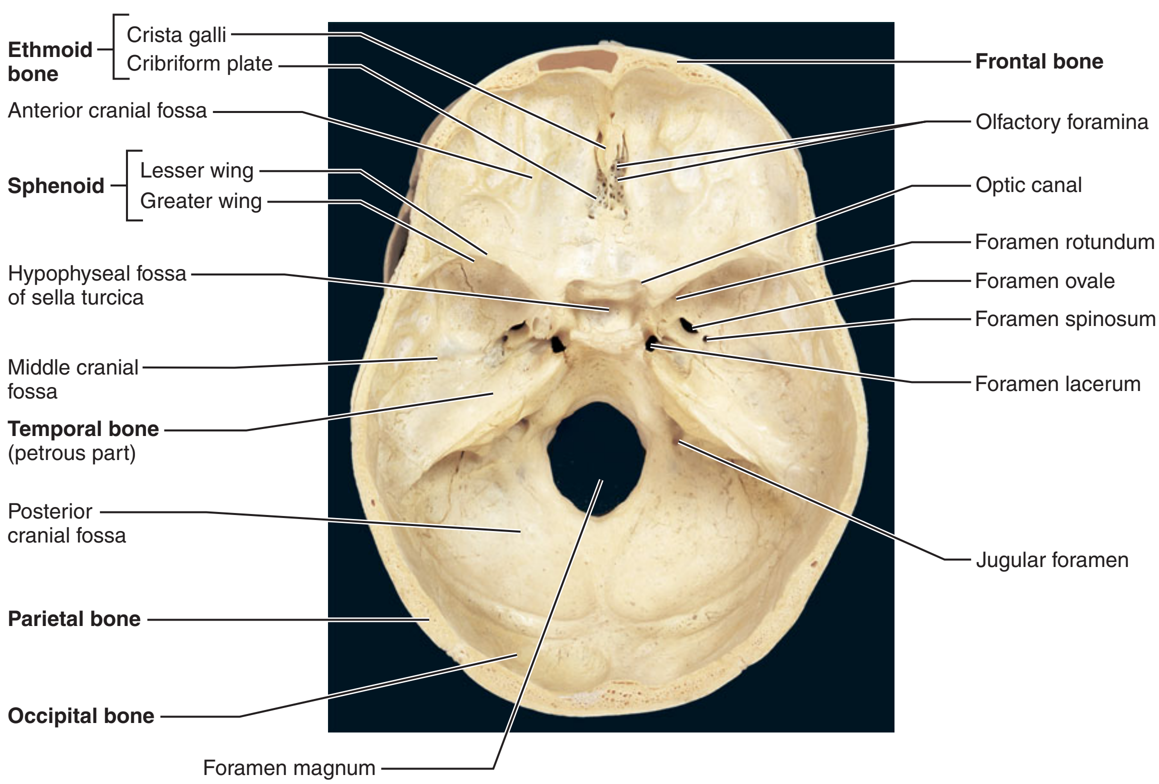
Sphenoid Bone (FIGURES 7.9 AND 7.10)

The **sphenoid bone** (sfe′noid; "wedge-shaped") spans the width of the cranial floor (Figure 7.9) and has been said to resemble a bat with its wings spread. It is considered the keystone of the cranium because it forms a central wedge that articulates with every other cranial bone. It is a challenging bone to study because of its complex shape and orientation: Portions of the sphenoid are viewable from most aspects of the skull. It also has a number of foramina for the passage of cranial nerves and vessels.

As shown in **Figure 7.10**, the sphenoid consists of a central **body** and three pairs of processes: the *greater wings, lesser wings,* and *pterygoid* (ter′ĭ-goid) *processes.* The superior surface of the body bears a saddle-shaped prominence, the **sella turcica** (sel′ah ter′sik-ah; "Turkish saddle"). The seat of this saddle, called the *hypophyseal*

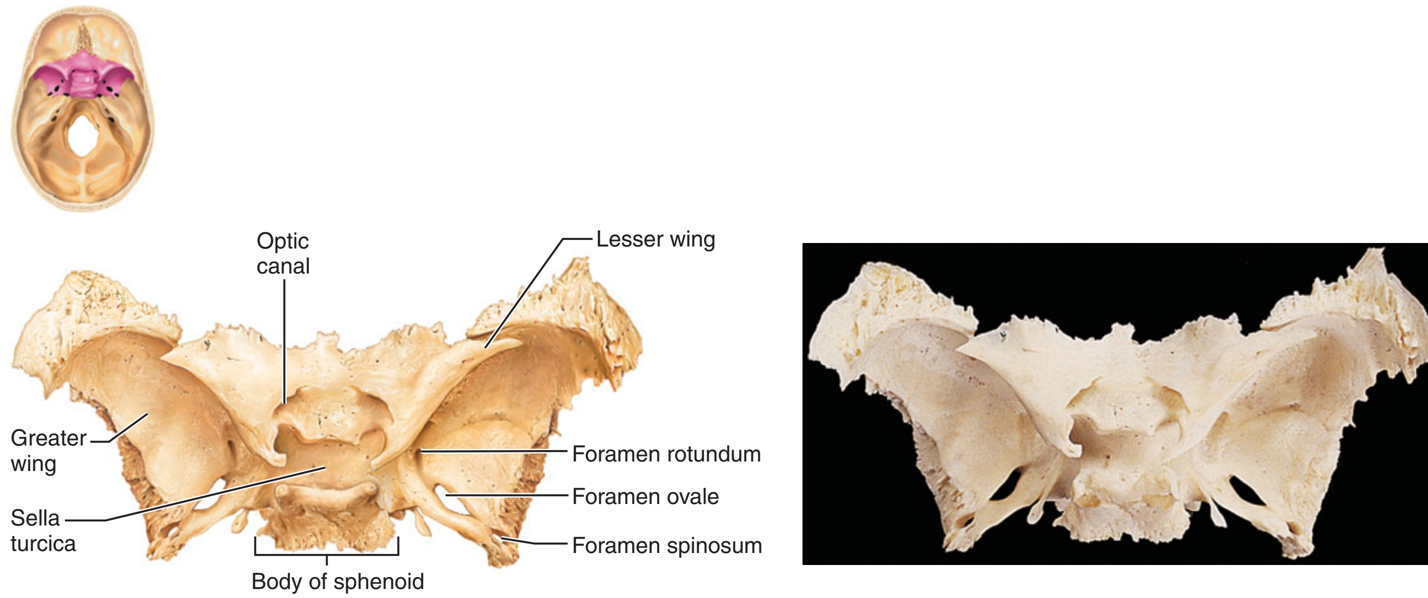


(a) Superior view of the skull, calvaria removed

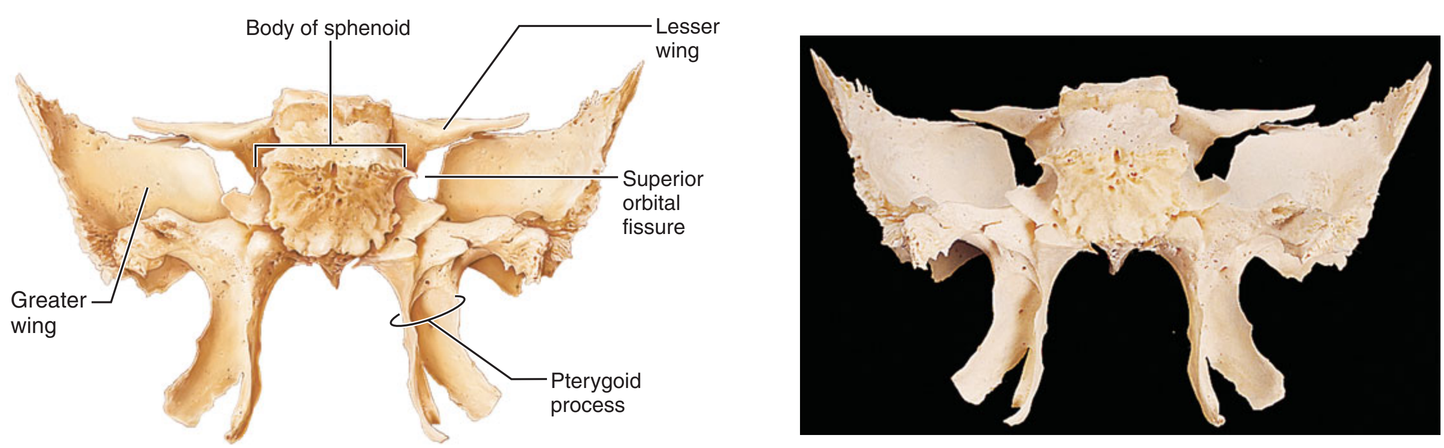


(b) Superior view of the skull, calvaria removed

FIGURE 7.9 **Floor of the cranial cavity.** (See *A Brief Atlas of the Human Body,* Second Edition, Figures 4 and 5).



(a) Superior view, as in Figure 7.9

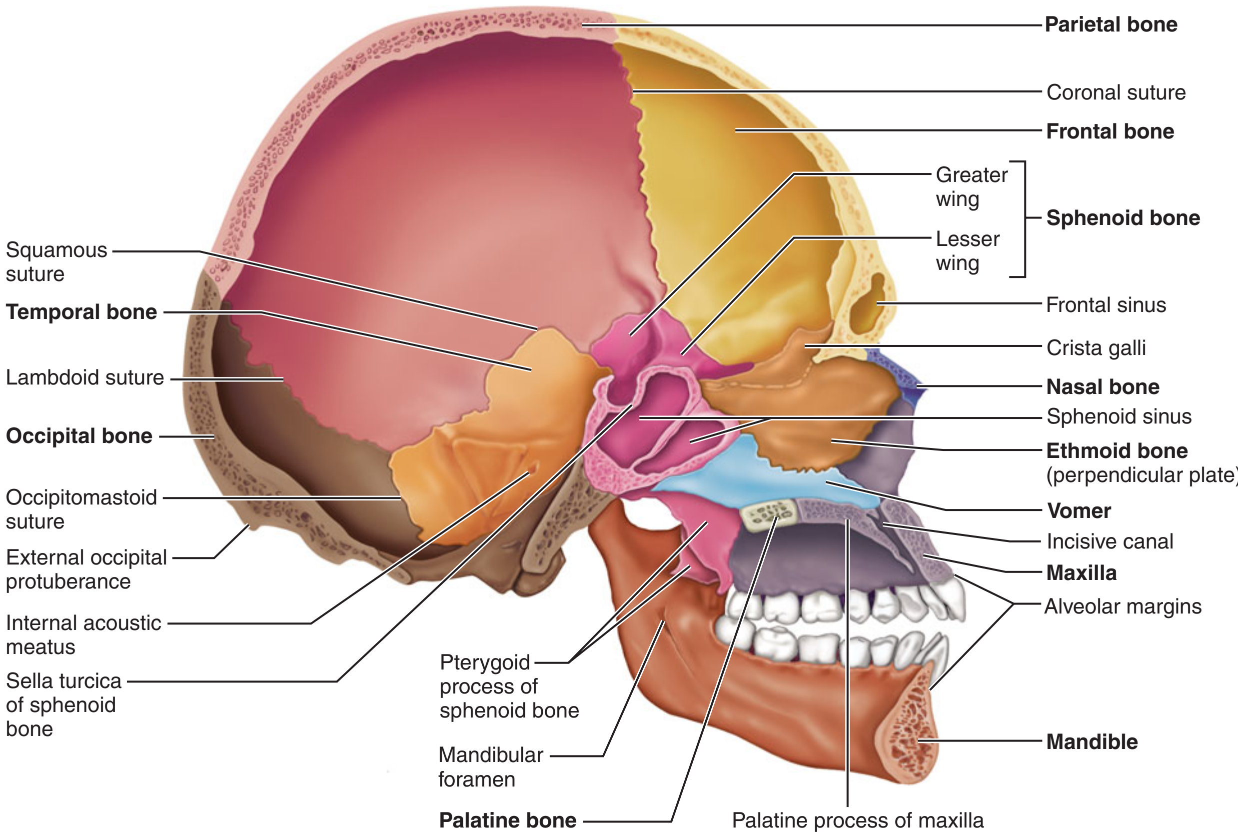


(b) Posterior view

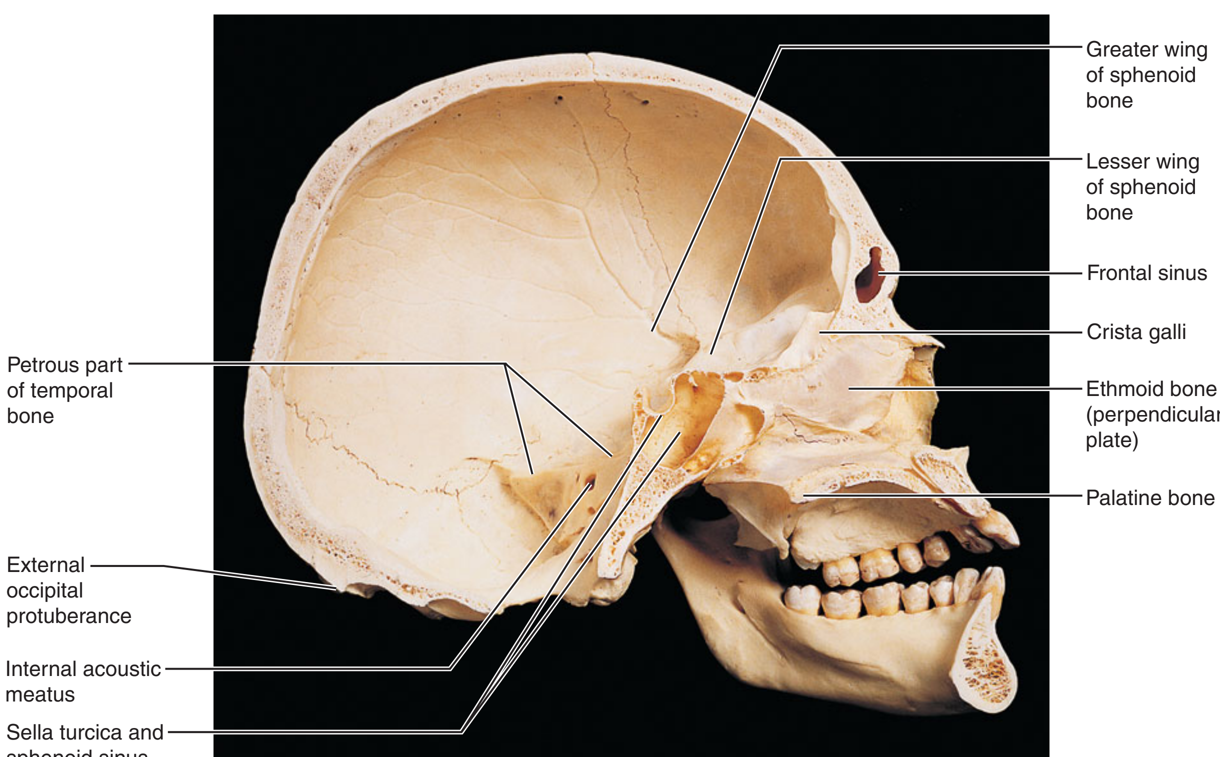
FIGURE 7.10 The sphenoid bone. (See *A Brief Atlas of the Human Body,* Second Edition, Figures 3 and 9.)

(hi″po-fiz′e-al) *fossa,* holds the pituitary gland, or hypophysis. Within the sphenoid body are the paired **sphenoid sinuses** (**Figure 7.11**). The **greater wings** project laterally from the sphenoid body, forming parts of the middle cranial fossa (Figure 7.9) and the orbit. On the lateral wall of the skull, the greater wing appears as a flag-shaped area medial to the zygomatic arch (Figure 7.4a). The horn-shaped **lesser wings** form part of the floor of the anterior cranial fossa (Figure 7.9) and a part of the orbit. The trough-shaped **pterygoid** ("winglike") **processes** project inferiorly from the greater wings (see Figures 7.7 and 7.10). These processes, which have both medial and lateral plates, are attachment sites for the pterygoid muscles that help close the jaw in chewing.

The sphenoid bone has five important openings (Figures 7.9 and 7.10) on each side. The **optic canal** lies just anterior to the sella turcica. Cranial nerve II, the optic nerve, passes through this hole from the orbit into the cranial cavity. The other four openings lie in a crescent-shaped row just lateral to the sphenoid body on each side. The most anterior of these openings, the **superior orbital fissure,** is a long slit between the greater and lesser wings (Figure 7.10b). It transmits several structures to and from the orbit, such as the cranial nerves that control eye movements (III, IV, and VI). This fissure is best seen in an anterior view of the orbit (Figure 7.6). The **foramen rotundum** lies in the medial part of the greater wing. It is usually oval, despite its name, which means "round opening." The **foramen ovale** (o-val′e) is an oval hole posterolateral to the



(a) Medial view of the left half of skull



(b) Photo of skull cut through the midline, same view as in (a)

FIGURE 7.11 Midsagittal section through the skull.

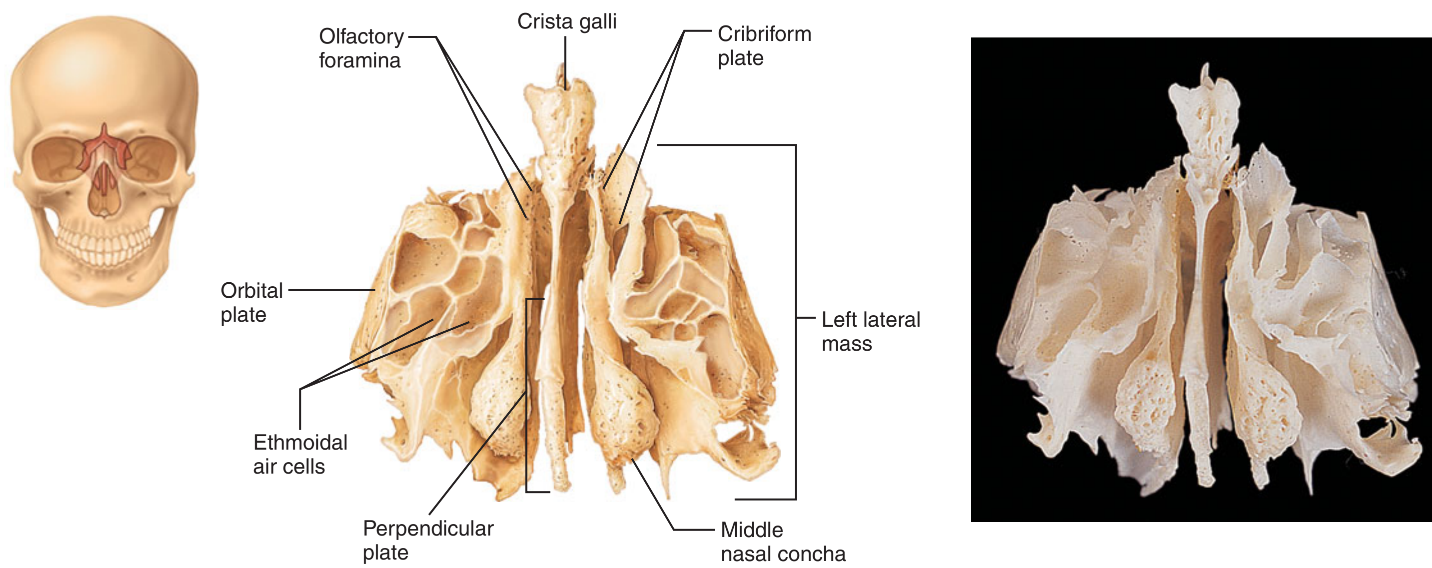


FIGURE 7.12 The ethmoid bone. Anterior view. (See *A Brief Atlas of the Human Body,* Second Edition, Figures 3 and 10.)

foramen rotundum. The foramen rotundum and foramen ovale are passageways through which two large branches of cranial nerve V (the maxillary and mandibular nerves) exit the cranium. Posterior and lateral to the foramen ovale lies the small **foramen spinosum** (spi-no′sum), named for a short spine that projects from its margin on the inferior aspect of the skull. Through this foramen passes the middle meningeal artery, which supplies blood to the broad inner surfaces of the parietal and the squamous temporal bones.

Ethmoid Bone (FIGURES 7.11 AND 7.12)

The **ethmoid bone** **(Figure 7.12)** is the most deeply situated bone of the skull. It lies anterior to the sphenoid bone and posterior to the nasal bones (Figure 7.11), forming most of the medial bony area between the nasal cavity and the orbits. The ethmoid is a remarkably thin-walled and delicate bone. In the articulated skull, only small portions of the ethmoid are viewable.

Its superior surface is formed by paired, horizontal **cribriform** (krib′rĭ-form; "perforated like a sieve") **plates** that contribute to the roof of the nasal cavities and the floor of the anterior cranial fossa (Figure 7.9). The cribriform plates are perforated by tiny holes called *olfactory foramina.* The filaments of cranial nerve I, the olfactory nerve, pass through these holes as they run from the nasal cavity to the brain. Between the two cribriform plates, in the midline, is a superior projection called the **crista galli** (kris′tah gal′li; "rooster's comb"). A fibrous membrane called the falx cerebri (discussed further in the dura mater discussion in Chapter 13, p. 409) attaches to the crista galli and helps to secure the brain within the cranial cavity.

The **perpendicular plate** of the ethmoid bone projects inferiorly in the median plane. It forms the superior part of the nasal septum, the vertical partition that divides the nasal cavity into right and left halves (Figure 7.6). Flanking the perpendicular plate on each side is a delicate **lateral mass** riddled with **ethmoidal air cells** (ethmoid sinuses). The ethmoid bone is named for these sinuses, as *ethmos* means "sieve" in Greek. Extending medially from the lateral masses are the thin **superior** and **middle nasal conchae** (kong′ke), which protrude into the nasal cavity (see Figure 7.14a). The conchae are curved like scrolls and are named after the conch shells one finds on warm ocean beaches. The lateral surfaces of the ethmoid's lateral masses are called **orbital plates** because they contribute to the medial walls of the orbits.

check your understanding

1. Name the bones that form the anterior cranial fossa.
2. For each feature listed, name the bone that contains the feature: crista galli, mastoid process, nuchal line, sella turcica, supraorbital foramen, zygomatic process.
3. What four bones articulate with the left parietal bone? Name the sutures that join these bones to the left parietal bone.

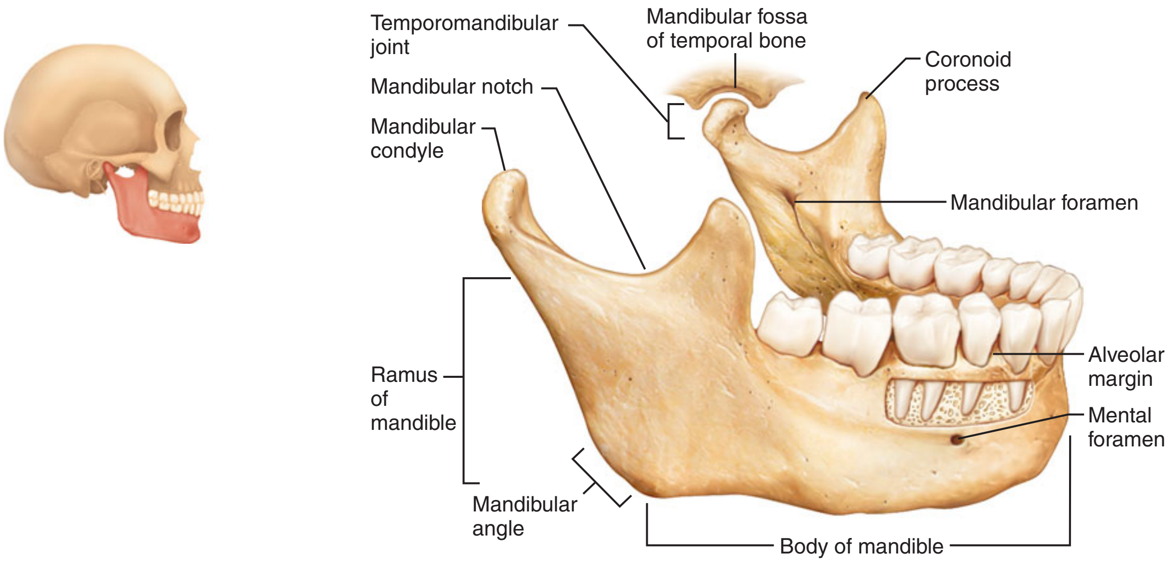
For answers, see Appendix B.

Facial Bones

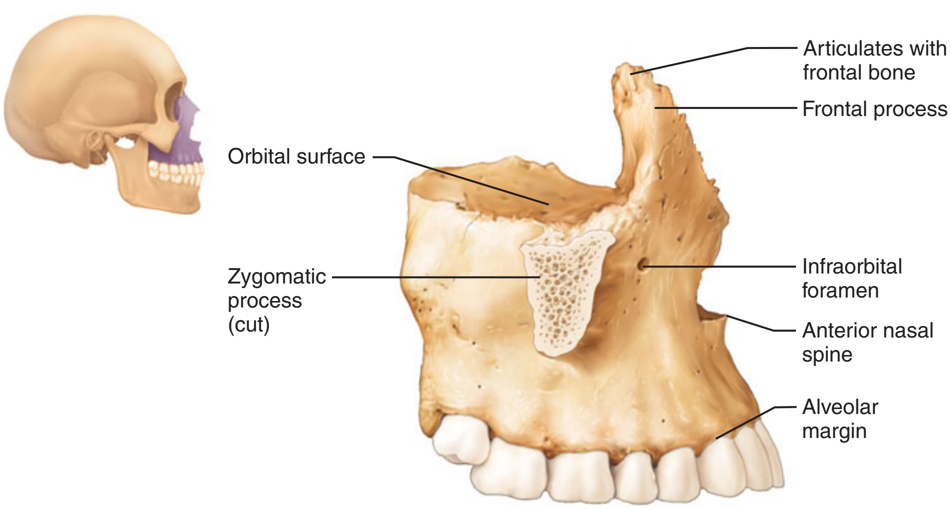
The skeleton of the face consists of 14 bones (see Figures 7.4 and 7.6). These are the unpaired mandible and the vomer, plus the paired maxillae, zygomatics, nasals, lacrimals, palatines, and inferior nasal conchae.

Mandible (FIGURE 7.13a)

The U-shaped **mandible** (man′dĭ-bl), or lower jawbone, is the largest, strongest bone in the face **(Figure 7.13a)**. It has a horizontal *body* that forms the inferior jawline, and two upright *rami* (ra′mi; "branches"). Each **ramus** meets the body posteriorly at a **mandibular angle.** At the superior margin of each ramus are two processes. The anterior **coronoid**



(a) Mandible, right lateral view



(b) Maxilla, right lateral view

(c) Maxilla, photo of right lateral view

FIGURE 7.13 Detailed anatomy of the mandible and the maxilla. (See *A Brief Atlas of the Human Body,* Second Edition, Figures 11 and 12.)

process (kor′o-noid; "crown-shaped") is a flat, triangular projection. The temporalis muscle, which elevates the lower jaw during chewing, inserts here. The posterior *condylar process* enlarges superiorly to form the **mandibular condyle,** or **head of the mandible.** It articulates with the temporal bone to form the temporomandibular joint. The coronoid and condylar processes are separated by the **mandibular notch.**

The **body** of the mandible anchors the lower teeth and forms the chin. Its superior border is the **alveolar** (al-ve′o-lar) **margin.** The tooth sockets, called *alveoli,* open onto this margin. Anteriorly, the fusion between the two halves of the mandible is called the **mental protuberance** (Figure 7.6).

Several openings pierce the mandible. On the medial surface of each ramus is a **mandibular foramen** (Figure 7.13a), through which a nerve responsible for tooth sensation (inferior alveolar nerve, a branch of cranial nerve V) enters the mandibular body and supplies the roots of the lower teeth. Dentists inject anesthetic into this foramen before working on the lower teeth. The **mental** ("chin") **foramen,** which opens on the anterolateral side of the mandibular body, transmits blood vessels and nerves to the lower lip and the skin of the chin.

Maxillary Bones *(FIGURES 7.6 AND 7.13b)*

The **maxillary bones,** or **maxillae** (mak-sil′e; "jaws"), form the upper jaw and the central part of the facial skeleton (see Figures 7.6 and 7.13b). They are considered the keystone bones of the face because they articulate with all other facial bones except the mandible.

Like the mandible, the maxillae have an **alveolar margin** that contains teeth in alveoli. The **palatine** (pal′ah-t-ēn) **processes** project medially from the alveolar margins to form the anterior region of the **hard palate,** or bony roof of the mouth (Figure 7.7a). The **frontal processes** extend superiorly to reach the frontal bone, forming part of the lateral aspect of the bridge of the nose (Figure 7.6). The maxillae lie just lateral to the nasal cavity and contain the **maxillary sinuses.** These sinuses, the largest of the paranasal air sinuses, extend from the orbit down to the roots of the upper teeth. Laterally, the maxillae articulate with the zygomatic bones at the **zygomatic processes.**

The maxilla, along with several other bones, forms the borders of the **inferior orbital fissure** in the floor of the orbit. This fissure transmits several vessels and nerves (see Table 7.1), including the maxillary nerve (a branch of cranial nerve V) or its continuation, the infraorbital nerve. The infraorbital nerve proceeds anteriorly to enter the face through the **infraorbital foramen.**

Zygomatic Bones (FIGURES 7.4 AND 7.6)

The irregularly shaped **zygomatic bones** are commonly called the cheekbones (*zygoma* = cheekbone). Each joins the zygomatic process of a temporal bone posteriorly, the zygomatic process of the frontal bone superiorly, and the zygomatic process of the maxilla anteriorly (Figure 7.4). The zygomatic bones form the prominences of the cheeks and define part of the margin of each orbit.

Nasal Bones (FIGURE 7.6)

The paired, rectangular **nasal bones** join medially to form the bridge of the nose. They articulate with the frontal bone superiorly, the maxillae laterally, and the perpendicular plate of the ethmoid bone posteriorly. Inferiorly, they attach to the cartilages that form most of the skeleton of the external nose (see Figure 22.2).

Lacrimal Bones (FIGURE 7.4)

The delicate, fingernail-shaped **lacrimal** (lak′rĭ-mal) **bones** are located in the medial orbital walls. They articulate with the frontal bone superiorly, the ethmoid bone posteriorly, and the maxilla anteriorly. Each lacrimal bone contains a deep groove that contributes to a *lacrimal fossa.* This fossa contains a *lacrimal sac* that gathers tears, allowing the fluid to drain from the eye surface into the nasal cavity (*lacrima* = tear).

Palatine Bones (FIGURES 7.7 AND 7.14)

The **palatine bones** lie posterior to the maxillae **(Figure 7.14a)**. These paired, L-shaped bones articulate with each other at their inferior **horizontal plates,** which complete the posterior part of the hard palate. The **perpendicular plates** form the posterior part of the lateral walls of the nasal cavity (Figure 7.14a) and a small part of the orbits (Figure 7.16).

Vomer (FIGURE 7.14b)

The slender, plow-shaped **vomer** (vo′mer; "plowshare") lies in the nasal cavity, where it forms the inferior part of the nasal septum (Figures 7.6, 7.7 and 7.14b).

Inferior Nasal Conchae (FIGURE 7.14a)

The paired **inferior nasal conchae** are thin, curved bones in the nasal cavity (see Figures 7.6 and 7.14a). Projecting medially from the lateral walls of the nasal cavity, just inferior to the middle nasal conchae of the ethmoid bone, they are the largest of the three pairs of conchae.

check your understanding

4. Name all the bones that articulate with the maxilla.
5. What bones or bony processes form the hard palate?
6. What are the alveolar margins, and on what bones are they located?

For answers, see Appendix B.

Special Parts of the Skull

➤ Define the bony boundaries of the nasal cavity, paranasal sinuses, and orbit.

Next we will examine four special parts of the skull: the nasal cavity and the orbits, which are restricted regions of the skull formed from many bones; the paranasal sinuses, which are extensions of the nasal cavity; and the hyoid bone.

Nasal Cavity (FIGURE 7.14)

The **nasal cavity** is constructed of bone and cartilage. Its *roof* is the ethmoid's cribriform plates. The *floor* is formed by the palatine processes of the maxillae and the horizontal plates of the palatine bones. Keep in mind that these same nasal-floor structures also form the roof of the mouth and are collectively called the hard palate. Contributing to the *lateral walls* of the nasal cavity are the nasal bones, the superior and middle conchae of the ethmoid, the inferior nasal conchae, a part of the maxilla, and the perpendicular plates of the palatine bones (Figure 7.14a). On these lateral walls, each of the three conchae forms a roof over a groove-shaped air passageway called a *meatus* (me-a′tus; "a passage"). Therefore, there are **superior, middle,** and **inferior meatuses.**

Recall that the nasal cavity is divided into right and left halves by the nasal septum. The bony part of this septum is formed by the vomer inferiorly and by the perpendicular plate of the ethmoid superiorly (Figure 7.14b). A sheet of cartilage, called the *septal cartilage,* completes the septum anteriorly.

The walls of the nasal cavity are covered with a mucosa that moistens and warms inhaled air. This membrane also secretes mucus that traps dust, thereby cleansing the air of debris. The three pairs of scroll-shaped nasal conchae cause the air flowing through the nasal cavity to swirl. This turbulence increases the contact of inhaled air with the mucosa throughout the nasal cavity, such that the air is warmed, moistened, and filtered more efficiently.

DEVIATED SEPTUM The nasal septum in many people is slightly off center. A septum that is markedly off center is referred to as a *deviated septum.* This condition is commonly a result of trauma to the nose and can cause difficulty in breathing through the nose, as well as nasal congestion, frequent nosebleeds, and frequent sinus infections. Surgery to correct the deviation (septoplasty) may be indicated if the symptoms are severe.

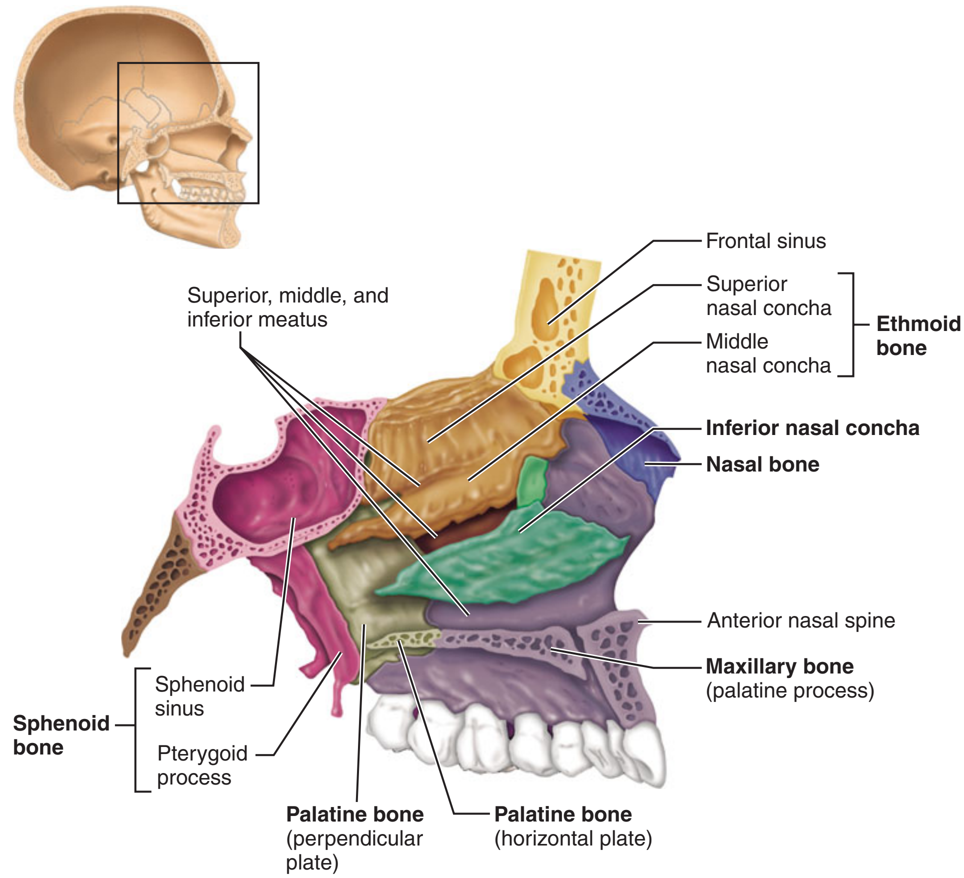
TABLE 7.1 Bones of the Skull

Bone	Comments	Important Markings
CRANIAL BONES		
Parietal (2) (Figures 7.4 and 7.5)	Forms most of the superior and lateral aspects of the skull	
Frontal (1) (Figures 7.5, 7.6, and 7.9)	Forms forehead, superior part of orbits, and most of the anterior cranial fossa; contains sinuses	**Supraorbital foramina (notches):** allow the supraorbital arteries and nerves to pass
Occipital (1) (Figures 7.4, 7.5, and 7.7)	Forms posterior aspect and most of the base of the skull	**Foramen magnum:** allows passage of the spinal cord from the brain stem to the vertebral canal **Hypoglossal canals:** allow passage of the hypoglossal nerve (cranial nerve XII) **Occipital condyles:** articulate with the atlas (first vertebra) **External occipital protuberance and nuchal lines:** sites of muscle attachment **External occipital crest:** attachment site of ligamentum nuchae
Temporal (2) (Figures 7.4, 7.7, 7.8, and 7.9)	Forms inferolateral aspects of the skull and contributes to the middle cranial fossa; has squamous, mastoid, tympanic, and petrous regions	**Zygomatic process:** helps to form the zygomatic arch, which forms the prominence of the cheek **Mandibular fossa:** articular point of the mandibular condyle **External acoustic meatus:** canal leading from the external ear to the eardrum **Styloid process:** attachment site for several neck muscles and for a ligament to the hyoid bone **Mastoid process:** attachment site for several neck and tongue muscles **Stylomastoid foramen:** allows cranial nerve VII (facial nerve) to pass **Jugular foramen:** allows passage of the internal jugular vein and cranial nerves IX, X, and XI **Internal acoustic meatus:** allows passage of cranial nerves VII and VIII **Carotid canal:** allows passage of the internal carotid artery
Sphenoid (1) (Figures 7.4, 7.6, 7.7, 7.9, 7.10, and 7.11)	Keystone of the cranium; contributes to the middle cranial fossa and orbits; main parts are the body, greater wings, lesser wings, and pterygoid processes	**Sella turcica:** hypophyseal fossa portion is the seat of the pituitary gland **Optic canals:** allow passage of cranial nerve II and the ophthalmic arteries **Superior orbital fissures:** allow passage of cranial nerves III, IV, VI, part of V (ophthalmic division), and ophthalmic vein **Foramen rotundum** (2): allows passage of the maxillary division of cranial nerve V **Foramen ovale** (2): allows passage of the mandibular division of cranial nerve V **Foramen spinosum** (2): allows passage of the middle meningeal artery
Ethmoid (1) (Figures 7.6, 7.9, 7.11, 7.12, and 7.15)	Helps to form the anterior cranial fossa; forms part of the nasal septum and the lateral walls and roof of the nasal cavity; contributes to the medial wall of the orbit	**Crista galli:** attachment point for the falx cerebri, a dural membrane fold **Cribriform plates:** allow passage of filaments of the olfactory nerves (cranial nerve I) **Superior** and **middle nasal conchae:** form part of lateral walls of nasal cavity; increase turbulence of air flow

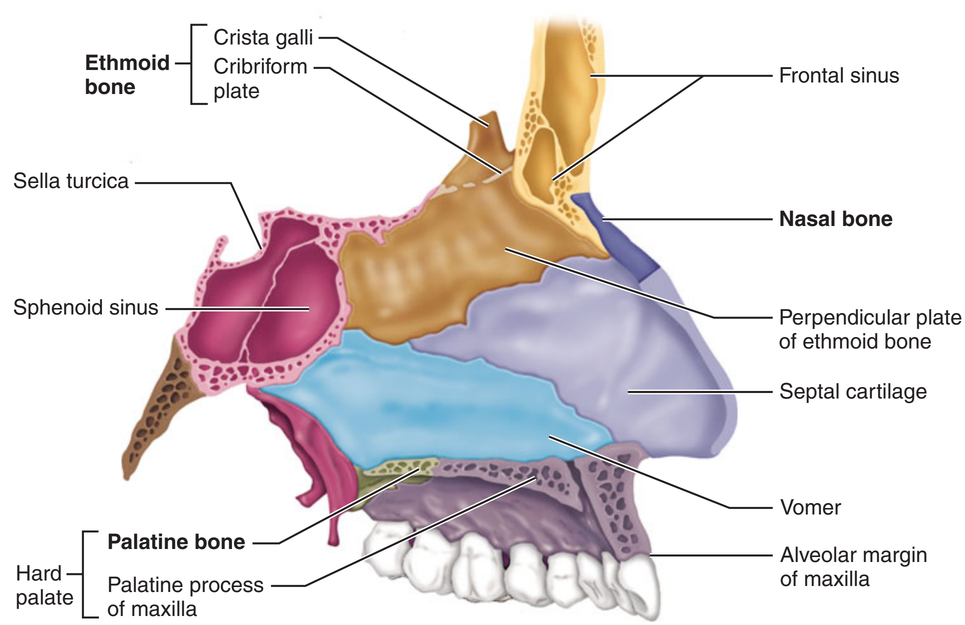
TABLE 7.1 *continued*

Bone*	Comments	Important Markings
FACIAL BONES		
Mandible (1) (Figures 7.4, 7.6, and 7.13)	The lower jaw	**Coronoid processes:** insertion points for the temporalis muscles **Mandibular condyles:** articulate with the temporal bones in the jaw (temporomandibular) joints **Mandibular symphysis:** medial fusion point of the mandibular bones **Alveoli:** sockets for the teeth **Mandibular foramina:** permit the inferior alveolar nerves to pass **Mental foramina:** allow blood vessels and nerves to pass to the chin and lower lip
Maxilla (2) (Figures 7.4, 7.6, 7.7, 7.11, and 7.13)	Keystone bones of the face; form the upper jaw and parts of the hard palate, orbits, and nasal cavity walls	**Alveoli:** sockets for teeth **Zygomatic process:** helps form the zygomatic arches **Palatine process:** forms the anterior hard palate; meet medially in middle palatine suture **Frontal process:** forms part of lateral aspect of bridge of nose **Incisive fossa:** permits blood vessels and nerves to pass through hard palate (fused palatine processes) **Inferior orbital fissure:** permits maxillary branch of cranial nerve V, the zygomatic nerve, and blood vessels to pass **Infraorbital foramen:** allows passage of infraorbital nerve to skin of face
Zygomatic (2) (Figures 7.4 and 7.6)	Form the cheek and part of the orbit	
Nasal (2) (Figures 7.4 and 7.6)	Form the bridge of the nose	
Lacrimal (2) (Figures 7.4 and 7.6)	Form part of the medial orbit wall	**Lacrimal fossa:** houses the lacrimal sac, which helps to drain tears into the nasal cavity
Palatine (2) (Figures 7.7, 7.11, and 7.14)	Form posterior part of the hard palate and a small part of nasal cavity and orbit walls	
Vomer (1) (Figures 7.6, 7.11, and 7.14)	Inferior part of the nasal septum	
Inferior nasal concha (2) (Figures 7.6 and 7.14)	Form part of the lateral walls of the nasal cavity	
Auditory ossicles (malleus, incus, and stapes) (2 each)	Found in middle ear cavity; involved in sound transmission; see Chapter 16	

*The color code beside each bone name corresponds to the bone's color in Figures 7.4 to 7.16. The number in parentheses ( ) following the bone name indicates the total number of such bones in the body.

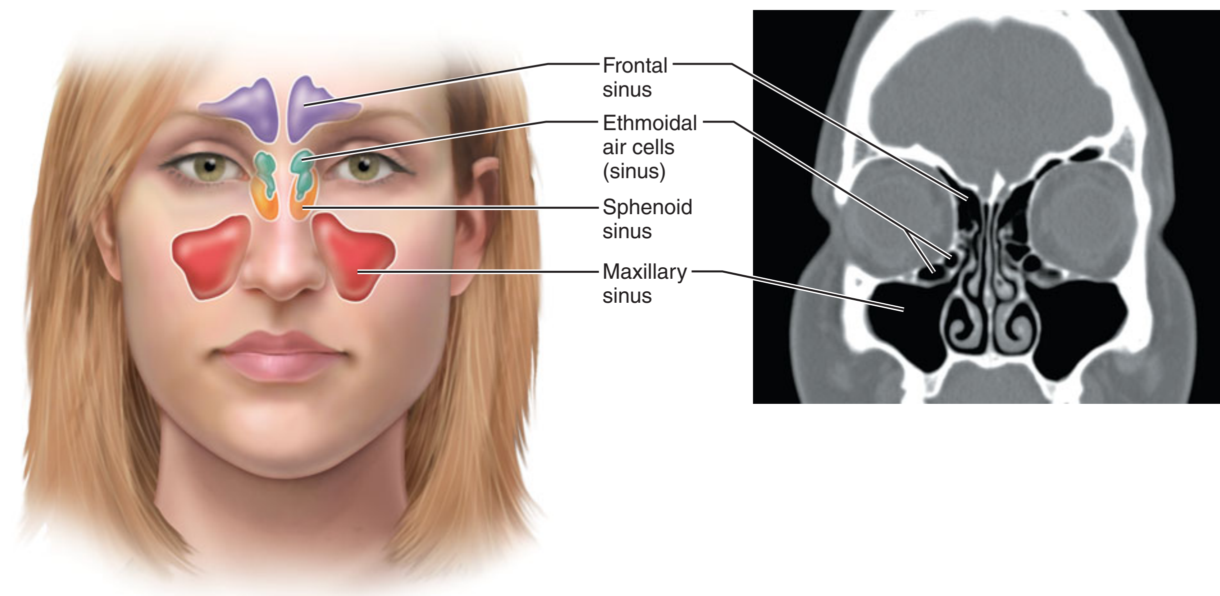


(a) Bones forming the left lateral wall of the nasal cavity (nasal septum removed)

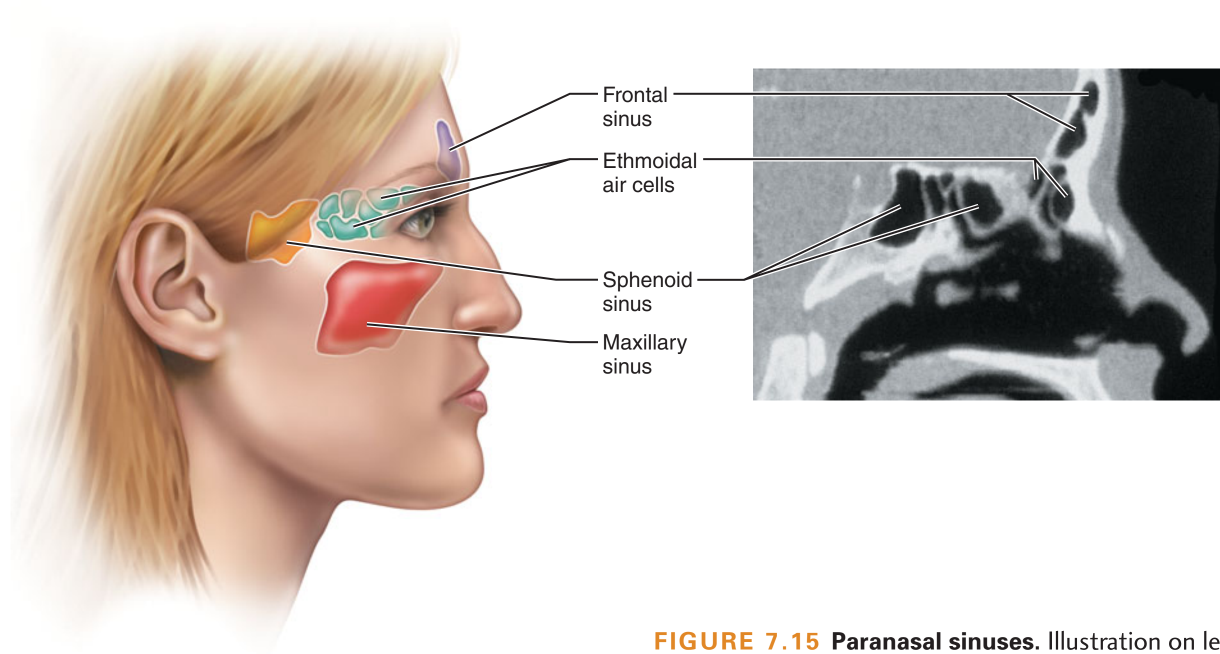


(b) Nasal cavity with septum in place showing the contributions of the ethmoid bone, the vomer, and septal cartilage

FIGURE 7.14 Bones of the nasal cavity. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 15.)



(a) Anterior aspect



(b) Medial aspect

FIGURE 7.15 Paranasal sinuses. Illustration on left, CT scan on right.

Paranasal Sinuses (*FIGURE 7.15*)

The bones surrounding the nasal cavity—the frontal, ethmoid, sphenoid, and both maxillary bones—contain air-filled sinuses that are called **paranasal sinuses** (*para* = near) because they cluster around the nasal cavity **(Figure 7.15)**. In fact, they are extensions of the nasal cavity, lined by the same mucous membrane and probably serving the same function of warming, moistening, and filtering inhaled air. The paranasal sinuses also lighten the skull, giving the bones they occupy a moth-eaten appearance in an X-ray image. These sinuses connect to the nasal cavity through small openings, most of which occur at the meatuses inferior to the conchae. For more on paranasal sinuses, see Chapter 22.

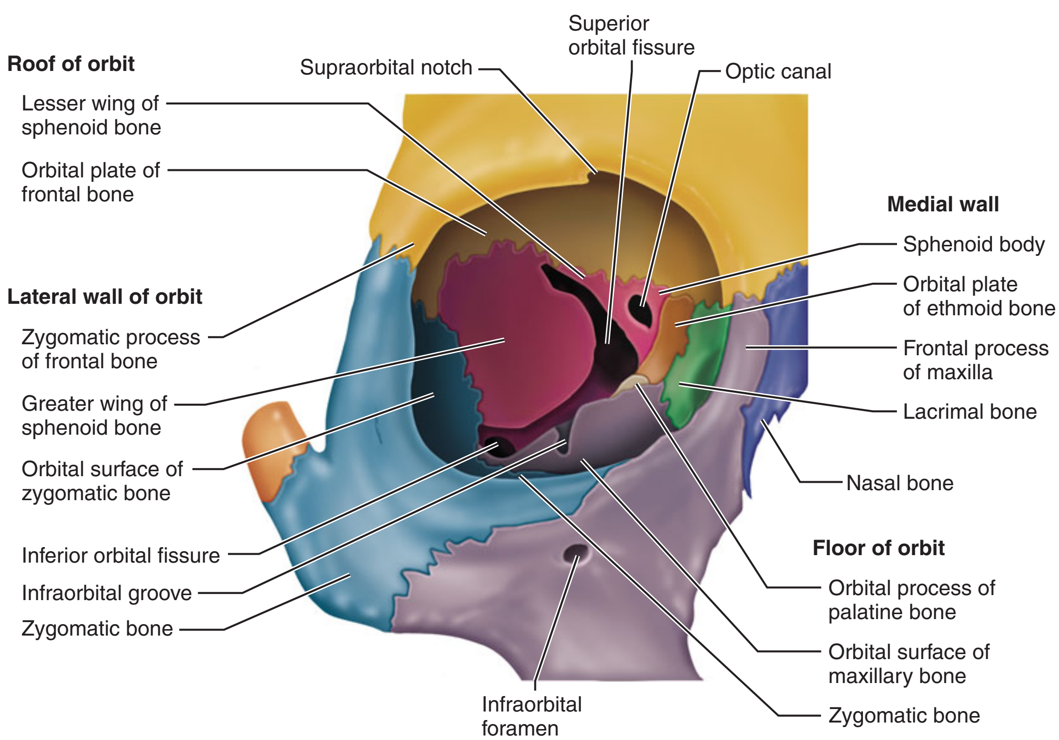
Orbits (*FIGURE 7.16*)

The **orbits** are cone-shaped bony cavities that hold the eyes, the muscles that move the eyes, some fat, and the tear-producing glands. The walls of each orbit are formed by parts of seven bones—the frontal, sphenoid, zygomatic, maxillary, palatine, lacrimal, and ethmoid bones **(Figure 7.16)**. The superior and inferior orbital fissures, optic canal, and lacrimal fossa (described earlier) are also in the orbit.

The Hyoid Bone (*FIGURE 7.17*)

Not really part of the skull but associated with it, the **hyoid bone** (hi′oid; "U-shaped") lies just inferior to the mandible in the anterior neck **(Figure 7.17)**. This bone resembles both an archer's bow and a miniature version of the

(a) Photograph, right orbit



(b) Contribution of each of the seven bones forming the right orbit

FIGURE 7.16 Bones that form the orbit. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 14.)

mandible. It has a **body** and two pairs of **horns,** each of which is also called a *cornu,* the Latin word for "horn." The hyoid is the only bone in the skeleton that does not articulate directly with any other bone. Instead, its lesser horns are tethered by thin *stylohyoid ligaments* to the styloid processes of the temporal bones. Other ligaments connect the hyoid to the larynx (voice box) inferior to it. Functionally, the hyoid bone acts as a movable base for the tongue. Furthermore, its body and greater horns are points of attachment for neck muscles that raise and lower the larynx during swallowing.

check your understanding

7. What bones form the nasal conchae? What is the function of these structures?
8. Which of the bones that form the orbit are cranial bones? Which are facial bones?
9. Which paranasal sinuses are located along the lateral walls of the nasal cavity? What type of membrane lines all the paranasal sinuses?

For answers, see Appendix B.

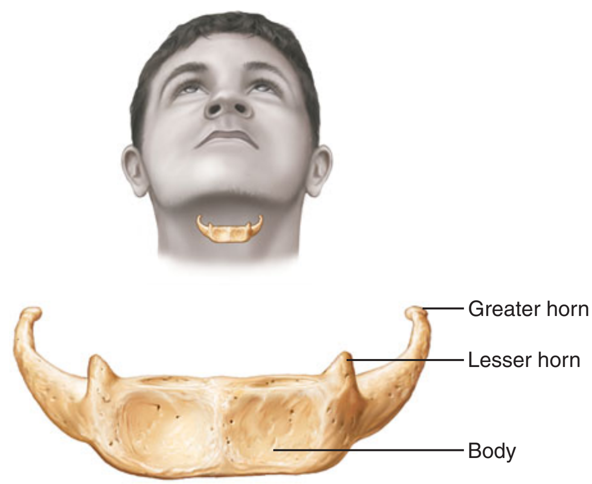


FIGURE 7.17 The hyoid bone. Anterior view.

THE VERTEBRAL COLUMN

- Describe the general structure of the vertebral column, and list its components.
- Name a function performed by both the spinal curvatures and the intervertebral discs.
- Discuss the structure of a typical vertebra, and describe the special features of cervical, thoracic, and lumbar vertebrae.

The **vertebral column (Figure 7.18)**, also called the *spinal column* or *spine,* consists of 26 bones connected into a flexible, curved structure. The main support of the body axis, the vertebral column extends from the skull to the pelvis, where it transmits the weight of the trunk to the lower limbs. It also surrounds and protects the delicate spinal cord and provides attachment points for the ribs and for muscles of the neck and back. In the fetus and infant, the vertebral column consists of 33 separate bones, or **vertebrae** (ver′te-bre). Inferiorly, nine of these eventually fuse to form two composite bones, the sacrum and the tiny coccyx (tailbone). The remaining 24 bones persist as individual vertebrae separated by *intervertebral discs* (discussed shortly).

Regions and Normal Curvatures

The vertebral column, which is about 70 cm (28 inches) long in an average adult, has five major regions (Figure 7.18). The 7 vertebrae of the neck are the **cervical vertebrae,** the next 12 are the **thoracic vertebrae,** and the 5 that support the lower back are the **lumbar vertebrae.** To remember the number of vertebrae in these three regions, think of the usual meal times of 7:00 A.M., 12:00 noon, and 5:00 P.M. The vertebrae become progressively larger from the cervical to the lumbar region as the weight they must support progressively increases. Inferior to the lumbar vertebrae is the **sacrum** (sa′krum), which articulates with the hip bones of the pelvis. The most inferior part of the vertebral column is the tiny **coccyx** (kok′siks).

All people (and in fact the majority of mammals) have seven cervical vertebrae. Variations in numbers of vertebrae in the other regions occur in about 5% of people.

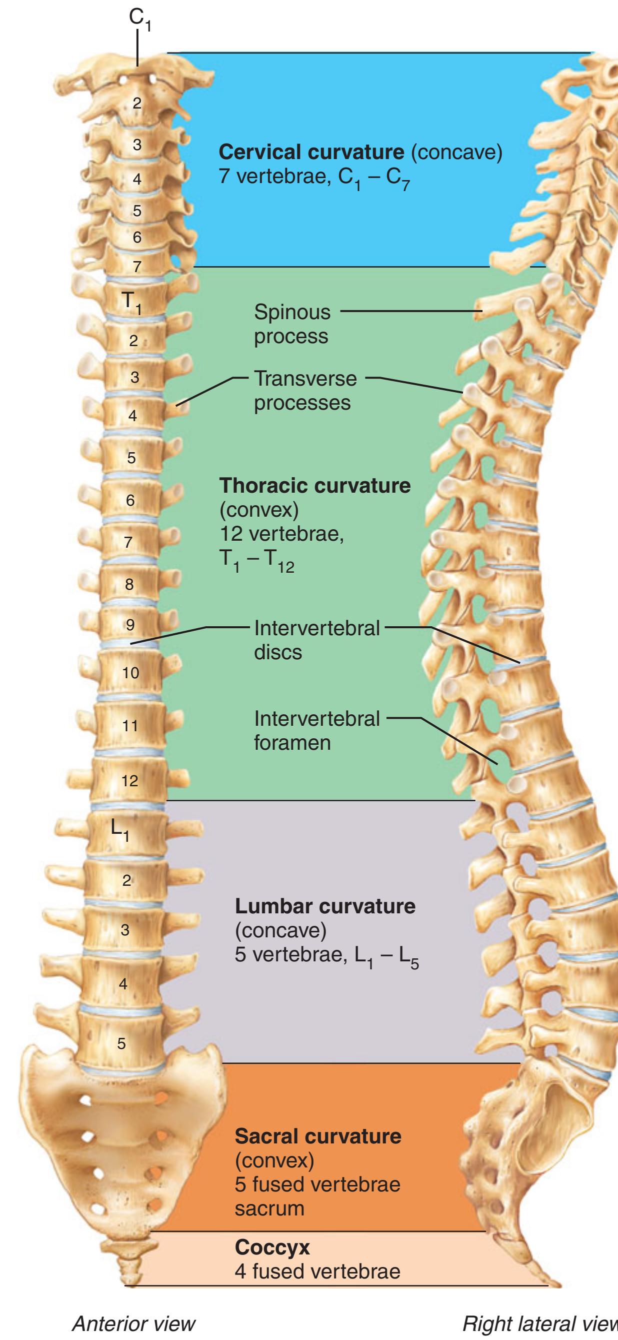
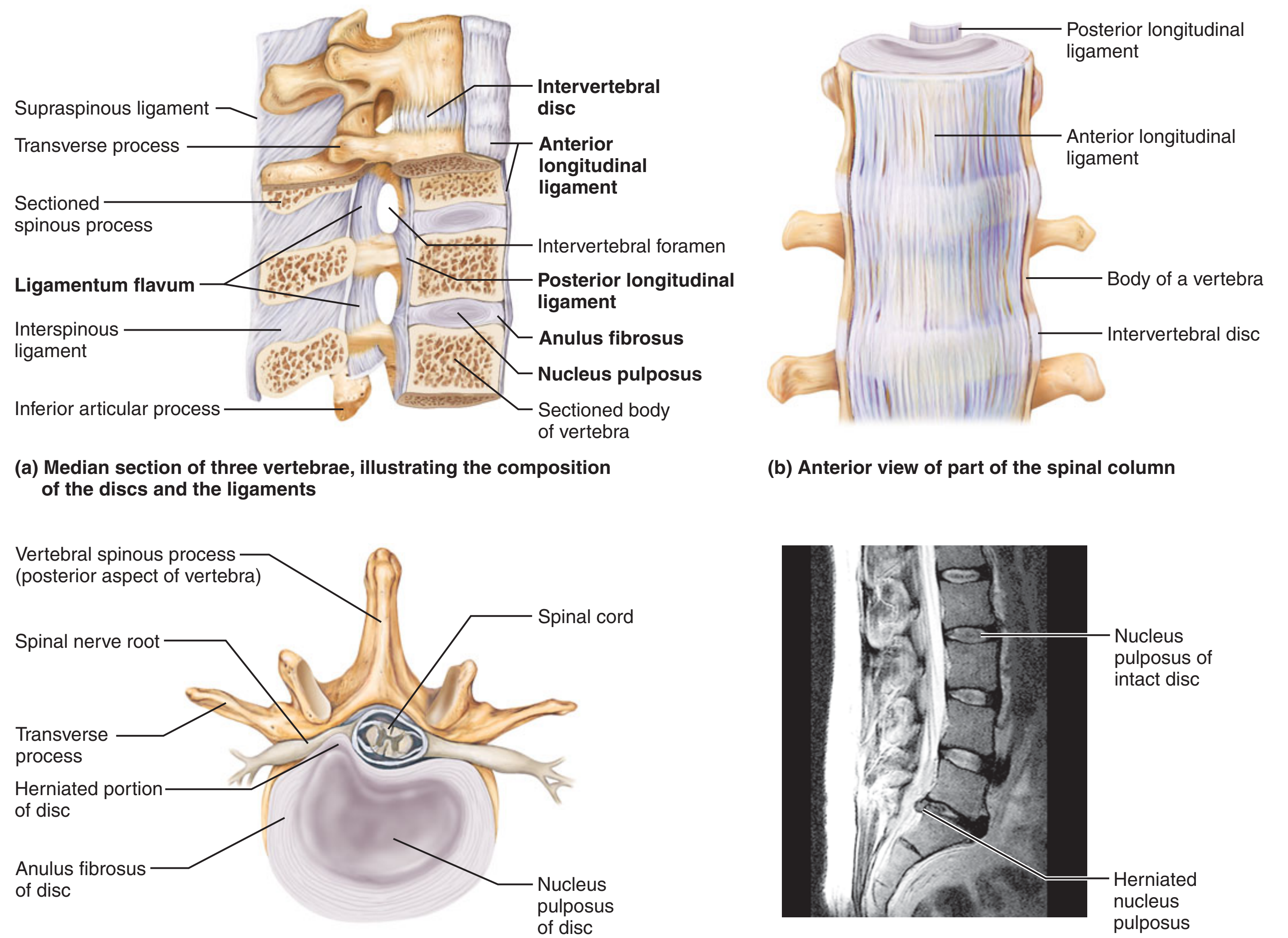


FIGURE 7.18 The vertebral column. Note the four curvatures in the lateral view at right. The terms *convex* and *concave* are relative to the *posterior* aspect of the column. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 17.)

From a lateral view, four curvatures that give the vertebral column an S shape are visible (Figure 7.18, right). The **cervical** and **lumbar curvatures** are concave posteriorly, whereas the **thoracic** and **sacral curvatures** are convex posteriorly. These curvatures increase the resilience of the spine, allowing it to function like a spring rather than a straight, rigid rod.

Only the thoracic and sacral curvatures are well developed at birth. Both of these *primary curvatures* are convex



(a) Median section of three vertebrae, illustrating the composition of the discs and the ligaments

(b) Anterior view of part of the spinal column

(c) Superior view of a herniated intervertebral disc

(d) MRI of lumbar region of vertebral column in sagittal section showing normal and herniated discs

FIGURE 7.19 Ligaments and intervertebral discs of the spine. In **(c)** and **(d)**, a tear in the anulus fibrosus of the intervertebral disc allows the gelatinous center core, the nucleus pulposus, to protrude. The resulting compression on the spinal nerve roots causes pain and weakness in the region served by the affected spinal nerve.

posteriorly, so that an infant's spine arches (is C-shaped) like that of a four-legged animal. The *secondary curvatures,* the cervical and lumbar curvatures, are concave posteriorly and develop during the first 2 years of childhood as the intervertebral discs are reshaped. The cervical curvature is present before birth but is not pronounced until the baby starts to lift its head at 3 months, and the lumbar curvature develops when the baby begins to walk, at about 1 year. The lumbar curvature positions the weight of the upper body over the lower limbs, providing optimal balance during standing.

Ligaments of the Spine

Like a tremulous telecommunication transmitting tower, the vertebral column cannot stand upright by itself. It must be held in place by an elaborate system of supports. Serving this role are the straplike ligaments of the back and the muscles of the trunk. (The trunk muscles are discussed in Chapter 11, pp. 285–288.) The major supporting ligaments are the **anterior** and **posterior longitudinal ligaments** (Figure 7.19) that run vertically along the anterior and posterior surfaces of the bodies of the vertebrae, from the neck to the sacrum. The anterior longitudinal ligament is wide and attaches strongly to both the bony vertebrae and the intervertebral discs. Along with its supporting role, this thick anterior ligament prevents hyperextension of the back (bending too far backward). The posterior longitudinal ligament, which is narrow and relatively weak, attaches only to the intervertebral discs. This ligament helps to prevent hyperflexion (bending the vertebral column too sharply forward).

Several other posterior ligaments connect each vertebra to those immediately superior and inferior (Figure 7.19a).

Among these is the **ligamentum flavum** (fla′vum; "yellow"), which connects the lamina of adjacent vertebrae. It contains elastic connective tissue and is especially strong: It stretches as we bend forward, then recoils as we straighten to an erect position.

Intervertebral Discs

Each **intervertebral disc** (Figure 7.19) is a cushionlike pad composed of an inner sphere, the **nucleus pulposus** (pul-po′-sus; "pulp"), and an outer collar of about 12 concentric rings, the **anulus fibrosus** (an′u-lus fi-bro′sus; "fibrous ring"). Each nucleus pulposus is gelatinous and acts like a rubber ball, enabling the spine to absorb compressive stress. In the anulus fibrosus, the outer rings consist of ligament and the inner ones consist of fibrocartilage. The main function of these rings is to contain the nucleus pulposus, limiting its expansion when the spine is compressed. However, the rings also function like a woven strap, binding the successive vertebrae together, resisting tension on the spine, and absorbing compressive forces. Collagen fibers in adjacent rings in the anulus cross like an X, allowing the spine to withstand twisting. This arrangement creates the same antitwisting design provided by bone lamellae in osteons (see Figure 6.8 on p. 133).

The intervertebral discs act as shock absorbers during walking, jumping, and running. At points of compression, the discs flatten and bulge out a bit between the vertebrae. The discs are thickest in the lumbar (lower back) and cervical (neck) regions of the vertebral column. Collectively, the intervertebral discs make up about 25% of the height of the vertebral column. As a result of compression and loss of fluid from the gelatinous nucleus pulposus, they flatten somewhat by the end of each day. So, you are probably 1 to 2 centimeters shorter at night than when you awake in the morning.

HERNIATED DISC Severe or sudden physical trauma to the spine—for example, due to lifting a heavy object—may cause one or more **herniated discs** (also called **prolapsed discs** or, in common terms, *slipped discs*). This condition usually involves rupture of the anulus fibrosus followed by protrusion of the nucleus pulposus. Aging is a contributing factor, because the nucleus pulposus loses its cushioning properties over time, and the anulus fibrosus weakens and tears. This mechanical fatigue allows the nucleus to rupture through the anulus. The anulus is thinnest posteriorly, but the posterior longitudinal ligament prevents the herniation from proceeding directly posteriorly, so the rupture proceeds posterolaterally—toward the spinal nerve roots exiting from the spinal cord (see Figure 7.19c). The resulting pressure on these nerve roots causes pain or numbness. In most cases, the pain eventually resolves, so treatment is usually conservative: moderate exercise, physical therapy, massage, heat therapy, and painkillers. If these treatments fail, the herniated disc may be removed surgically, and bone grafts are used to fuse the adjacent vertebrae.

In many of these cases, back pain results not from herniation of the disc but instead from small nerves that enter tears in the disc on newly invading veins. A new, simple, and low-pain treatment called IDET (intradiscal electrothermal annuloplasty) consists of threading a fine catheter with a heated tip into the disc, burning away the invading nerves, and at the same time sealing the tears in the anulus.

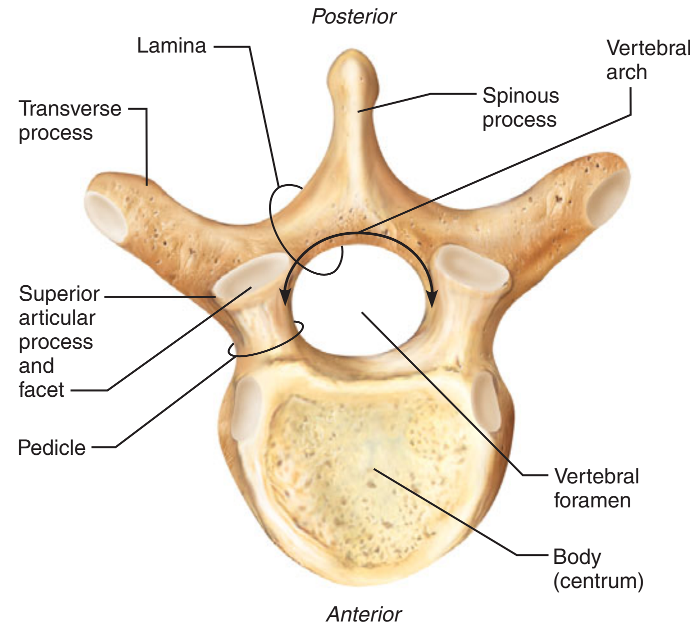


FIGURE 7.20 Structure of a typical vertebra. Superior view. Only features of the bone are illustrated in this and subsequent figures in Chapters 7 and 8. Articular cartilage is not depicted.

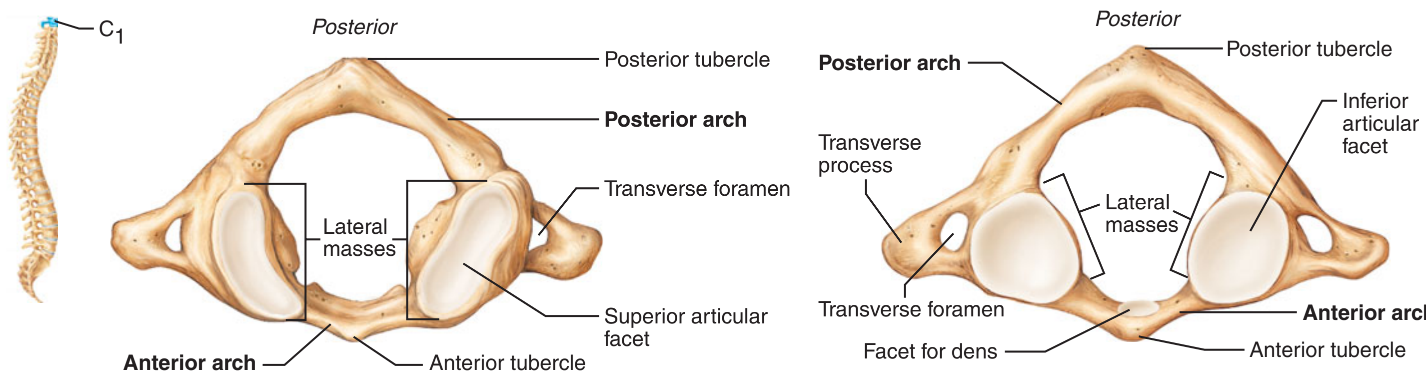
check your understanding

10. What portion of the intervertebral disc expands under compression? What portion resists twisting forces?
11. When and how do the secondary curvatures of the vertebral column develop?
12. Why do intervertebral discs usually herniate in the posterolateral direction?

For answers, see Appendix B.

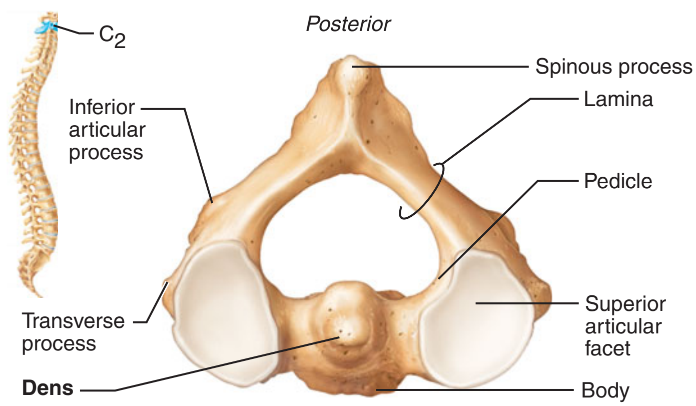
General Structure of Vertebrae

Vertebrae from all regions share a common structural pattern (Figure 7.20). A vertebra consists of a **body,** or **centrum,** anteriorly and a **vertebral arch** posteriorly. The disc-shaped body is the weight-bearing region. Together, the body and vertebral arch enclose an opening called the **vertebral foramen.** Successive vertebral foramina of the articulated vertebrae form the long *vertebral canal,* through which the spinal cord passes.



(a) Superior view of atlas (C_1)

(b) Inferior view of atlas (C_1)



(c) Superior view of axis (C_2)

FIGURE 7.21 The first and second cervical vertebrae. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 18.)

The vertebral arch is a composite structure formed by two pedicles and two laminae. The sides of the arch are **pedicles** (ped′ĭ-klz; "little feet"), short bony walls that project posteriorly from the vertebral body. The **laminae** (lam′ĭ-ne; "sheets") are flat roof plates that complete the arch posteriorly.

Seven different processes project from each vertebral arch. The **spinous process,** or **vertebral spine,** is a median, posterior projection arising at the junction of the two laminae. A **transverse process** projects laterally from each pedicle-lamina junction. Both the spinous and transverse processes are attachment sites for muscles that move the vertebral column and for ligaments that stabilize it. The paired **superior** and **inferior articular processes** protrude superiorly and inferiorly, respectively, from the pedicle-lamina junctions. The inferior articular processes of each vertebra form movable joints with the superior articular processes of the vertebra immediately inferior. Thus, successive vertebrae are joined by both intervertebral discs and by articular processes. The smooth joint surfaces of these processes are **facets** ("little faces").

The pedicles have notches on their superior and inferior borders, forming lateral openings between adjacent vertebrae called **intervertebral foramina** (see Figure 7.18). The spinal nerves issuing from the spinal cord pass through these foramina.

Regional Vertebral Characteristics

The different regions of the spine perform slightly different functions, so vertebral structure shows regional variation. In general, the types of movements that can occur between vertebrae are (1) flexion and extension (anterior bending and posterior straightening of the spine), (2) lateral flexion (bending the upper body to the right or left), and (3) rotation, in which the vertebrae rotate on one another in the long axis of the vertebral column. Refer to Table 7.2 on p. 172 while reading the following discussions of vertebral characteristics.

Cervical Vertebrae

The seven cervical vertebrae, identified as C_1–C_7, are the smallest, lightest vertebrae.

The first two cervical vertebrae are the *atlas* (C_1) and the *axis* (C_2) **(Figure 7.21)**. These two vertebrae are unusual: No intervertebral disc lies between them, and they have unique structural and functional features.

The **atlas** lacks a body and a spinous process. Essentially, it is a ring of bone consisting of **anterior** and **posterior arches,** plus a **lateral mass** on each side. Each lateral mass has articular facets on both its superior and inferior surfaces. The superior articular facets receive the occipital condyles of the skull. Thus, they "carry" the skull, just as the giant Atlas supported the heavens in Greek mythology. These joints participate in flexion and extension of the head on the neck, as when you nod "yes." The inferior articular facets form joints with the axis.

The **axis,** which has a body, a spinous process, and the other typical vertebral processes, is not as specialized as the atlas. In fact, its only unusual feature is the knoblike **dens** ("tooth") projecting superiorly from its body. The dens is actually the "missing" body of the atlas that fuses with the axis during embryonic development. Cradled in the anterior arch of the atlas **(Figure 7.22a)**, the dens acts as a pivot for the rotation of the atlas and skull. Hence, this joint participates in rotating the head from side to side to indicate "no." *Axis* is a good name for the second cervical vertebra because its dens allows the head to rotate on the neck's axis.

THE DENS AND FATAL TRAUMA In cases of severe head trauma in which the skull is driven inferiorly toward the spine, the dens may be forced into the brain stem, causing death. Alternatively, if the neck is jerked forward, as in an automobile collision, the dens may be driven posteriorly into the cervical spinal cord. This injury is also fatal.

The typical cervical vertebrae, C_3–C_7, have the following distinguishing features, as shown in **Table 7.2** on page 172:

1. The body is wider laterally than in the anteroposterior dimension.
2. Except in C_7, the spinous process is short, projects directly posteriorly, and is bifid (bi′fid; "cleaved in two" or forked); that is, split at its tip.
3. The vertebral foramen is large and generally triangular.
4. Each transverse process contains a hole, a **transverse foramen,** through which the vertebral blood vessels pass. These vessels ascend and descend through the neck to help serve the brain.
5. The superior articular facets face superoposteriorly, whereas the inferior articular facets face inferoanteriorly. Thus these articulations lie in an oblique plane. The orientation of these articulations allows the neck to carry out an extremely wide range of movements: flexion and extension, lateral flexion, and rotation.

The spinous process of C_7 is not bifid and is much larger than those of the other cervical vertebrae (Figure 7.22a). Because its large spinous process can be seen and felt through the skin, C_7 is called the **vertebra prominens** ("prominent vertebra") and is used as a landmark for counting the vertebrae in living people. To locate this landmark, run your fingers inferiorly along the back of your neck, in the posterior midline, where you can feel the spinous processes of the cervical vertebrae. The spine of C_7 is especially prominent.

Thoracic Vertebrae

The 12 thoracic vertebrae, T_1–T_{12} (Figure 7.22b and Table 7.2), all articulate with ribs. Their other unique characteristics are:

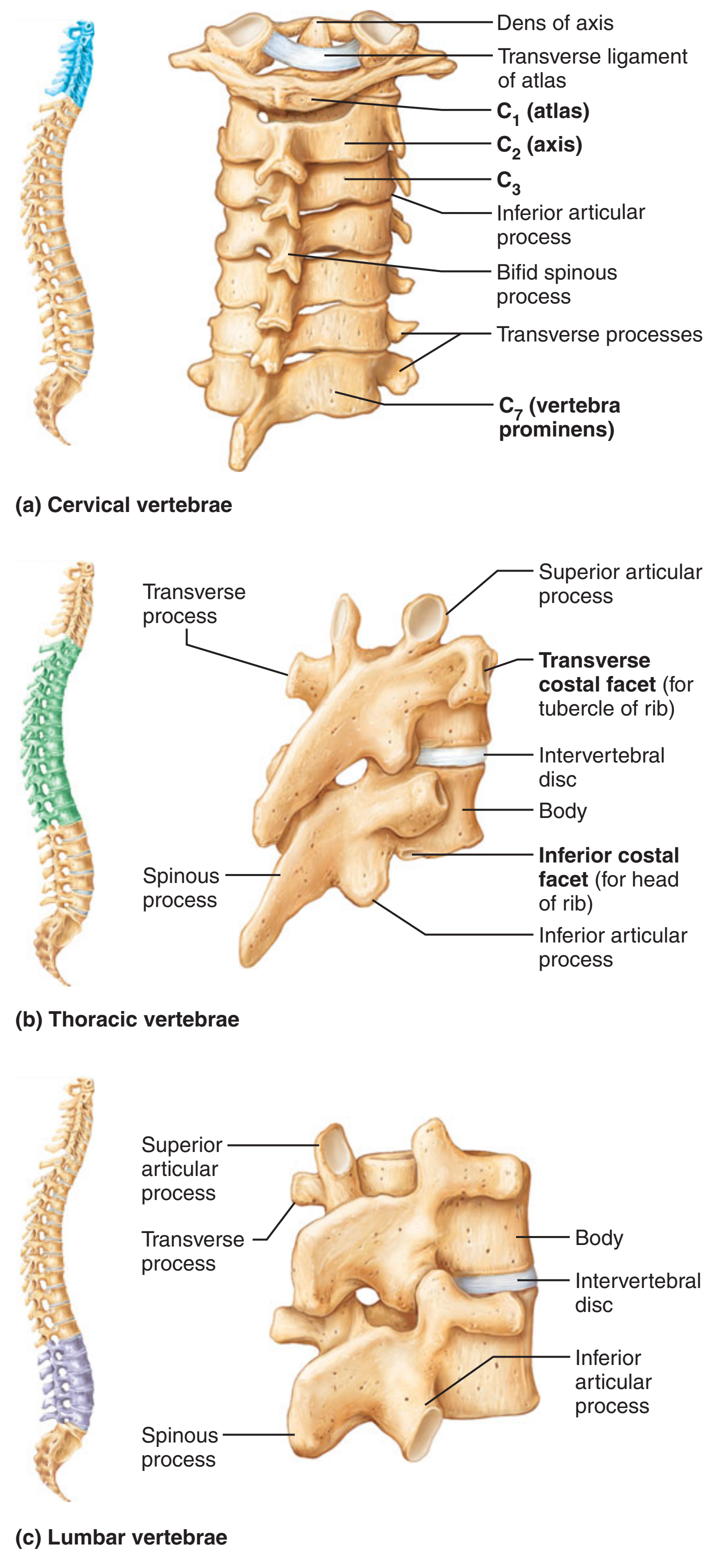
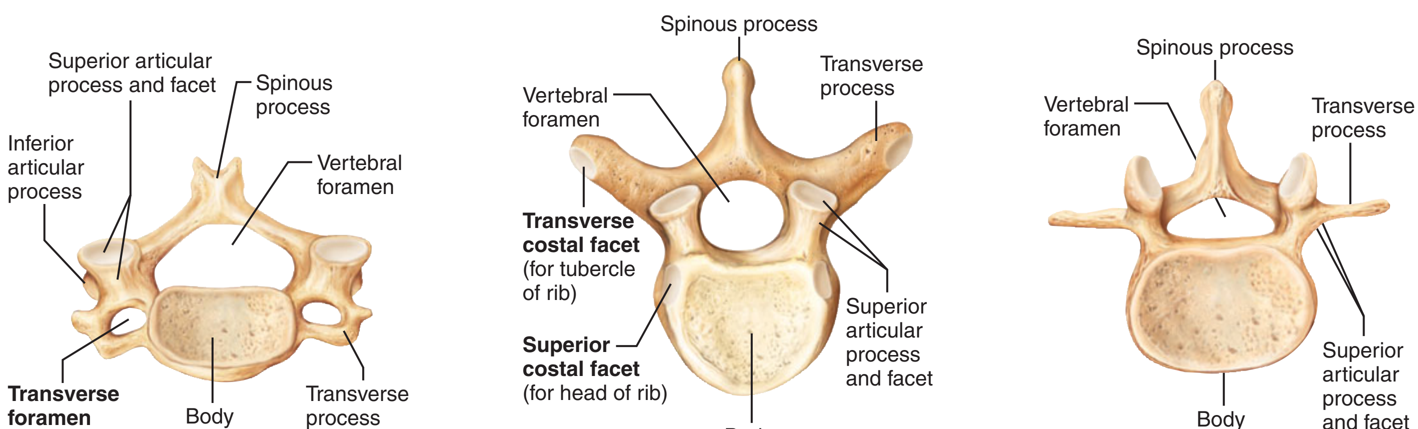


FIGURE 7.22 Posterolateral views of articulated vertebrae. In (a), note the prominent spinous process of C_7, the vertebra prominens. (See *A Brief Atlas of the Human Body*, Second Edition, Figures 19, 20, and 21.)

TABLE 7.2 Regional Characteristics of Cervical, Thoracic, and Lumbar Vertebrae

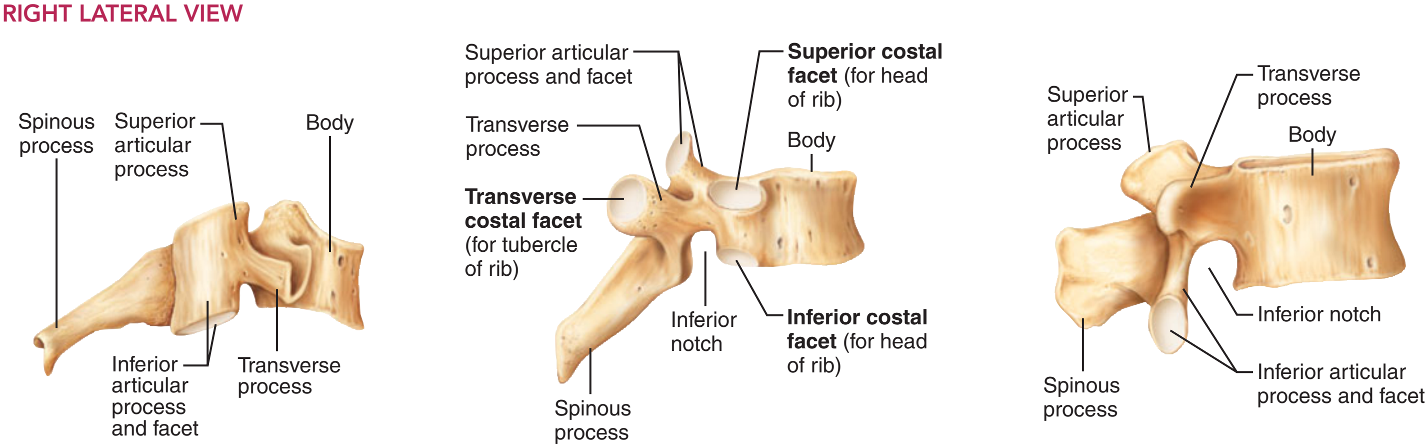
Characteristic	Cervical (3–7)	Thoracic	Lumbar
Body	Small, wide side to side	Larger than cervical; heart-shaped; bears two costal facets	Massive; kidney-shaped
Spinous process	Short; forked; projects directly posteriorly	Long; sharp; projects inferiorly	Short; blunt; rectangular; projects directly posteriorly
Vertebral foramen	Triangular	Circular	Triangular
Transverse processes	Contain foramina	Bear facets for ribs (except T_{11} and T_{12})	Thin and tapered
Superior and inferior articulating processes	Superior facets directed superoposteriorly	Superior facets directed posteriorly	Superior facets directed posteromedially (or medially)
	Inferior facets directed inferoanteriorly	Inferior facets directed anteriorly	Inferior facets directed anterolaterally (or laterally)
Movements allowed	Flexion and extension; lateral flexion; rotation; the spine region with the greatest range of movement	Rotation; lateral flexion possible but restricted by ribs; flexion and extension limited	Flexion and extension; some lateral flexion; rotation prevented

SUPERIOR VIEW



(a) Cervical **(b) Thoracic** **(c) Lumbar**

RIGHT LATERAL VIEW



(a) Cervical **(b) Thoracic** **(c) Lumbar**

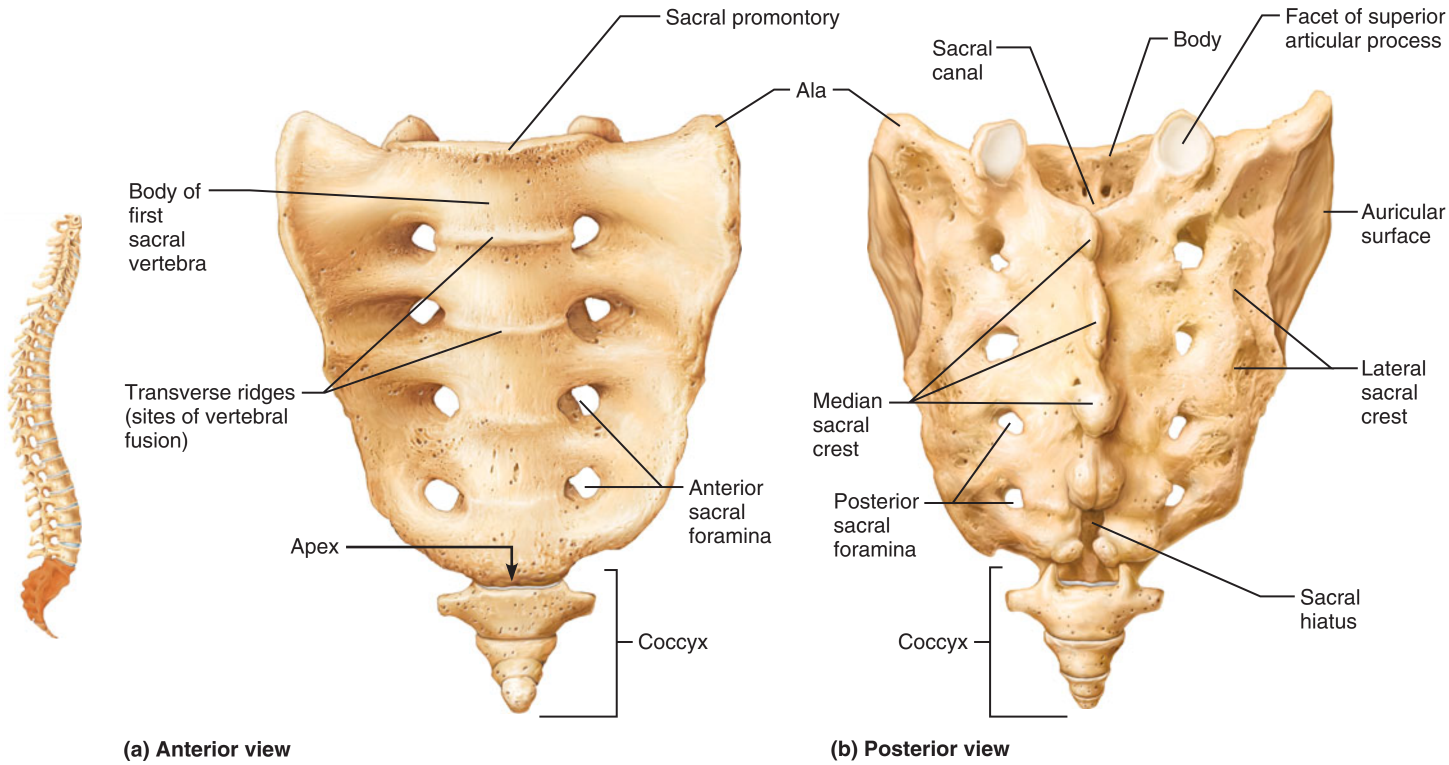


FIGURE 7.23 The sacrum and coccyx. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 22.)

1. From a superior view, the vertebral body is roughly heart-shaped. Laterally, each side of the vertebral body bears two facets, commonly referred to as demifacets (dem′e-fas″ets), one at the superior edge, the **superior costal facet,** and the other at the inferior edge, the **inferior costal facet** (*costa* = rib; *facet* = joint surface). The heads of the ribs articulate with these facets. In general, the head of the rib is attached to the bodies of two vertebrae, the inferior costal facet of the superior vertebra and the superior costal facet of the inferior vertebra. Vertebra T_1 differs from this general pattern in that its body bears a full facet for the first rib and a demifacet for the second rib; furthermore, the bodies of T_{10}–T_{12} have only single facets to receive their respective ribs.
2. The spinous process is long and points inferiorly.
3. The vertebral foramen is circular.
4. With the exception of T_{11} and T_{12}, the transverse processes have facets that articulate with the tubercles of the ribs called **transverse costal facets** (Figure 7.22b).
5. The superior and inferior articular facets, which join adjacent vertebrae, lie mainly in the frontal plane; that is, the superior articular facets face posteriorly, whereas the inferior articular facets face anteriorly. Such articulations limit flexion and extension, but they allow rotation between successive vertebrae. Much of the ability to rotate the trunk comes from the thoracic region of the vertebral column. Lateral flexion is also possible but is restricted by the ribs.

Lumbar Vertebrae

The lumbar region of the vertebral column, the area commonly referred to as the small of the back, receives the most stress. The enhanced weight-bearing function of the five lumbar vertebrae (L_1–L_5) is reflected in their sturdy structure: Their bodies are massive and appear kidney-shaped from a superior view (see Table 7.2). Their other characteristics are as follows:

1. The pedicles and laminae are shorter and thicker than those of other vertebrae.
2. The spinous processes are short, flat, and hatchet-shaped, and they project straight posteriorly. These processes are robust for the attachment of large back muscles.
3. The vertebral foramen is triangular.
4. The superior articular facets face posteromedially (or medially), whereas the inferior articular facets face anterolaterally (or laterally) (see Figure 7.22c), oriented approximately in the sagittal plane. Such articulations provide stability by preventing rotation between the lumbar vertebrae. Flexion and extension are possible, however. The lumbar region flexes, for example, when you do sit-ups or bend forward to pick up a coin from the ground. Additionally, lateral flexion is allowed by this spinal region.

Sacrum

The curved, triangular **sacrum** shapes the posterior wall of the pelvis **(Figure 7.23)**. It is formed by five fused vertebrae (S_1–S_5). Superiorly, it articulates with L_5 through a pair of **superior articular processes** (Figure 7.23b) and an intervertebral disc. Inferiorly, it joins the coccyx.

The anterosuperior margin of the first sacral vertebra bulges anteriorly into the pelvic cavity as the **sacral promontory** (prom′on-tor-ē, "a high point of land projecting into the sea"). The human body's center of gravity lies about 1 cm posterior to this landmark. Four **transverse ridges** cross the anterior surface of the sacrum, marking the lines of fusion of the sacral vertebrae. The **anterior sacral foramina** transmit the ventral divisions (ventral rami) of the sacral spinal nerves. The large region lateral to these foramina is simply called the *lateral part.* This part expands superiorly into the flaring **ala** (a′lah; "wing"), which develops from fused *rib* elements of S_1–S_5. (Embryonic rib elements form in association with *all* vertebrae, although they only become true ribs in the thorax. Elsewhere, they fuse into the ventral surfaces of the transverse processes.) The alae articulate at the auricular surface with the two hip bones to form the *sacroiliac* (sa″kro-il′e-ak) *joints* of the pelvis.

On the posterior surface, in the midline, is the bumpy **median sacral crest,** which represents the fused spinous processes of the sacral vertebrae. Lateral to it are the **posterior sacral foramina,** which transmit the dorsal rami of the sacral spinal nerves. Just lateral to these is the **lateral sacral crest,** representing the tips of the transverse processes of the sacral vertebrae.

The vertebral canal continues within the sacrum as the **sacral canal.** The laminae of the fifth (and sometimes the fourth) sacral vertebrae fail to fuse medially, leaving an enlarged external opening called the **sacral hiatus** (hi-a′tus; "gap") at the inferior end of the sacral canal.

Coccyx

The **coccyx,** or tailbone, is small and triangular (Figure 7.23). The name *coccyx* is from a Greek word for "cuckoo," and the bone was so named because of a fancied resemblance to a bird's beak. The coccyx consists of three to five vertebrae fused together. Except for the slight support it affords the pelvic organs, it is an almost useless bone. Injury to the coccyx, such as from an abrupt fall, is extremely painful. Occasionally, a baby is born with an unusually long coccyx. In most such cases, this bony "tail" is discreetly snipped off by a physician.

check your understanding

13. What does the superior articular process of a vertebra articulate with?
14. Name one feature that is unique for all cervical vertebrae.
15. How can you distinguish thoracic vertebra T_{12} from lumbar vertebra L_1?
16. What part of the vertebrae form the median sacral crest?

For answers, see Appendix B.

THE THORACIC CAGE

- Identify the distinctive features of the ribs and sternum.
- Differentiate true ribs from false ribs, and explain how they relate to floating ribs.
- Describe how a typical rib attaches to the vertebral column.

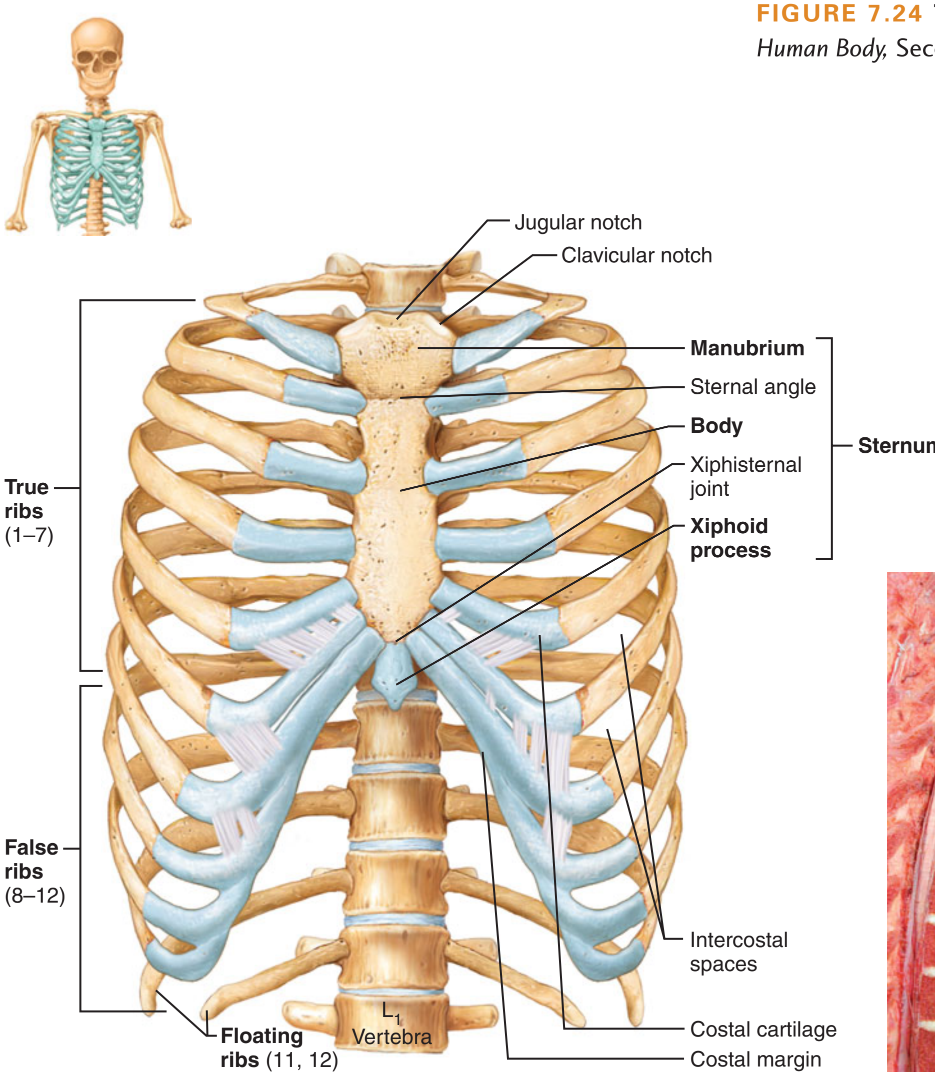
The bony framework of the chest (thorax), called the **thoracic cage,** is roughly barrel-shaped and includes the thoracic vertebrae posteriorly, the ribs laterally, and the sternum and costal cartilages anteriorly **(Figure 7.24)**. The thoracic cage forms a protective cage around the heart, lungs, and other organs. It also supports the shoulder girdles and upper limbs and provides attachment points for many muscles of the back, neck, chest, and shoulders. In addition, the *intercostal spaces* (*inter* = between; *costa* = the ribs) are occupied by the intercostal muscles, which lift and depress the thorax during breathing.

Sternum

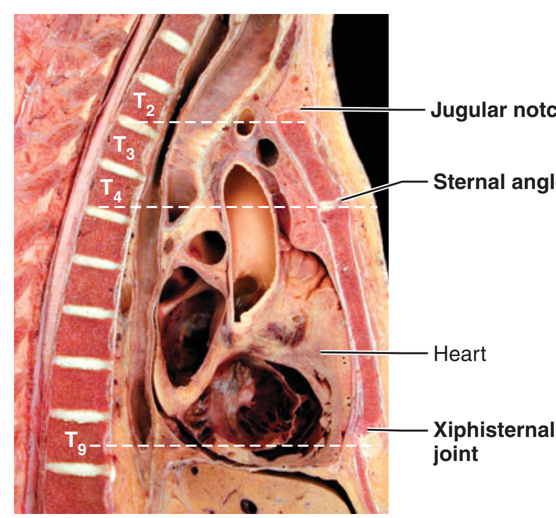
The **sternum** (breastbone) lies in the anterior midline of the thorax. Resembling a dagger, it is a flat bone about 15 cm long consisting of three sections: the manubrium, body, and xiphoid process. The **manubrium** (mah-nu′bre-um; "knife handle"), the superior section, is shaped like the knot in a necktie. Its **clavicular notches** articulate with the clavicles (collarbones) superolaterally. Just below this, the manubrium also articulates with the first and second ribs. The **body,** or midportion, makes up the bulk of the sternum. It is formed from four separate bones, one inferior to the other, that fuse after puberty. The sides of the sternal body are notched where it articulates with the costal cartilages of the second to seventh ribs. The **xiphoid process** (zif′oid; "sword-like") forms the inferior end of the sternum. This tongue-shaped process is a plate of hyaline cartilage in youth, and it does not fully ossify until about age 40. In some people, the xiphoid process projects posteriorly. Blows to the chest can push such a xiphoid into the underlying heart or liver, causing massive hemorrhage.

The sternum has three important anatomical landmarks that can be palpated: the jugular notch, the sternal angle, and the xiphisternal joint (Figure 7.24a). The **jugular notch,** also called the *suprasternal notch,* is the central indentation in the superior border of the manubrium. If you slide your finger down the anterior surface of your neck, it will land in the jugular notch. The jugular notch generally lies in the same horizontal plane as the disc between the second and third thoracic vertebrae (Figure 7.24b). Just inferior is the **sternal angle,** a horizontal ridge across the anterior suface of the sternum where the manubrium joins the body. This fibrocartilage joint acts like a hinge, allowing the sternal body to swing anteriorly when we inhale. The sternal angle is in line with the disc between the fourth and fifth thoracic vertebrae. Anteriorly, it lies at the level of the second ribs. It is a handy reference point for finding the second rib. Once the second rib is located, you can count down to identify all the other ribs

FIGURE 7.24 The thoracic cage. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 23.)



(a) Skeleton of the thoracic cage, anterior view



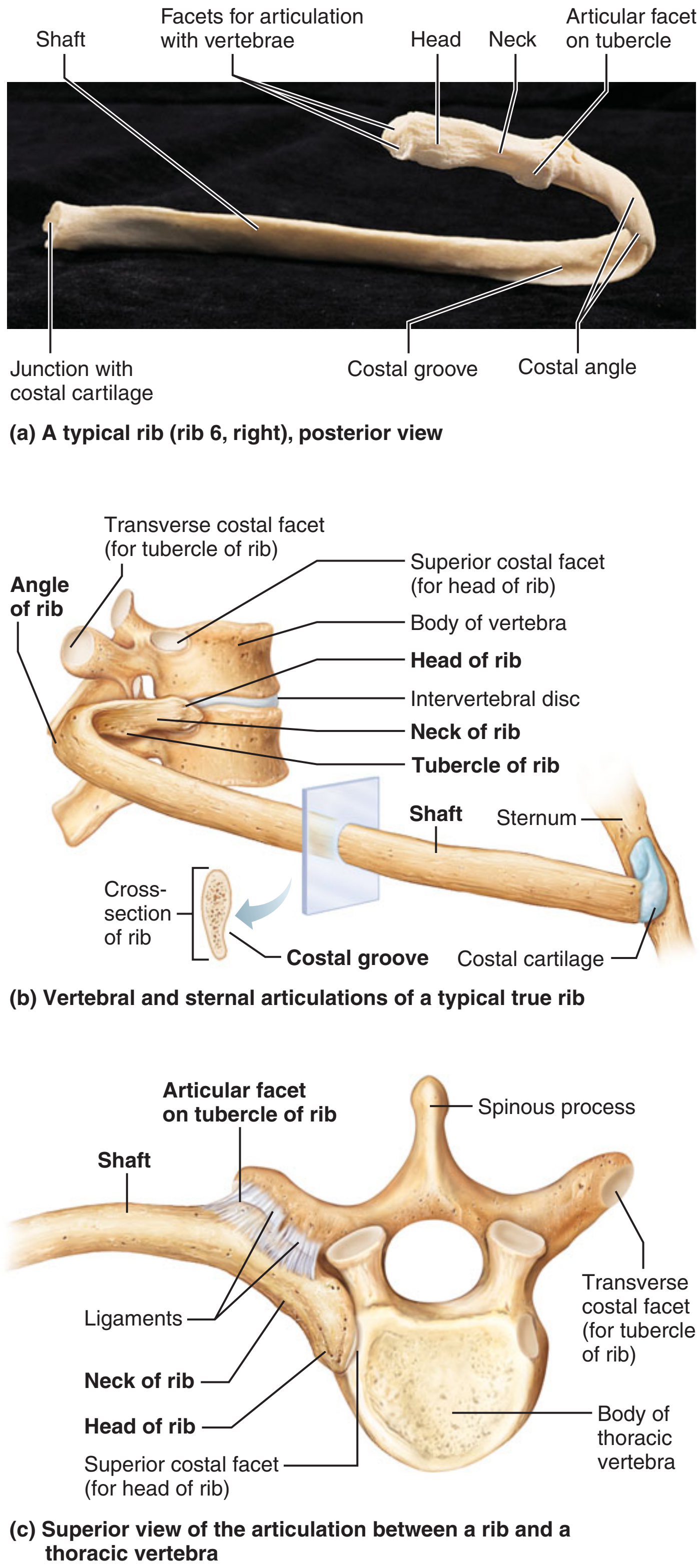
(b) Midsagittal section through the thorax, showing the relationship of surface anatomical landmarks of the thorax to the vertebral column

(except the first and sometimes the twelfth, which are too deep to be palpated). By locating the individual ribs, you attain a series of horizontal lines of "latitude" by which to locate the underlying visceral organs of the thoracic cavity. The **xiphisternal** (zif″ĭ-ster′nal) **joint** is where the sternal body and xiphoid process fuse. It lies at the level of the ninth thoracic vertebra. Deep to this joint, the heart lies on the diaphragm.

Ribs

Twelve pairs of **ribs** (Latin: *costa)* form the flaring sides of the thoracic cage (see Figure 7.24a). All ribs attach to the thoracic vertebrae posteriorly and run anteroinferiorly to reach the front of the chest. The superior seven pairs, which attach directly to the sternum by their *costal cartilages,* are the **true ribs,** or *vertebrosternal* (ver″tĕ-bro-ster′nal) *ribs.* The inferior five pairs, ribs 8–12, are called **false ribs** because they attach to the sternum either indirectly or not at all. Ribs 8–10 attach to the sternum indirectly, as each joins the costal cartilage above it; these are called *vertebrochondral* (ver″tĕ-bro-kon′dral) *ribs.* Ribs 11 and 12 are called **floating ribs** or *vertebral ribs* because they have no anterior attachments. Instead, their costal cartilages lie embedded in the muscles of the lateral body wall. The ribs increase in length from pair 1 to 7, then decrease in length from pair 8 to 12. The inferior margin of the rib cage, or **costal margin,** is formed by the costal cartilages of ribs 7 to 10. The right and left costal margins diverge from the region of the xiphisternal joint, where they form the **infrasternal angle** (*infra* = below).

A typical rib is a bowed flat bone (Figure 7.25a–c). The bulk of a rib is simply called the **shaft** or **body.** Its superior border is smooth, but its inferior border is sharp and thin and has a **costal groove** on its inner face. The intercostal nerves and vessels are located in the costal groove. In addition to the shaft, each rib has a head, neck, and tubercle. The wedge-shaped **head** articulates with the vertebral bodies by two facets: One facet joins the body of the thoracic vertebra of the same number; the other joins the body of the vertebra



(a) A typical rib (rib 6, right), posterior view

(b) Vertebral and sternal articulations of a typical true rib

(c) Superior view of the articulation between a rib and a thoracic vertebra

FIGURE 7.25 Ribs. All ribs illustrated in this figure are right ribs. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 23e and f.)

immediately superior (Figure 7.25b). The **neck** of a rib is the short, constricted region just lateral to the head. Just lateral to the neck on the posterior surface, the knoblike **tubercle** articulates with the transverse process of the thoracic vertebra of the same number (Figure 7.25c). Lateral to the tubercle, the shaft angles sharply anteriorly (at the **angle** of the rib) and extends to the costal cartilage anteriorly. The costal cartilages provide secure but flexible attachments of ribs to the sternum and contribute to the elasticity of the thoracic cage.

The first rib is atypical because it is flattened from superior to inferior and is quite broad (Figure 7.24a). The subclavian vessels, the large artery and vein servicing the upper limb, run in a groove along its superior surface. There are other exceptions to the typical rib pattern: Rib 1 and ribs 10–12 articulate with only one vertebral body, and ribs 11 and 12 do not articulate with a vertebral transverse process.

check your understanding

17. Define the sternal angle. Which rib articulates with the sternum at this landmark?
18. What specific features of the thoracic vertebrae articulate with the head of a rib? Where does the tubercle of a rib articulate?

For answers, see Appendix B.

DISORDERS OF THE AXIAL SKELETON

- Describe the causes and consequences of cleft palate.
- List three types of abnormal curvatures of the spinal column, and explain spinal stenosis.

Cleft Palate

Several congenital abnormalities may distort the skull. Most common is **cleft palate,** in which the right and left halves of the palate fail to join medially. This defect leaves an opening between the mouth and the nasal cavity that interferes with sucking and the baby's ability to nurse. Cleft palate can lead to aspiration (inhalation) of food into the nasal cavity and lungs, resulting in pneumonia. Often accompanied by cleft lip **(Figure 7.26)**, it is repaired surgically. Recently it has been found that the likelihood of cleft palate is minimized if the mother takes multivitamins containing folic acid during early pregnancy.

Stenosis of the Lumbar Spine

The condition known as **stenosis of the lumbar spine** (steno′sis; "narrowing") is a narrowing of the vertebral canal in the lumbar region. This disorder can compress the roots of the spinal nerves and cause back pain. The narrowing may result from degenerative or arthritic changes in the vertebral joints and ligaments or be caused by bone spurs projecting into the vertebral canal.

(a) A boy born with a cleft palate and lip.

(b) The boy as a toddler, following surgical repair during infancy.

(c) By adolescence, there was little evidence of the original defect.

FIGURE 7.26 Cleft palate.

Abnormal Spinal Curvatures

There are several types of abnormal spinal curvatures. Some are congenital (present at birth), whereas others result from disease, poor posture, or unequal pull of muscles on the spine.

Scoliosis (sko″le-o′sis; "twisted disease") is an abnormal *lateral* curvature of more than 10 degrees that occurs most often in the thoracic region **(Figure 7.27a)**. One type, of unknown cause, is common in adolescents, particularly girls. Other, more severe cases result from abnormally structured vertebrae, lower limbs of unequal length, or muscle paralysis. If muscles on one side of the back are nonfunctional, those on the opposite side pull unopposed and move the spine out of alignment. To prevent permanent deformity, clinicians treat scoliosis with body braces or surgery before the child stops growing. Severe scoliosis can compress a lung, causing difficulty in breathing.

Kyphosis (ki-fo′sis; "humped disease"), or hunchback, is an exaggerated thoracic curvature that is most common in aged women because it often results from spinal fractures that follow osteoporosis (Figure 7.27b). It may also result from either tuberculosis of the spine or osteomalacia.

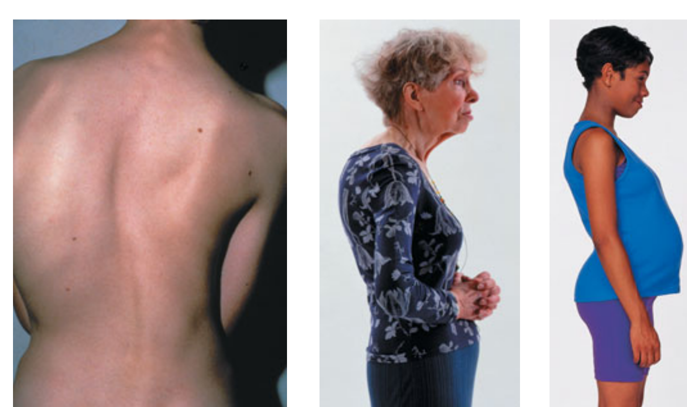
Lordosis (lor-do′sis: "bent-backward disease"), or swayback, is an accentuated lumbar curvature (Figure 7.27c). Temporary lordosis is common in people carrying a "large load in front," such as obese men and pregnant women. Like kyphosis, it can result from spinal tuberculosis or osteomalacia.

THE AXIAL SKELETON THROUGHOUT LIFE

➤ Describe how the axial skeleton changes as we grow.

The membrane bones of the skull begin to ossify late in the second month of development. In these flat bones, bone tissue grows outward from **ossification centers** within the mesenchyme membranes. At birth, the skull bones remain incomplete and are separated by still-unossified remnants of the membranes, called **fontanelles** (fon″tah-nelz′) **(Figure 7.28)**. The major fontanelles—the **anterior, posterior, mastoid,** and **sphenoidal fontanelles**—allow the skull to be compressed slightly as the infant passes through the narrow birth canal, and they accommodate brain growth in the baby. A baby's pulse surging in these "soft spots" feels like gushing water (*fontanelle* means "little fountain"). The large, diamond-shaped anterior fontanelle can be felt for 1½ to 2 years after birth. The others usually are replaced by bone by the end of the first year.

Whereas the bones of the skullcap and face form directly from mesenchyme by intramembranous ossification, those at the base of the skull develop from cartilage by endochondral ossification. More specifically, the skull's endochondral bones are the occipital (except for its extreme posterosuperior part), the petrous and mastoid parts of the temporal, most of the sphenoid, and the ethmoid.



(a) Scoliosis **(b)** Kyphosis **(c)** Lordosis

FIGURE 7.27 Abnormal spinal curvatures.

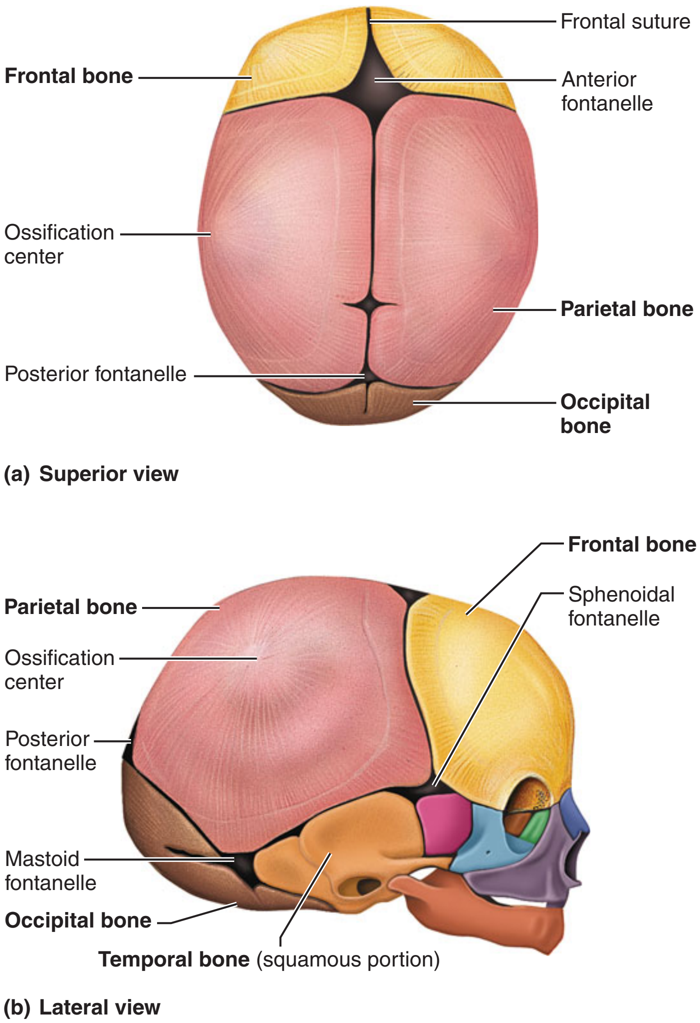


FIGURE 7.28 Skull of a newborn. Note the fontanelles and ossification centers. (See *A Brief Atlas of the Human Body,* Second Edition, Figure 16.)

At birth, the skull bones are thin. The frontal bone and the mandible begin as paired bones that fuse medially during childhood. The tympanic part of the temporal bone is merely a C-shaped ring in the newborn.

The skull changes throughout life, but the changes are most dramatic during childhood. At birth, the baby's cranium is huge relative to its small face (see Figure 7.28). The maxillae and mandible are comparatively tiny, and the contours of the face are flat. By 9 months of age, the skull is already half its adult size. By 2 years, it is three-quarters of its full size, and by 8 or 9 years, the cranium is almost full-sized. However, between the ages of 6 and 13, the head appears to enlarge substantially because the face literally grows out from the skull as the jaws, cheekbones, and nose become more prominent. The enlargement of the face correlates with an expansion of the nose, paranasal sinuses, and chewing muscles, plus the development of the large permanent teeth.

Problems with the vertebral column, such as lordosis or scoliosis, may appear during the early school years, when rapid growth of the long limb bones stretches many muscles. Children normally have a slight lordosis because holding the abdomen anteriorly helps to counterbalance the weight of their relatively large heads, held slightly posteriorly. During childhood, the thorax grows wider, but true adult posture (head erect, shoulders back, abdomen in, and chest out) does not develop until adolescence.

Aging affects many parts of the skeleton, especially the spine. The water content of the intervertebral discs declines. As the discs become thinner and less elastic, the risk of herniation increases. By 55 years, a loss of several centimeters from a person's height is common. Further shortening of the trunk can be produced by osteoporosis of the spine that leads to kyphosis, which is sometimes called "dowager's hump" in older adults.

The thorax becomes more rigid with increasing age, largely because the costal cartilages ossify. This loss of elasticity of the rib cage leads to shallow breathing, which in turn leads to less efficient gas exchange in the lungs.

Recall that all bones lose mass with age. Skull bones lose less mass than most, but they lose enough to change the facial contours of the older person. As the bony tissue of the mandible and maxilla decreases, the jaws come to look small and childlike once again. If an elderly person loses his or her teeth, bone loss from the jaws is accelerated because the bone of the alveolar region (tooth sockets) is reabsorbed.

check your understanding

19. Which skull bones form as two individual bones that fuse during childhood to form a single bone in the adult?
20. Which abnormal spinal curvature is associated with age-related degenerative bone loss?

For answers, see Appendix B.

RELATED CLINICAL TERMS

CRANIOTOMY ("cutting the skull") Surgery to remove part of the cranium, usually done to gain access to the brain—for example, to remove a brain tumor, a blood clot, or a sample of brain tissue for a biopsy. The piece of skull is removed by drilling a series of round holes through the bone at regular intervals to outline a square and then cutting between these holes with a stringlike saw. At the end of the operation, the square piece of bone is replaced, and it heals normally.

LAMINECTOMY (lam″ĭ-nek′to-me; "lamina-cutting") Surgical removal of a vertebral lamina. Laminectomies are usually done to reach and relieve a herniated disc.

ORTHOPEDIST (or″tho-pe′dist) or **ORTHOPEDIC SURGEON** A physician who specializes in restoring lost function or repairing damage to bones and joints.

SPINAL FUSION Surgical procedure involving insertion of bone chips as a tissue graft to stabilize a portion of the vertebral column, particularly after the fracture of a vertebra or the prolapse of a disc.

WHIPLASH An injury to the neck region caused by a rapid sequence of hyperextension followed by hyperflexion of the neck. Often results when a car is hit from the rear. Damage and pain usually result from stretching of the ligaments and joints between the neck vertebrae, and torn neck muscles. Treatment typically involves use of a neck brace, painkillers, muscle-relaxing drugs, and physical therapy.

CHAPTER SUMMARY

You can use the following media study tool for additional help when you review specific key topics in Chapter 7.

PAL = ***Practice Anatomy Lab™***

1. The axial skeleton forms the long axis of the body. Its parts are the skull, vertebral column, and thoracic cage. The appendicular skeleton, by contrast, consists of the pectoral (shoulder) and pelvic girdles and the long bones of the limbs.

The Skull (pp. 149–167)

2. The cranium forms the vault and base of the skull and protects the brain. The facial skeleton provides openings for the eyes, openings for respiratory and digestive passages, and areas of attachment for facial muscles.
3. Almost all bones of the skull are joined by immobile sutures.
4. The eight bones of the cranium are the paired parietal and temporal bones and the unpaired frontal, occipital, sphenoid, and ethmoid bones (see Table 7.1, pp. 162–163).
5. The 14 facial bones are the paired maxillae, zygomatics, nasals, lacrimals, palatines, and inferior nasal conchae, plus the unpaired mandible and vomer (see Table 7.1).
6. The nasal cavity and orbits are complicated regions of the skull, each formed by many bones (see Figures 7.14 and 7.16).
7. The air-filled paranasal sinuses occur in the frontal, ethmoid, sphenoid, and maxillary bones. They are extensions of the nasal cavity, to which they are connected.
8. The bowed hyoid bone in the anterior neck serves as a movable base for the tongue, among other functions.

The Vertebral Column (pp.167–174)

9. The vertebral column includes 26 irregular bones: 24 vertebrae plus the sacrum and coccyx.
10. The vertebral column has five major regions: the cervical vertebrae (7), the thoracic vertebrae (12), the lumbar vertebrae (5), the sacrum, and the coccyx. The cervical and lumbar curvatures are concave posteriorly, and the thoracic and sacral curvatures are convex posteriorly.
11. The thoracic and sacral curvatures are primary curvatures, present at birth. The cervical curvature becomes pronounced when a baby starts to lift its head, and the lumbar curvature develops when a toddler starts to walk. These are secondary curvatures.
12. The spinal column is supported by a number of ligaments, including the anterior and posterior longitudinal ligaments, which run along the bodies of the vertebrae from the neck to the sacrum; and the ligamentum flavum, an especially strong elastic ligament running between the lamina of adjacent vertebrae.
13. Intervertebral discs, with their nucleus pulposus cores and anulus fibrosus rings, act as shock absorbers and give flexibility to the spine. Herniated discs usually involve rupture of the anulus followed by protrusion of the nucleus.
14. With the exception of C_1, all cervical, thoracic, and lumbar vertebrae have a body, two transverse processes, two superior and two inferior articular processes, a spinous process, and a vertebral arch.
15. The atlas and axis (C_1 and C_2) are atypical vertebrae. The ringlike atlas supports the skull and helps make nodding movements possible. The axis has a dens that helps the head to rotate.
16. Special characteristics distinguish the cervical, thoracic, and lumbar vertebrae from one another (see Table 7.2, p. 172). The orientation of the articular facets determines the movements possible in the different regions of the spinal column. The sacrum and coccyx, groups of fused vertebrae, contribute to the bony pelvis.

The Thoracic Cage (pp. 174–176)

17. The thoracic cage includes the 12 pairs of ribs, the sternum, and the thoracic vertebrae.
18. The sternum consists of the manubrium, body, and xiphoid process. The sternal angle marks the joint between the manubrium and body, where the second ribs attach.
19. The first seven pairs of ribs are called true ribs; the rest are false ribs. The eleventh and twelfth are called floating ribs. A typical rib consists of a head with facets, a neck, a tubercle, and a shaft. A costal cartilage occurs on the ventral end of each rib.

PAL **Human Cadaver/Axial Skeleton**

Disorders of the Axial Skeleton (pp. 176–177)

20. Cleft palate, a congenital malformation, results when the bones of the hard palate do not fuse medially. Stenosis of the lumbar spine is a pathological narrowing of the vertebral canal in the lumbar region. Scoliosis, kyphosis, and lordosis are three types of abnormal spinal curvature.

The Axial Skeleton Throughout Life (pp. 177–178)

21. Fontanelles are membrane-covered regions between the cranial bones in the infant skull. They allow growth of the brain and ease birth passage.
22. Most skull bones are membrane bones. The skull's only endochondral bones are most of the occipital and sphenoid, the petrous and mastoid parts of the temporal, and the ethmoid.
23. Growth of the cranium early in life is closely related to the rapid growth of the brain. Enlargement of the face in late childhood follows tooth development and expansion of the nose, paranasal sinuses, and chewing muscles.
24. In old age, the intervertebral discs thin. This, along with osteoporosis, leads to a gradual decrease in height.

REVIEW QUESTIONS

Multiple Choice/Matching Questions

For answers, See Appendix B.

1. Match the bones in column B to their descriptions in column A. (Some entries in column A will require more than one answer from column B.)

Column A	Column B
____ **(1)** bones connected by the coronal suture	**(a)** ethmoid
____ **(2)** keystone bone of the cranium	**(b)** frontal
____ **(3)** keystone bone of the face	**(c)** mandible
____ **(4)** bones that form the hard palate	**(d)** maxillary
____ **(5)** bone that contains the foramen magnum	**(e)** occipital
____ **(6)** forms the chin	**(f)** palatine
____ **(7)** contain paranasal sinuses	**(g)** parietal
____ **(8)** contains mastoid air cells	**(h)** sphenoid
	(i) temporal

2. Herniated intervertebral discs tend to herniate (a) superiorly, (b) anterolaterally, (c) posterolaterally, (d) laterally.
3. The parts of the sternum that articulate at the sternal angle are (a) xiphoid and body, (b) xiphoid and manubrium, (c) manubrium and body, (d) second ribs.
4. The only rib whose shaft is flattened in the horizontal plane, instead of vertically, is the (a) first rib, (b) seventh rib, (c) eleventh rib, (d) twelfth rib.
5. The name of the first cervical vertebra is (a) atlas, (b) axis, (c) occiput, (d) vertebra prominens.
6. Match the vertebrae listed in column B with the features in column A.

Column A	Column B
____ **(1)** no spinous process	**(a)** atlas only
____ **(2)** transverse foramen	**(b)** axis only
____ **(3)** superior articular facets	**(c)** cervical vertebrae
____ **(4)** dens process	**(d)** thoracic vertebrae
____ **(5)** transverse costal facets	**(e)** lumbar vertebrae
____ **(6)** kidney-shaped body	**(f)** all vertebrae
____ **(7)** forked spinous process	
____ **(8)** circular vertebral foramen	
____ **(9)** transverse process	
____ **(10)** articular facets directed medially/laterally	

7. Match the foramen in column B with the bone in column A in which it is located.

Column A	Column B
____ **(1)** ethmoid bone	**(a)** hypoglossal canal
____ **(2)** maxillary bone	**(b)** foramen ovale
____ **(3)** sphenoid bone	**(c)** external acoustic meatus
____ **(4)** occipital bone	**(d)** infraorbital foramen
____ **(5)** temporal bone	**(e)** olfactory foramina

Short Answer Essay Questions

8. In the fetus, how do the relative proportions of the cranium and face compare with those in the skull of a young adult?
9. Name and diagram the four normal vertebral curvatures. Which are primary and which are secondary?
10. List two specific structural characteristics each for cervical, thoracic, and lumbar vertebrae that would enable anyone to identify each type correctly.
11. (a) What is the function of intervertebral discs? (b) Distinguish the anulus fibrosus from the nucleus pulposus of a disc. (c) Which part herniates in the condition called prolapsed disc?
12. Is a floating rib a true rib or a false rib? Explain.
13. Briefly describe the anatomical characteristics and impairment of function seen in cleft palate.
14. Compare the skeleton of a young adult to that of an 85-year-old person, with respect to bone mass in general and the basic bony structure of the skull, thorax, and vertebral column.
15. Identify what types of movement are allowed by the lumbar region of the vertebral column, and compare these with the movements allowed by the thoracic region.
16. List the bones in each of the three cranial fossae.
17. Describe the important features of the sternum.
18. Define these structures in a way that shows you can tell them apart: vertebral arch, vertebral canal, vertebral foramen, and intervertebral foramen.

19. Describe where the four major fontanelles are located in relation to the major sutures of the skull.

20. Professor Ron Singer pointed to the foramen magnum of the skull and said, "That is where the food goes. The food passes down through this hole when you swallow." Some of the students believed him, but others said this was a big mistake. Can you correct his statement?

21. In your anatomy course, you may be handed an isolated vertebra and asked to determine whether it is cervical, thoracic, or lumbar. Devise a reliable scheme for distinguishing these three types of vertebrae.

22. Describe how a typical true rib (for instance, the fifth rib) articulates with both the vertebral column and the sternum.

CRITICAL REASONING & CLINICAL APPLICATION QUESTIONS

1. Antonio was hit in the face with a bad-hop grounder during baseball practice. An X-ray film revealed multiple fractures of the bones around an orbit. Name the bones that form the margins of an orbit.

2. Lindsey had polio as a child and was partially paralyzed in one lower limb for over a year. Although she is no longer paralyzed, she now has a severe lateral curvature of the lumbar spine. Explain what has happened, and name her condition.

3. Mr. Chester, a heavy beer drinker with a large potbelly, complained of severe lower back pains. After X-ray films were taken, he was found to have displacement of his lumbar vertebrae. What would this condition be called, and what would cause it?

4. Which region of the vertebral column (cervical, thoracic, or lumbar) is most likely to experience a herniated disc?

5. After falling off a horse, Mary complained of pain on the right side of her thorax that intensified when she took a deep breath or coughed. The emergency medical technician suspected a broken rib. Using palpation, how could the EMT identify the precise location of the injury?