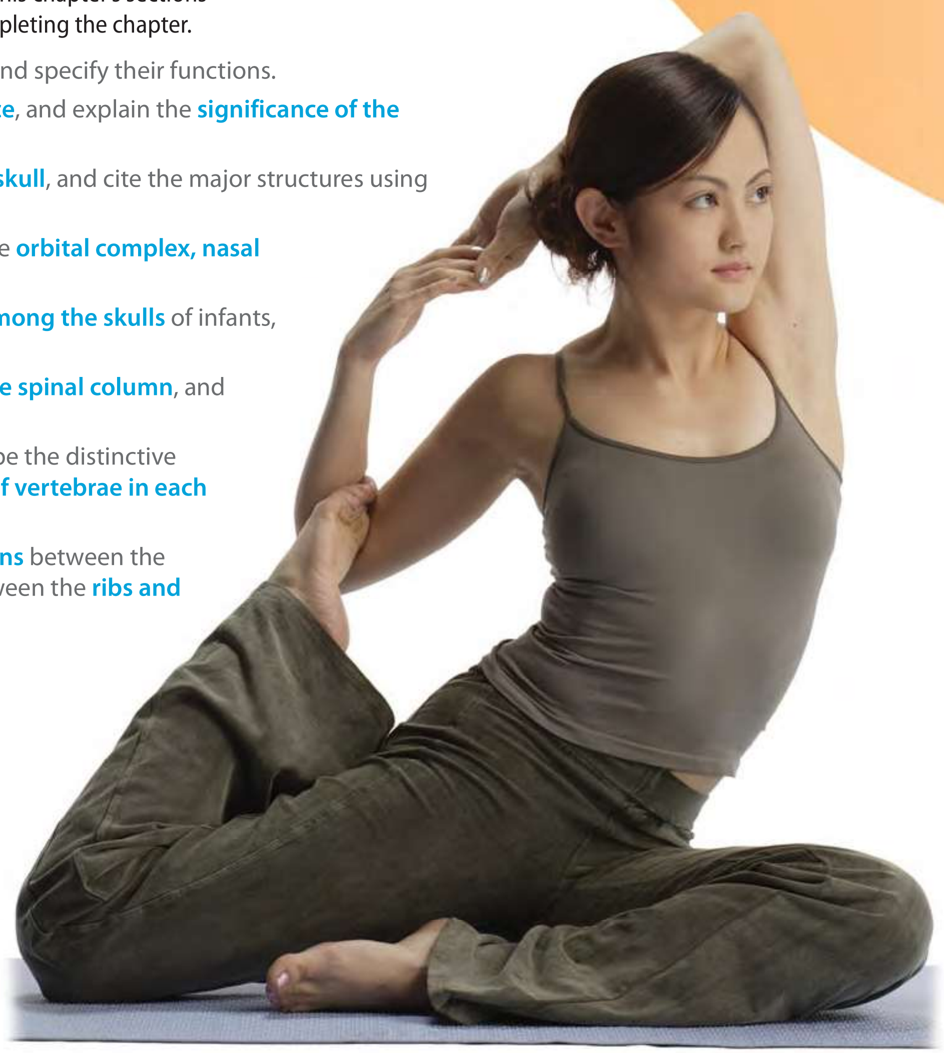
The Axial Skeleton

7

Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

- **7-1** Identify the **bones of the axial skeleton**, and specify their functions.
- **7-2** Identify the **bones of the cranium and face**, and explain the **significance of the markings** on the individual bones.
- **7-3** Identify the **foramina and fissures of the skull**, and cite the major structures using the passageways.
- **7-4** Describe the structure and functions of the **orbital complex, nasal complex, and paranasal sinuses**.
- **7-5** Describe the key **structural differences among the skulls** of infants, children, and adults.
- **7-6** Identify and describe the **curvatures of the spinal column**, and indicate the function of each.
- **7-7** Identify the **vertebral regions**, and describe the distinctive structural and functional **characteristics of vertebrae in each region**.
- **7-8** Explain the **significance of the articulations** between the **thoracic vertebrae and the ribs**, and between the **ribs and sternum**.



Clinical Notes

An Introduction to the Axial Skeleton

In this chapter, we turn our attention to the functional anatomy of the bones that form the longitudinal axis of the body. These bones include the skull and associated bones, the thoracic cage, and the vertebral column.

7-1 The 80 bones of the head and trunk make up the axial skeleton

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The **axial skeleton** forms the longitudinal axis of the body (**Figure 7–1**). The axial skeleton has 80 bones, roughly 40 percent of the bones in the human body. The axial components are as follows:

- The *skull* (8 *cranial bones* and 14 *facial bones*).
- Bones associated with the skull (6 *auditory ossicles* and the *hyoid bone*).
- The *vertebral column* (24 *vertebrae*, the *sacrum*, and the *coccyx*).
- The *thoracic cage* (the *sternum* and 24 *ribs*).

The axial skeleton provides a framework that supports and protects the brain, the spinal cord, and the organs in the subdivisions of the ventral body cavity. It also provides an extensive surface area for the attachment of muscles that (1) adjust the positions of the head, neck, and trunk; (2) perform respiratory movements; and (3) stabilize or position parts of the **appendicular skeleton,** which supports the limbs. The joints of the axial skeleton permit limited movement, but they are very strong and heavily reinforced with ligaments.

We will now consider each of the components of the axial skeleton, beginning with the skull.

Checkpoint

1. **Identify the bones of the axial skeleton.**
2. **List the primary functions of the axial skeleton.**

See the blue Answers tab at the back of the book.

7-2 The skull is composed of 8 cranial bones and 14 facial bones

The bones of the **skull** protect the brain and guard the entrances to the digestive and respiratory systems. The skull contains 22 bones: 8 form the **cranium,** or *braincase*, and 14 are associated with the face (**Figure 7–2**). Seven additional bones are associated with the skull: Six auditory ossicles are located within the *temporal bones* of the cranium, and the hyoid bone is connected to the inferior surfaces of the temporal bones by a pair of ligaments.

The cranium consists of 8 **cranial bones:** the *occipital bone*, *frontal bone*, *sphenoid*, *ethmoid*, and the paired *parietal* and *temporal bones*. Together, the cranial bones enclose the **cranial cavity,** a chamber that supports the brain. Blood vessels, nerves, and membranes that stabilize the position of the brain are attached to the inner surface of the cranium. Its outer surface provides an extensive area for the attachment of muscles that move the eyes, jaws, and head. A joint between the occipital bone and the first vertebra of the neck stabilizes the positions of the brain and spinal cord, while the joints between the vertebrae of the neck permit a wide range of head movements.

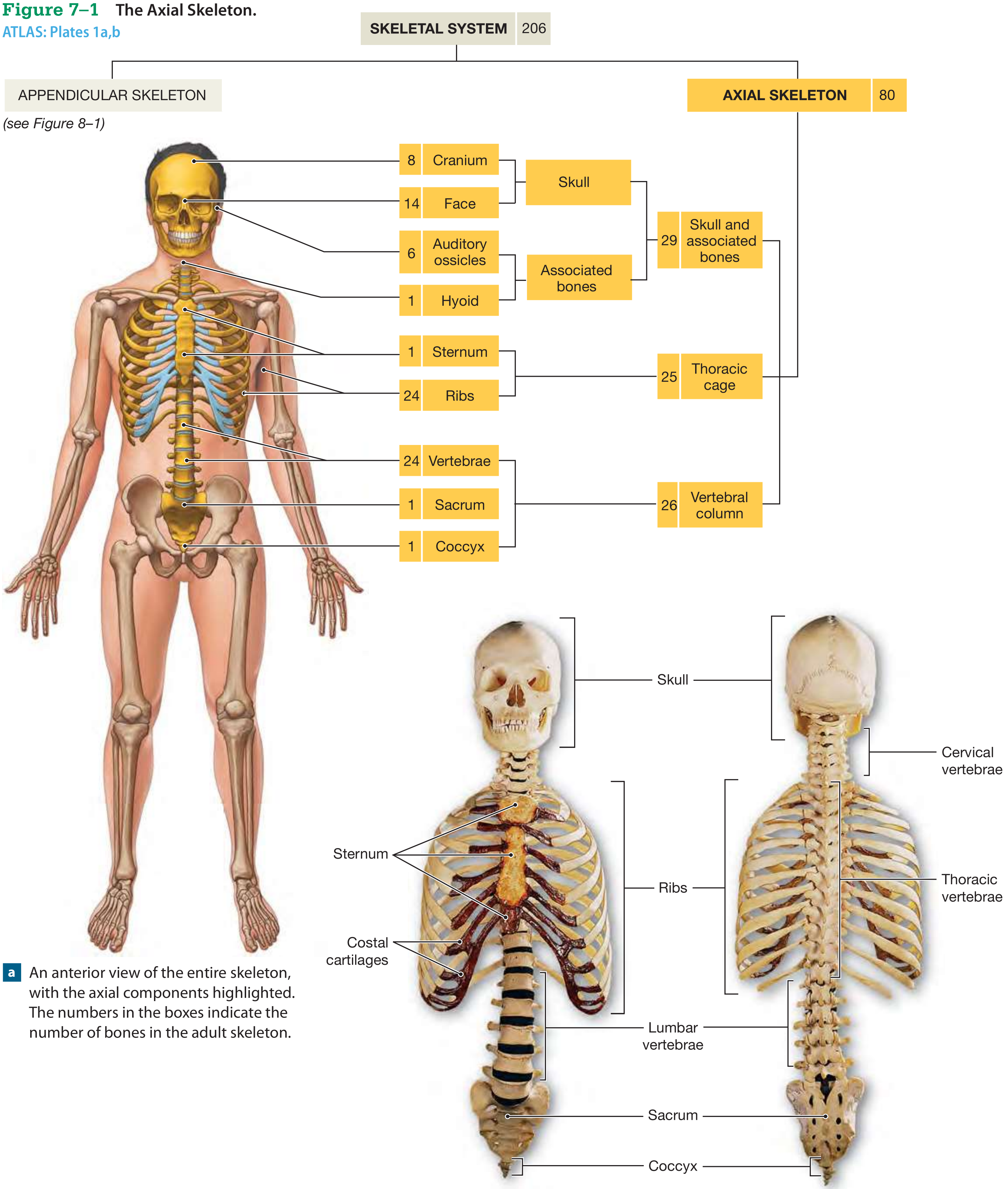
If the cranium is the house where the brain resides, the *facial complex* is the front porch. **Facial bones** protect and support the entrances to the digestive and respiratory tracts. The superficial facial bones (the paired *maxillae*, *lacrimal*, *nasal*, and *zygomatic bones*, and the *mandible*) (**Figure 7–2**) provide areas for the attachment of muscles that control facial expressions and assist in manipulating food. The deeper facial bones (the paired *palatine bones* and *inferior nasal conchae*, and the single median *vomer*) help separate the oral and nasal cavities, increase the surface area of the nasal cavities, or help form the **nasal septum** (*septum*, wall), which subdivides the nasal cavity.

Several bones of the skull contain air-filled chambers called **sinuses.** Sinuses have two major functions: (1) They make a bone weigh less than it would otherwise, and (2) the mucous membrane lining them produces mucus that moistens and cleans the air in and adjacent to the sinus. We will consider the sinuses as we discuss specific bones.

Joints, or *articulations*, form where two bones interconnect. Except where the mandible contacts the cranium, the connections between the skull bones of adults are immovable joints called **sutures.** At a suture, bones are tied firmly together with dense fibrous connective tissue. Each suture of the skull has a name, but at this point you need to know only four major sutures:

1. *Lambdoid Suture.* The **lambdoid** (LAM-doyd) suture (Greek *lambda* + *eidos*, shape) arches across the posterior surface of the skull (**Figure 7–3a**). This suture separates the occipital bone from the two parietal bones. One or more **sutural bones** *(Wormian bones)* may be present along the lambdoid suture. p. 170
2. *Coronal Suture.* The **coronal suture** attaches the frontal bone to the parietal bones of either side (**Figure 7–3b**). The occipital, parietal, and frontal bones form the **calvaria** (kal-VA-rē-uh), or skullcap. A cut through the body that

Figure 7–1 **The Axial Skeleton.**
ATLAS: Plates 1a,b



a An anterior view of the entire skeleton, with the axial components highlighted. The numbers in the boxes indicate the number of bones in the adult skeleton.

b Anterior (left) and posterior (right) views of the axial skeleton. The individual bones associated with the skull are not visible.

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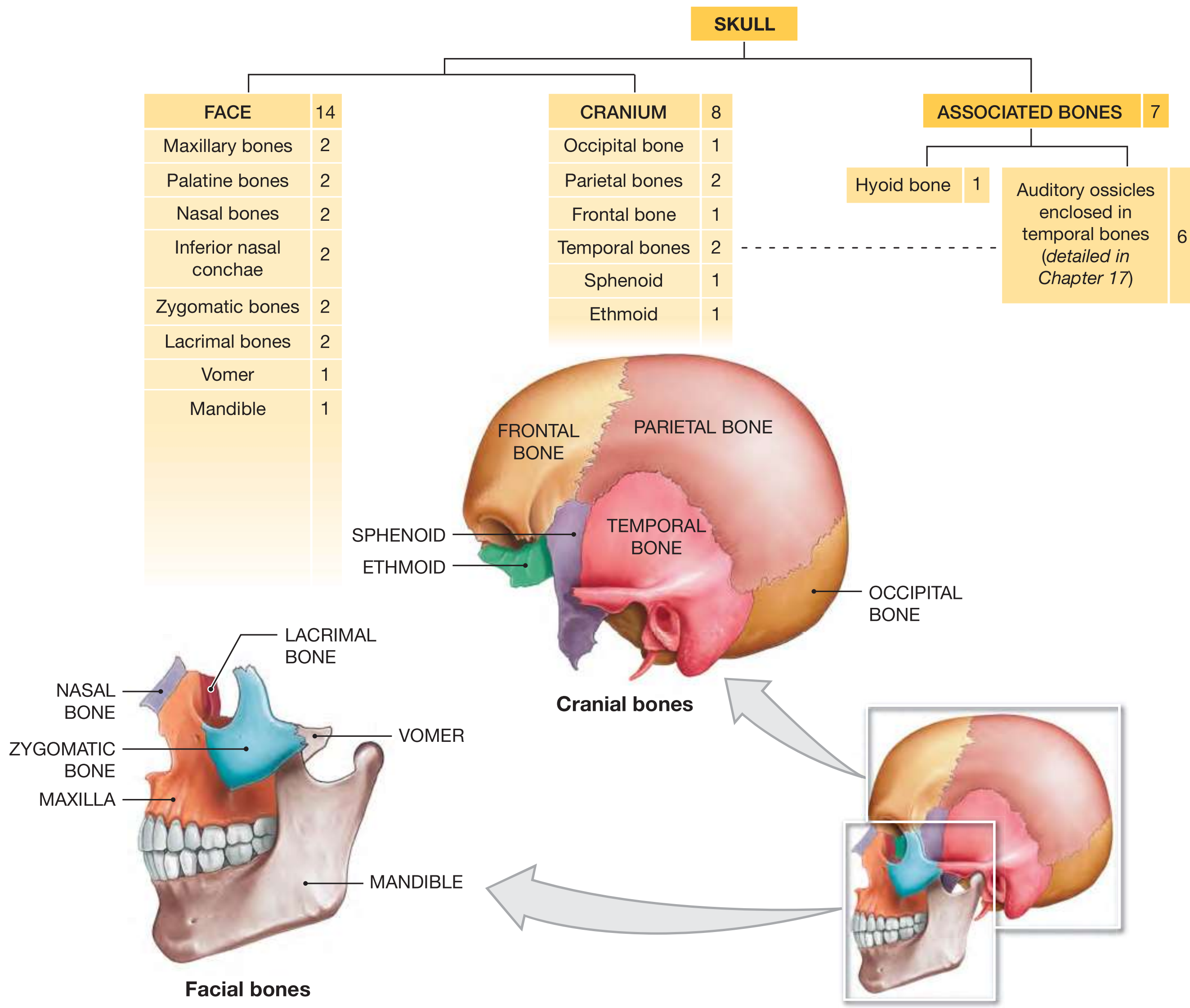
Figure 7–2 Cranial and Facial Subdivisions of the Skull. The seven associated bones are not illustrated.



parallels the coronal suture produces a *frontal section*, or *coronal section* (**Table 1–3**, p. 19).

3. *Sagittal Suture.* The **sagittal suture** extends from the lambdoid suture to the coronal suture, between the parietal bones (**Figure 7–3b**). A cut along the midline of the suture produces a midsagittal section; a slice that parallels the sagittal suture produces a parasagittal section. ⮌ p. 17

4. *Squamous Sutures.* A **squamous** (SKWĀ-mus) **suture** on each side of the skull forms the boundary between the temporal bone and the parietal bone of that side. **Figure 7–3a** shows the intersection between the squamous sutures and the lambdoid suture. **Figure 7–3c** shows the path of the squamous suture on the right side of the skull.

Figure 7–3 The Adult Skull. ATLAS: Plates 4a,b; 5a–e

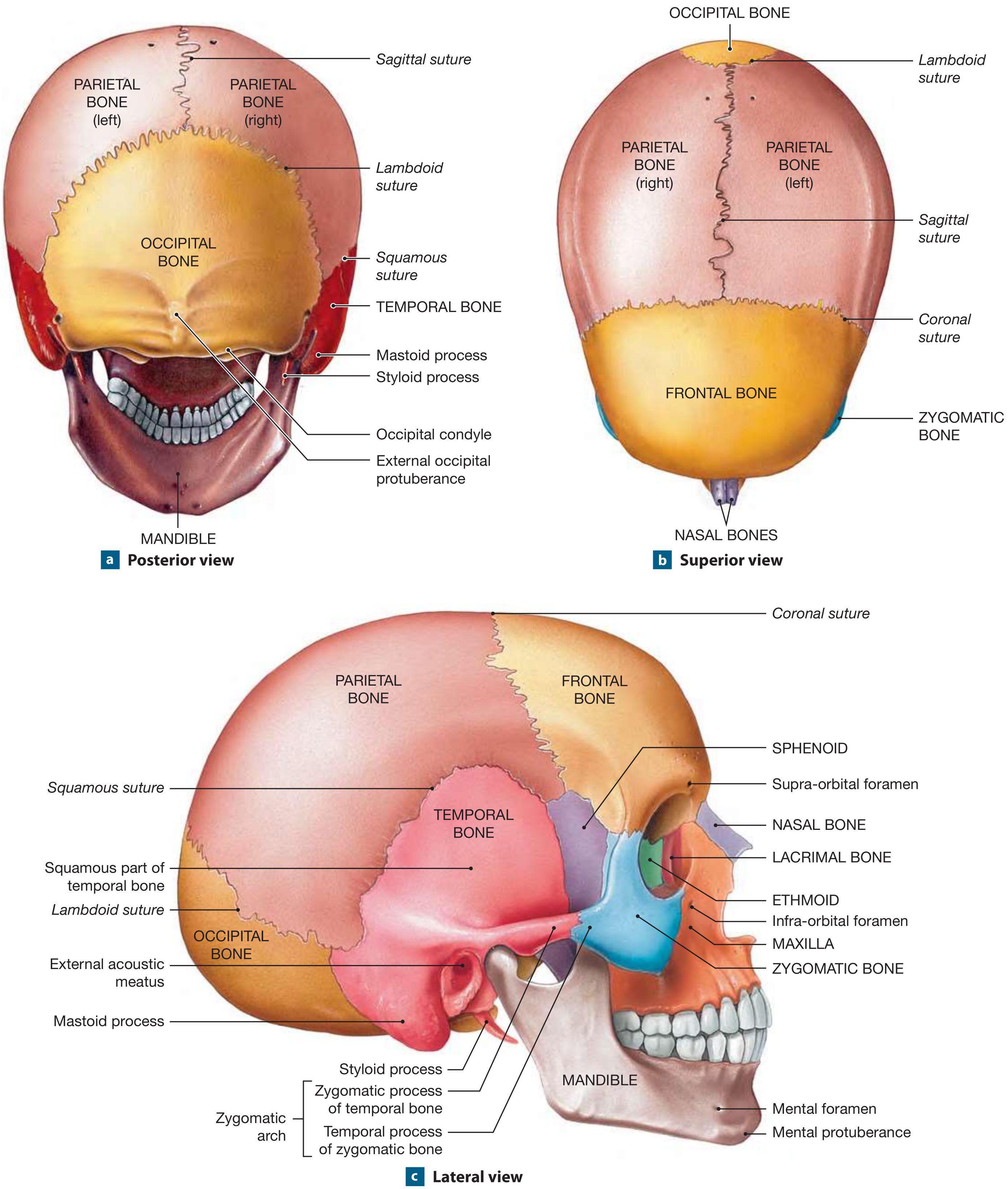


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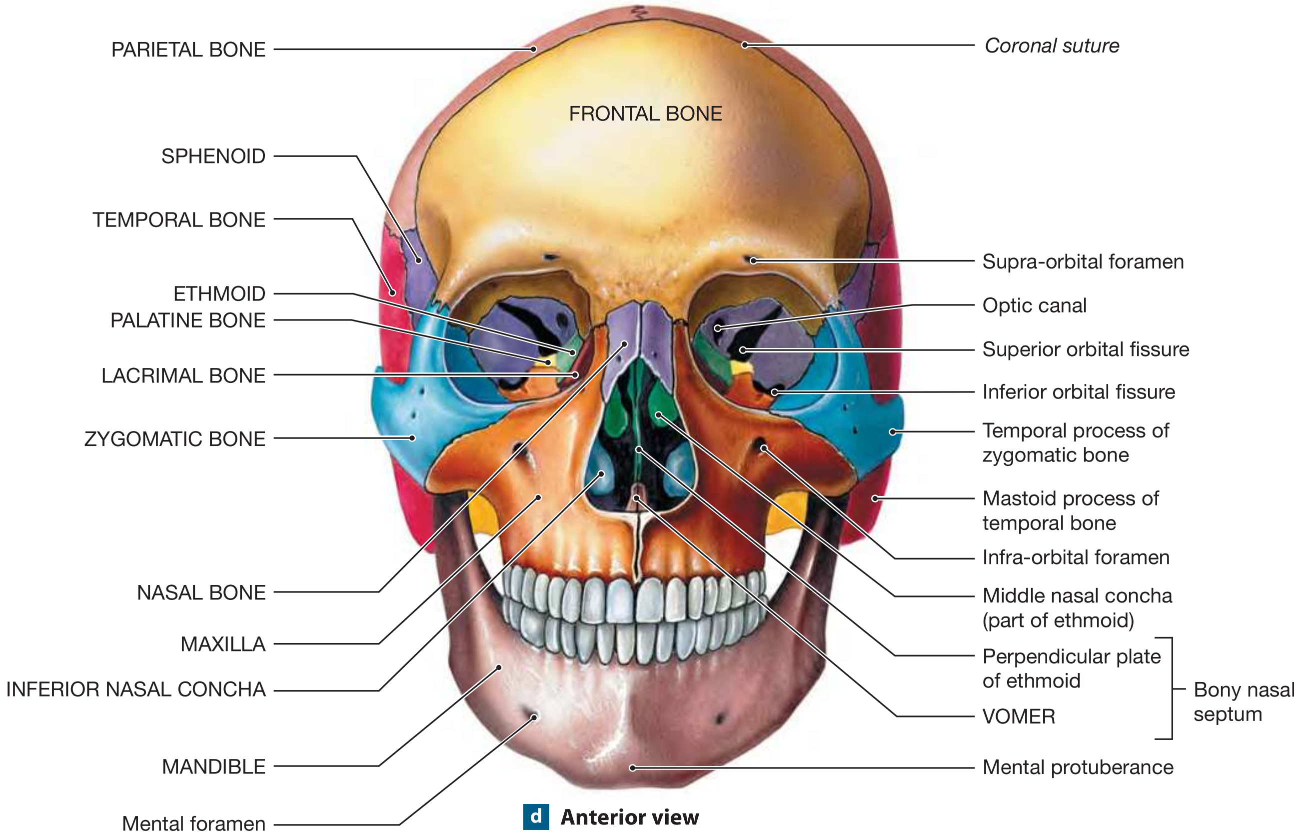
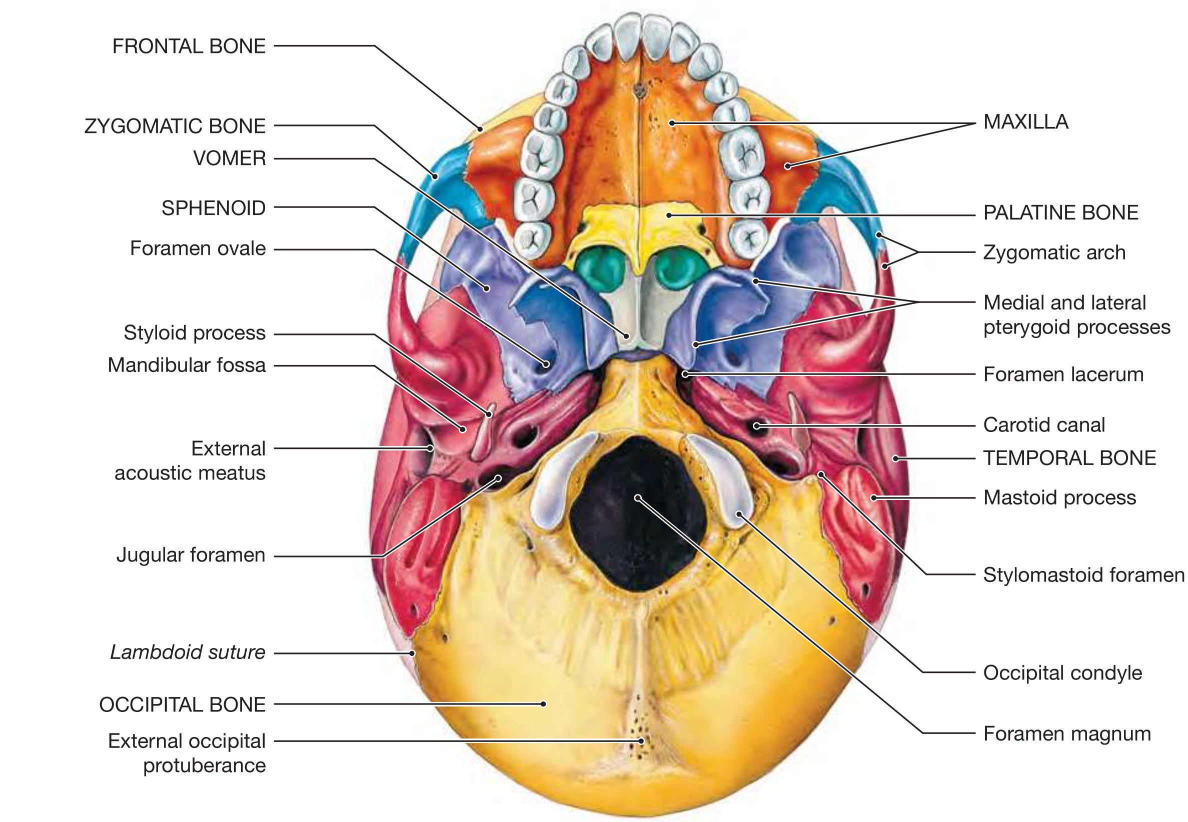
Figure 7–3 **The Adult Skull** ***(continued).***

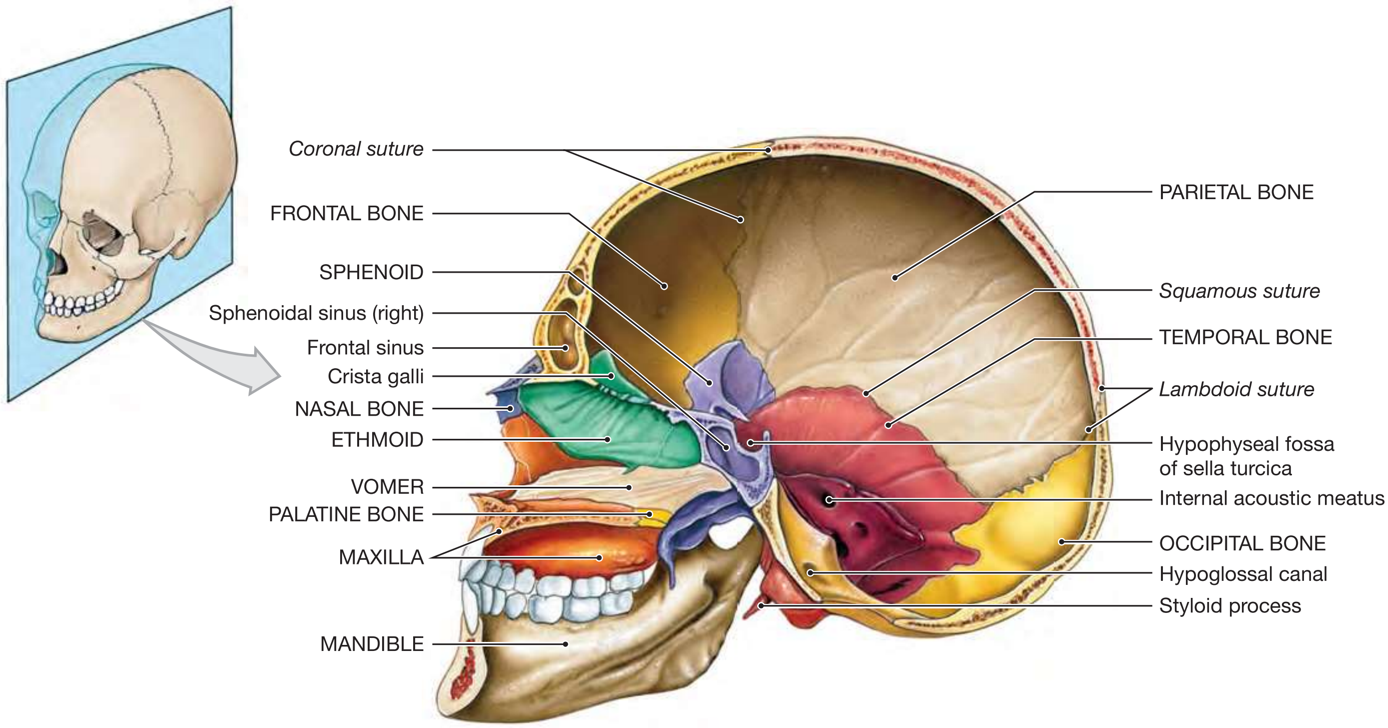


d **Anterior view**

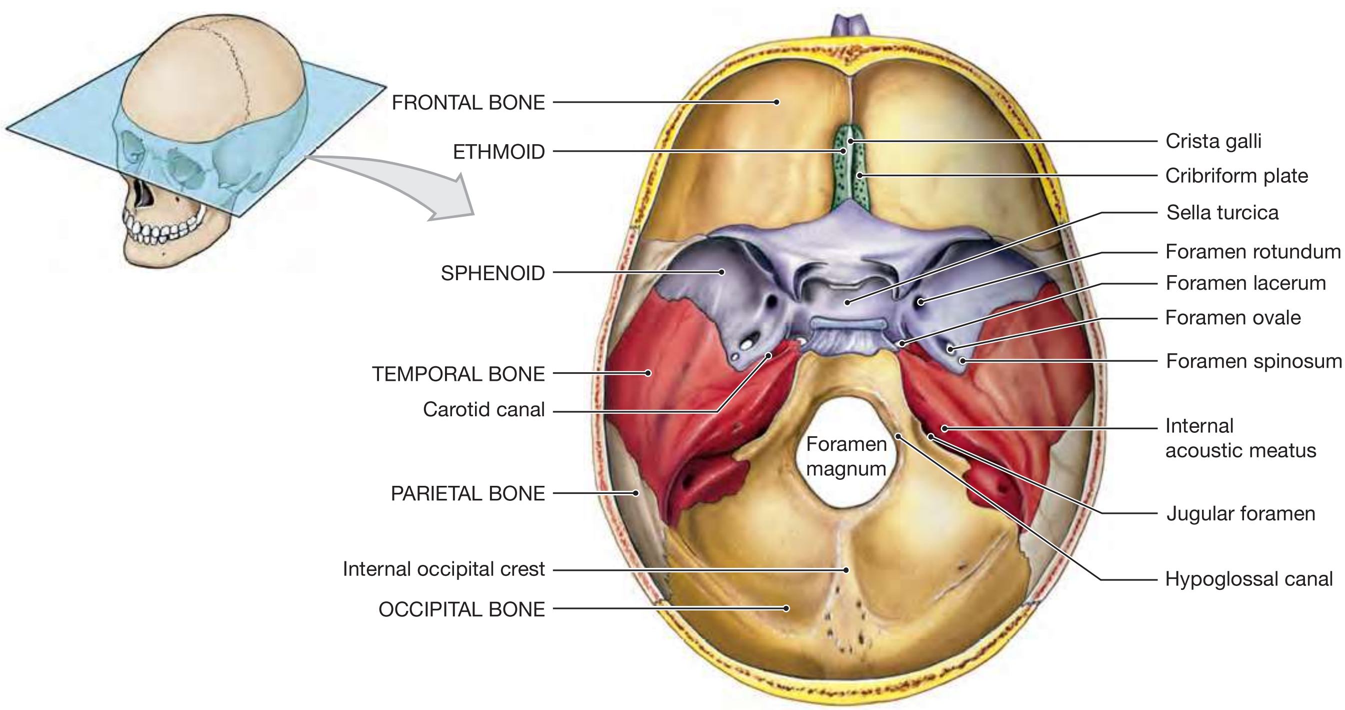


e **Inferior view**

Figure 7–4 **The Sectional Anatomy of the Skull.** ATLAS: Plates 4c; 6; 7a,b



a Medial view of a sagittal section through the skull.



b Superior view of a horizontal section through the skull, showing the floor of the cranial cavity. Compare with part (a) and with *Figure 7–3e*.

Focus The Individual Bones of the Skull

The surface features of these bones can be explored further, using the related images in the *Atlas*. Foramina and fissures are present for the passage of vessels and nerves. The vessels are detailed in Chapter 21; the nerves are shown in the Focus box on cranial nerves in Chapter 14.

Cranial Bones

The Occipital Bone (Figure 7–5a)

General Functions: The **occipital bone** forms much of the posterior and inferior surfaces of the cranium.

Articulations: The occipital bone articulates with the parietal bones, the temporal bones, the sphenoid, and the first cervical vertebra (the atlas) (**Figures 7–3a–c,e** and **7–4**).

Regions/Landmarks: The **external occipital protuberance** is a small bump at the midline on the inferior surface.

The **external occipital crest,** which begins at the external occipital protuberance, marks the attachment of a ligament that helps stabilize the vertebrae of the neck.

The **occipital condyles** are the site of articulation between the skull and the first vertebra of the neck.

The *inferior* and *superior nuchal* (NOO-kul) *lines* are ridges that intersect the occipital crest. They mark the attachment sites of muscles and ligaments that stabilize the articulation at the occipital condyles and balance the weight of the head over the vertebrae of the neck.

The concave internal surface of the occipital bone (**Figure 7–4a**) closely follows the contours of the brain. The grooves follow the paths of major blood vessels, and the ridges mark the attachment sites of membranes that stabilize the position of the brain.

Foramina: The **foramen magnum** (**Figure 7–4b**) connects the cranial cavity with the vertebral canal, which is enclosed by the vertebral column. This foramen surrounds the connection between the brain and spinal cord.

The **jugular foramen** lies between the occipital bone and the temporal bone (**Figure 7–3e**). The *internal jugular vein* passes through this foramen, carrying venous blood from the brain.

The **hypoglossal canals** (**Figure 7–4b**) begin at the lateral base of each occipital condyle and end on the inner surface of the occipital bone near the foramen magnum. The *hypoglossal nerves*, cranial nerves that control the tongue muscles, pass through these canals.

The Parietal Bones (Figure 7–5b)

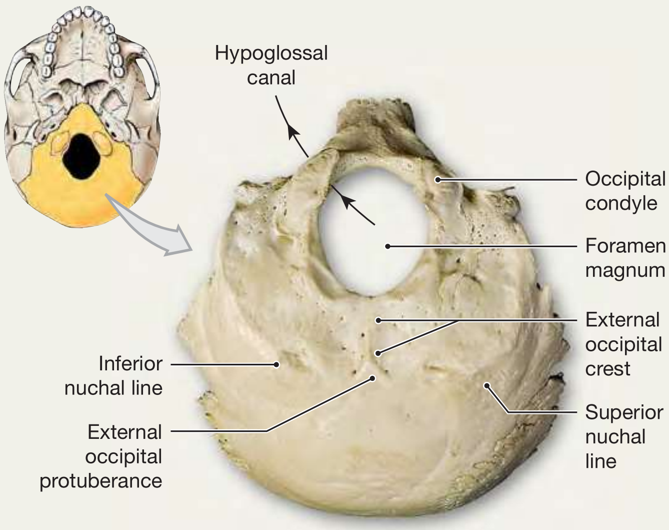
General Functions: The **parietal bones** form part of the superior and lateral surfaces of the cranium.

Articulations: The parietal bones articulate with one another and with the occipital, temporal, frontal, and sphenoid bones (**Figures 7–3a–d** and **7–4**).

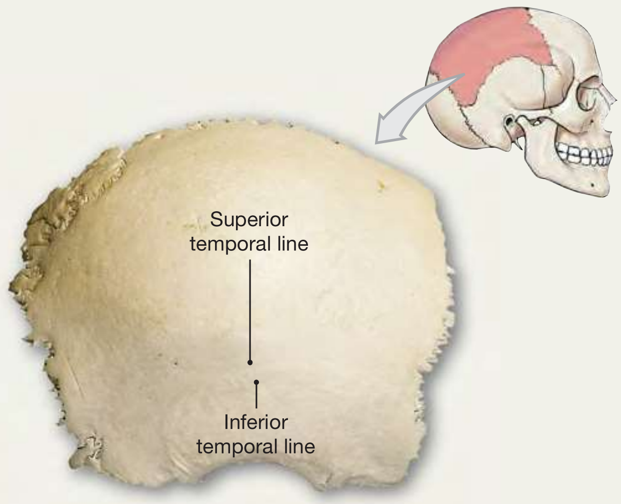
Regions/Landmarks: The *superior* and *inferior temporal lines* are low ridges that mark the attachment sites of the *temporalis muscle*, a large muscle that closes the mouth (**Figure 7–5b**).

Grooves on the inner surface of the parietal bones mark the paths of cranial blood vessels (**Figure 7–4a**).

Figure 7–5 The Occipital and Parietal Bones.



a Occipital bone, inferior view



b Right parietal bone, lateral view

The Frontal Bone (Figure 7–6a,b)

General Functions: The **frontal bone** forms the anterior portion of the cranium and the roof of the *orbits* (eye sockets). Mucous secretions of the *frontal sinuses* within this bone help flush the surfaces of the nasal cavities.

Articulations: The frontal bone articulates with the parietal, sphenoid, ethmoid, nasal, lacrimal, maxillary, and zygomatic bones (**Figures 7–3b–e** and **7–4**).

Regions/Landmarks: The **frontal squama,** or forehead, forms the anterior, superior portion of the cranium and provides surface area for the attachment of facial muscles. The *superior temporal line* is continuous with the superior temporal line of the parietal bone.

The **supra-orbital margin** is a thickening of the frontal bone that helps protect the eye.

The **lacrimal fossa** on the superior and lateral surface of the orbit is a shallow depression that marks the location of the *lacrimal* (tear) *gland*, which lubricates the surface of the eye.

The **frontal sinuses** are extremely variable in size and time of appearance. They generally appear after age 6, but some people never develop them. We will describe the frontal sinuses and other sinuses of the cranium and face in a later section.

Foramina: The **supra-orbital foramen** provides passage for blood vessels that supply the eyebrow, eyelids, and frontal sinuses. In some cases, this foramen is incomplete; the vessels then cross the orbital rim within a **supra-orbital notch.**

Remarks: During development, the bones of the cranium form by the fusion of separate centers of ossification. At birth, the fusions are not yet complete: Two frontal bones articulate along the *frontal (metopic) suture*. Although the suture generally disappears by age 8 as the bones fuse, the adult skull commonly retains traces of the suture line. This suture, or what remains of it, runs down the center of the frontal squama.

The Temporal Bones (Figure 7–7a,b)

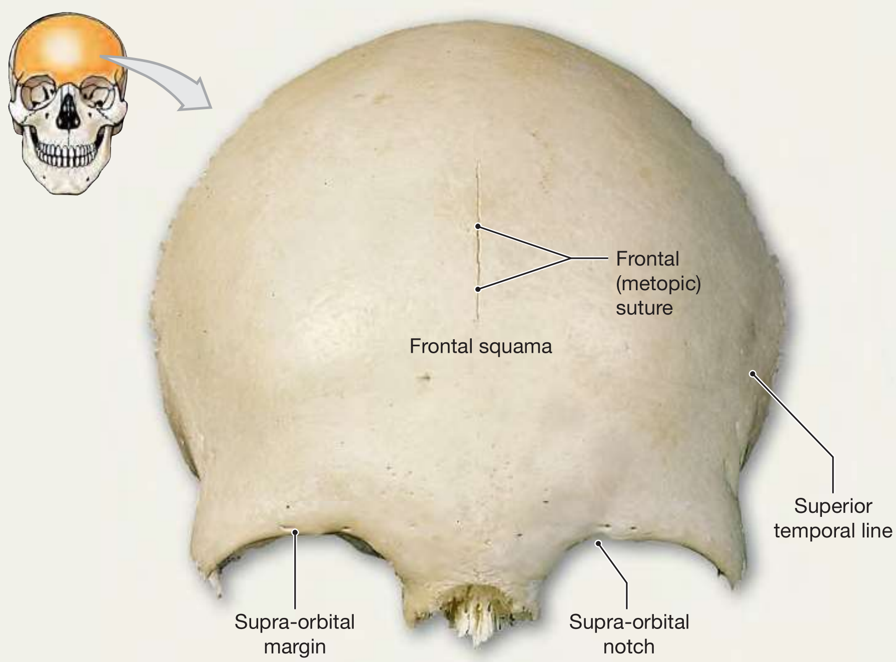
General Functions: The **temporal bones** (1) form part of both the lateral walls of the cranium and the *zygomatic arches*, (2) form the only articulations with the mandible, (3) surround and protect the sense organs of the inner ear, and (4) are attachment sites for muscles that close the jaws and move the head.

Articulations: The temporal bones articulate with the zygomatic, sphenoid, parietal, and occipital bones of the cranium and with the mandible (**Figures 7–3** and **7–4**).

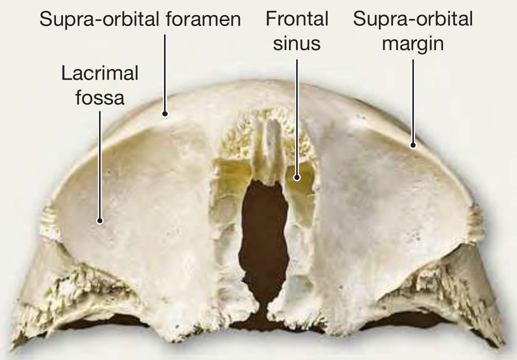
Regions/Landmarks: The **squamous part,** or *squama*, of the temporal bone is the convex, irregular surface that borders the squamous suture.

The **zygomatic process,** inferior to the squamous portion, articulates with the *temporal process* of the zygomatic bone.

Figure 7–6 The Frontal Bone.



a Anterior surface



b Inferior (orbital) surface

Together, these processes form the **zygomatic arch,** or cheekbone (**Figure 7–3c,e**).

The **mandibular fossa** on the inferior surface marks the site of articulation with the mandible.

The **mastoid process** (**Figure 7–7c**), is an attachment site for muscles that rotate or extend the head. It contains *mastoid air cells,* small interconnected cavities that connect to the middle ear cavity. If pathogens invade the mastoid air cells, *mastoiditis* develops. Signs and symptoms include severe earaches, fever, and swelling behind the ear.

The **styloid** (STĪ-loyd; *stylos*, pillar) **process,** near the base of the mastoid process, is attached to ligaments that support the hyoid bone and to the tendons of several muscles associated with the hyoid bone, the tongue, and the pharynx.

The **petrous part** of the temporal bone, located on its internal surface, encloses the structures of the *inner ear*—sense organs that provide information about hearing and balance.

The **auditory ossicles** are located in the *tympanic cavity*, or *middle ear*, a cavity within the petrous part. These tiny bones—three on each side—transfer sound vibrations from the delicate *tympanic membrane*, or eardrum, to the inner ear. (We will discuss these bones and their functions in Chapter 17.)

Foramina (**Figure 7–3e**): The *jugular foramen*, between the temporal and occipital bones, provides passage for the internal jugular vein.

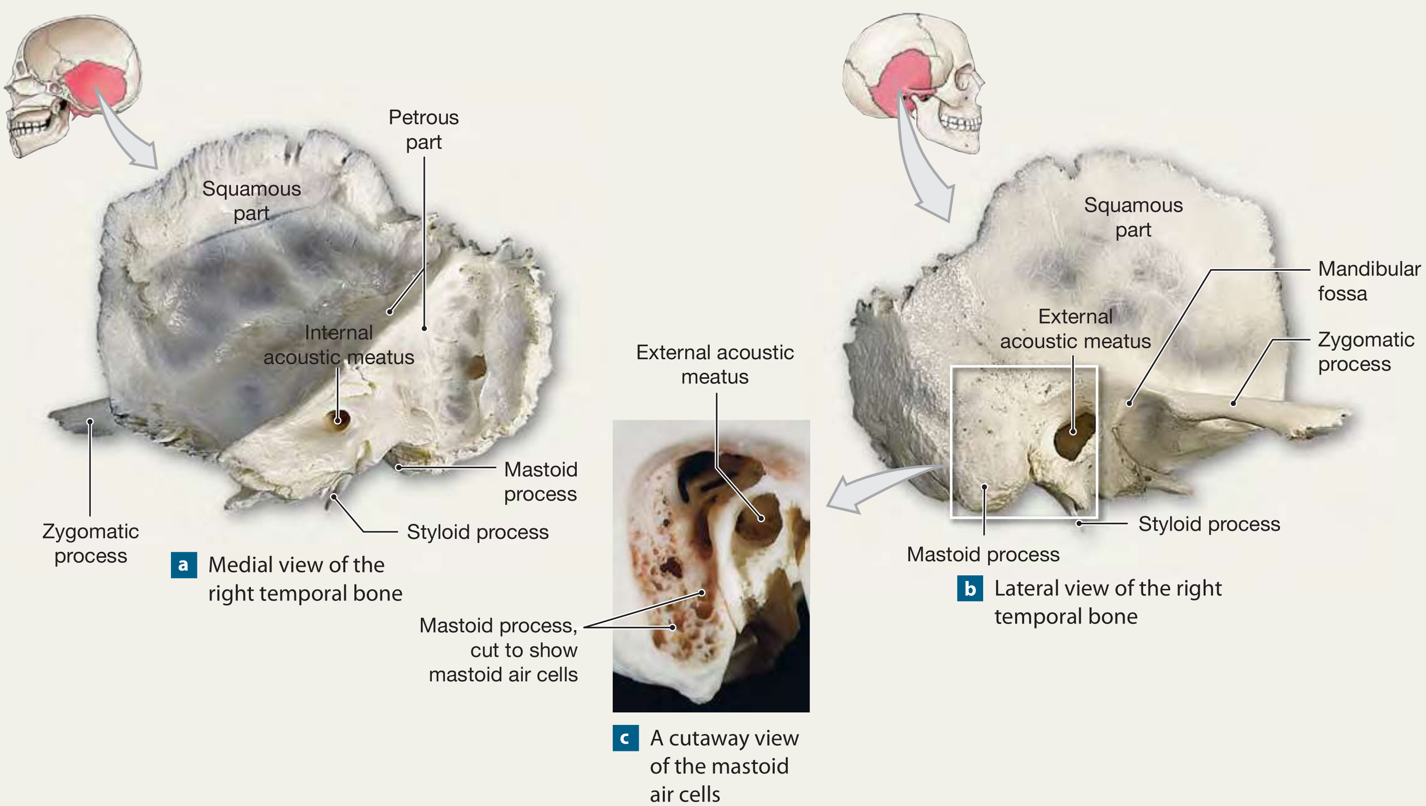
The **carotid canal** provides passage for the internal carotid artery, a major artery to the brain. As it leaves the carotid canal, the internal carotid artery passes through the anterior portion of the foramen lacerum.

The **foramen lacerum** (LA-se-rum; *lacerare*, to tear) is a jagged slit extending between the sphenoid and the petrous portion of the temporal bone and containing hyaline cartilage and small arteries that supply the inner surface of the cranium.

The *auditory tube*, an air-filled passageway that connects the pharynx to the tympanic cavity, passes through the posterior portion of the foramen lacerum.

The **external acoustic meatus,** or *external acoustic canal*,[1] on the lateral surface ends at the tympanic membrane (which disintegrates during the preparation of a dried skull).

Figure 7–7 **The Temporal Bones.**



a Medial view of the right temporal bone

b Lateral view of the right temporal bone

c A cutaway view of the mastoid air cells

The **stylomastoid foramen** lies posterior to the base of the styloid process. The *facial nerve* passes through this foramen to control the facial muscles.

The **internal acoustic meatus,** or *internal acoustic canal,*[1] begins on the medial surface of the petrous part of the temporal bone. It carries blood vessels and nerves to the inner ear and conveys the facial nerve to the stylomastoid foramen.

[1]The names for these passageways vary widely; the terms *acoustic* and *auditory* are used interchangeably, as are *meatus* and *canal*.

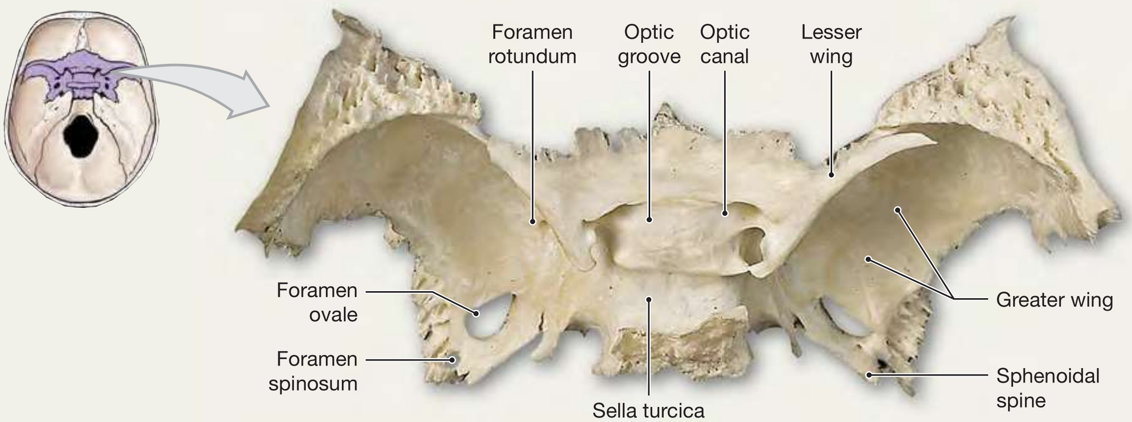
The Sphenoid (Figure 7–8a,b)

General Functions: The **sphenoid,** or *sphenoidal bone*, forms part of the floor of the cranium, unites the cranial and facial bones, and acts as a cross-brace that strengthens the sides of the skull. Mucous secretions of the *sphenoidal sinuses* within this bone help clean the surfaces of the nasal cavities.

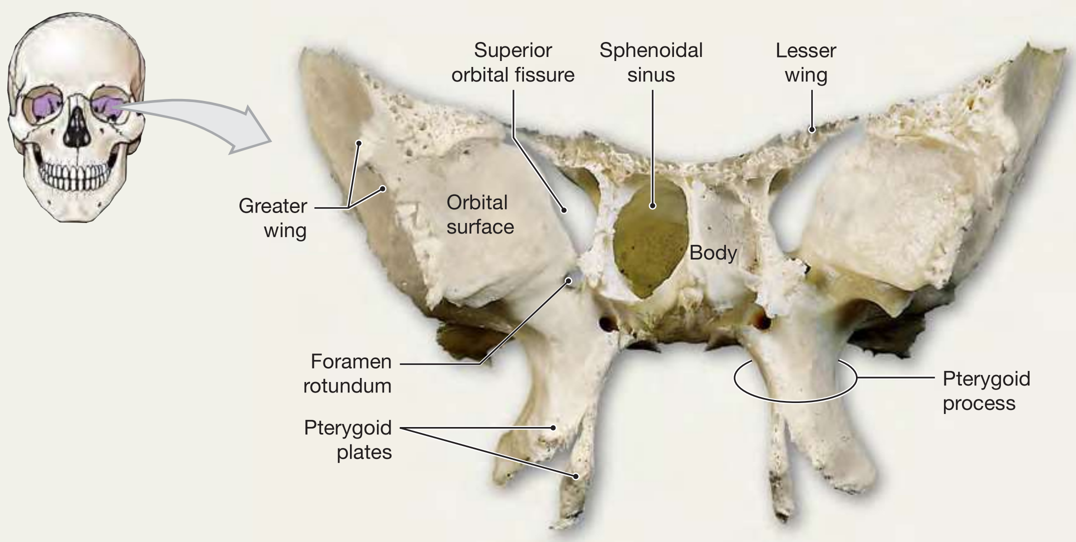
Articulations: The sphenoid articulates with the ethmoid and the frontal, occipital, parietal, and temporal bones of the cranium and the palatine bones, zygomatic bones, maxillae, and vomer of the face (**Figures 7–3c–e** and **7–4**).

Regions/Landmarks: The shape of the sphenoid has been compared to a bat with its wings extended. Although this bone is relatively large, much of it is hidden by more superficial bones.

Figure 7–8 **The Sphenoid.**



a Superior surface



b Anterior surface

The **body** forms the central axis of the sphenoid.

The **sella turcica** (TUR-si-kuh), or Turkish saddle, is a bony, saddle-shaped enclosure on the superior surface of the body.

The **hypophyseal** (hī-pō-FIZ-ē-ul) **fossa** is the depression within the sella turcica. The *pituitary gland* occupies this fossa.

The **sphenoidal sinuses** are on either side of the body, inferior to the sella turcica.

The **lesser wings** extend horizontally anterior to the sella turcica.

The **greater wings** extend laterally from the body and form part of the cranial floor. A sharp *sphenoidal spine* lies at the posterior, lateral corner of each greater wing. Anteriorly, each greater wing contributes to the posterior wall of the orbit.

The **pterygoid** (TER-i-goyd; *pterygion*, wing) **processes** are vertical projections that originate on either side of the body. Each pterygoid process forms a pair of *pterygoid plates*, which are attachment sites for muscles that move the mandible and soft palate.

Foramina: The **optic canals** permit passage of the optic nerves from the eyes to the brain.

A **superior orbital fissure**, **foramen rotundum, foramen ovale** (ō-VAH-lē), and **foramen spinosum** penetrate each greater wing. These passages carry blood vessels and nerves to the orbit, face, jaws, and membranes of the cranial cavity, respectively.

The Ethmoid (Figure 7–9a,b)

General Functions: The **ethmoid,** or *ethmoidal bone*, forms the anteromedial floor of the cranium, the roof of the nasal cavity, and part of the nasal septum and medial orbital wall. Mucous secretions from a network of sinuses, or *ethmoidal air cells*, within this bone flush the surfaces of the nasal cavities.

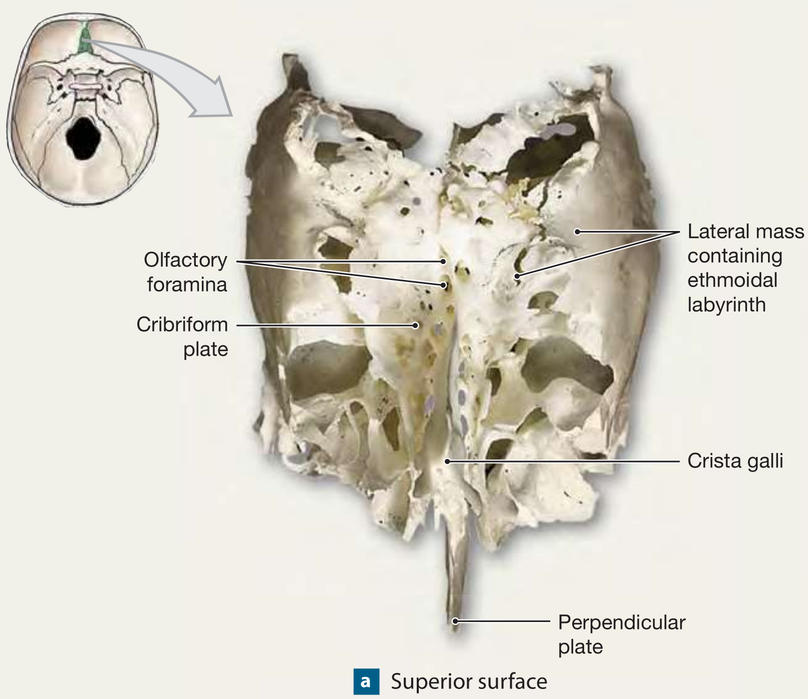
Articulations: The ethmoid articulates with the frontal bone and sphenoid of the cranium and with the nasal, lacrimal, palatine, and maxillary bones and the inferior nasal conchae and vomer of the face (**Figures 7–3c,d** and **7–4**).

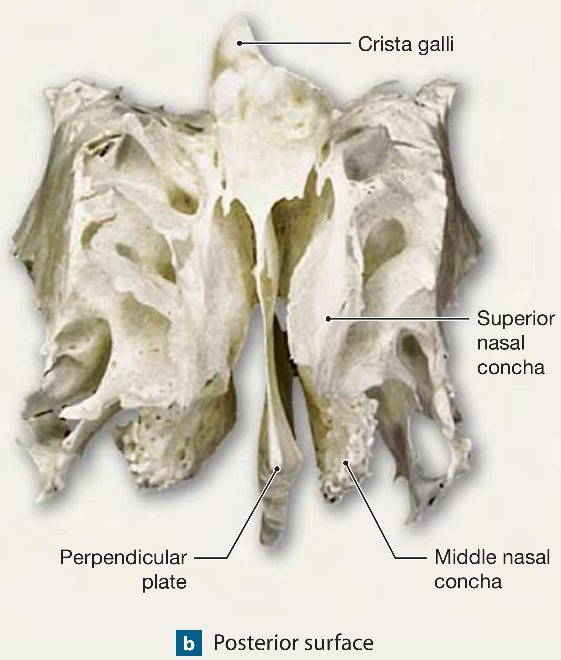
Regions/Landmarks: The ethmoid has three parts: (1) the cribriform plate, (2) the paired lateral masses, and (3) the perpendicular plate.

The **cribriform plate** (*cribrum*, sieve) forms the anteromedial floor of the cranium and the roof of the nasal cavity. The **crista galli** (*crista*, crest + *gallus*, chicken; cock's comb) is a bony ridge that projects superior to the cribriform plate. The *falx cerebri*, a membrane that stabilizes the position of the brain, attaches to this ridge.

The **lateral masses** contain the **ethmoidal labyrinth,** which consists of the interconnected **ethmoidal air cells** that open into the nasal cavity on each side. The **superior nasal conchae** (KONG-kē; singular, *concha*, a snail shell) and the **middle nasal conchae** are delicate projections of the lateral masses.

Figure 7–9 The Ethmoid.





The **perpendicular plate** forms part of the nasal septum, along with the vomer and a piece of hyaline cartilage.

Foramina: The **olfactory foramina** in the cribriform plate permit passage of the olfactory nerves, which provide the sense of smell.

Remarks: *Olfactory* (smell) *receptors* are located in the epithelium that covers the inferior surfaces of the cribriform plate, the medial surfaces of the superior nasal conchae, and the superior portion of the perpendicular plate.

The nasal conchae break up the airflow in the nasal cavity, creating swirls, turbulence, and eddies that have three major functions: (1) Particles in the air are thrown against the sticky mucus that covers the walls of the nasal cavity; (2) air movement is slowed, providing time for warming, humidification, and dust removal before the air reaches more delicate portions of the respiratory tract; and (3) air is directed toward the superior portion of the nasal cavity, adjacent to the cribriform plate, where the olfactory receptors are located.

Facial Bones

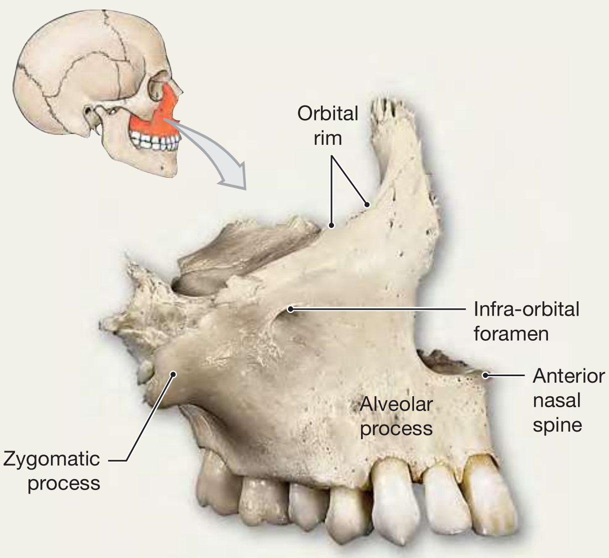
The Maxillae (Figure 7–10a,b)

General Functions: The **maxillae,** or *maxillary bones*, support the upper teeth and form the inferior orbital rim, the lateral margins of the external nares, the upper jaw, and most of the hard palate. The *maxillary sinuses* in these bones produce mucus that flushes the inferior surfaces of the nasal cavities. The maxillae are the largest facial bones, and the maxillary sinuses are the largest sinuses.

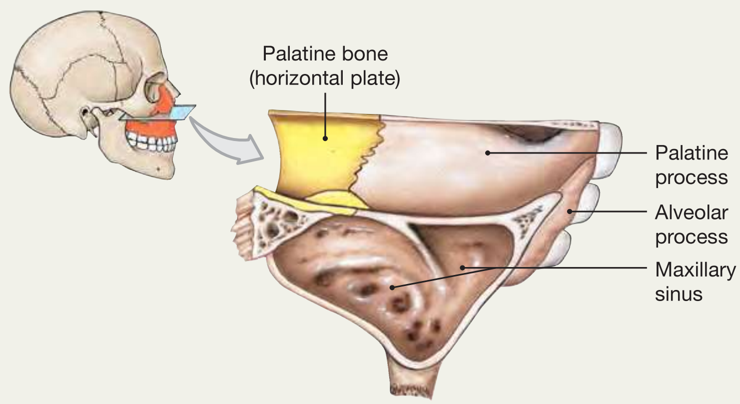
Articulations: The maxillae articulate with the frontal bones and ethmoid, with one another, and with all the other facial bones except the mandible (**Figures 7–3c–e** and **7–4a**).

Regions/Landmarks: The **orbital rim** protects the eye and other structures in the orbit. The *anterior nasal spine* is found at the anterior portion of the maxilla, at its articulation with the maxilla of the other side. It is an attachment point for the cartilaginous anterior portion of the nasal septum.

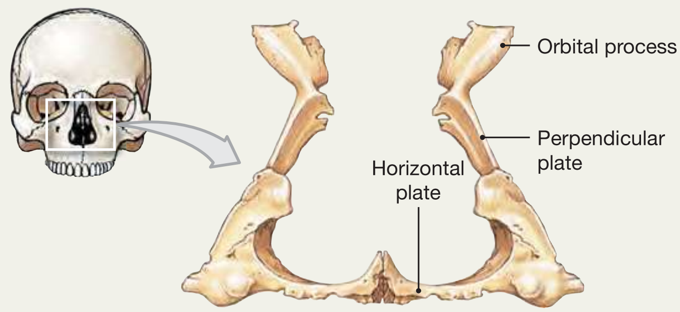
Figure 7–10 **The Maxillae and Palatine Bones.** ATLAS: Plates 8a–d; 12d



a An anterolateral view of the right maxilla.



b Superior view of a horizontal section through right maxilla and palatine bone; note the size and orientation of the maxillary sinus.



c An anterior view of the two palatine bones.

The **alveolar process** that borders the mouth supports the upper teeth.

The **palatine processes** form most of the **hard palate,** or bony roof of the mouth. One type of *cleft palate*, a developmental disorder, results when the maxillae fail to meet along the midline of the hard palate. ATLAS: Embryology Summary 6: The Development of the Skull

The **maxillary sinuses** lighten the portion of the maxillae superior to the teeth.

The **nasolacrimal canal,** formed by a maxilla and lacrimal bone, protects the *lacrimal sac* and the *nasolacrimal duct*, which carries tears from the orbit to the nasal cavity.

Foramina: The **infra-orbital foramen** marks the path of a major sensory nerve that reaches the brain via the foramen rotundum of the sphenoid.

The **inferior orbital fissure** (**Figure 7–3d**), which lies between the maxilla and the sphenoid, permits passage of cranial nerves and blood vessels.

The Palatine Bones (Figure 7–10b,c)

General Functions: The **palatine bones** form the posterior portion of the hard palate and contribute to the floor of each orbit.

Articulations: The palatine bones articulate with one another, with the maxillae, with the sphenoid and ethmoid, with the inferior nasal conchae, and with the vomer (**Figures 7–3e** and **7–4a**).

Regions/Landmarks: The palatine bones are roughly L-shaped. The **horizontal plate** forms the posterior part of the hard palate; the **perpendicular plate** extends from the horizontal plate to the **orbital process,** which forms part of the floor of the orbit. This process contains a small sinus that normally opens into the sphenoidal sinus.

Foramina: Small blood vessels and nerves supplying the roof of the mouth penetrate the lateral portion of the horizontal plate.

The Nasal Bones (Figure 7–11)

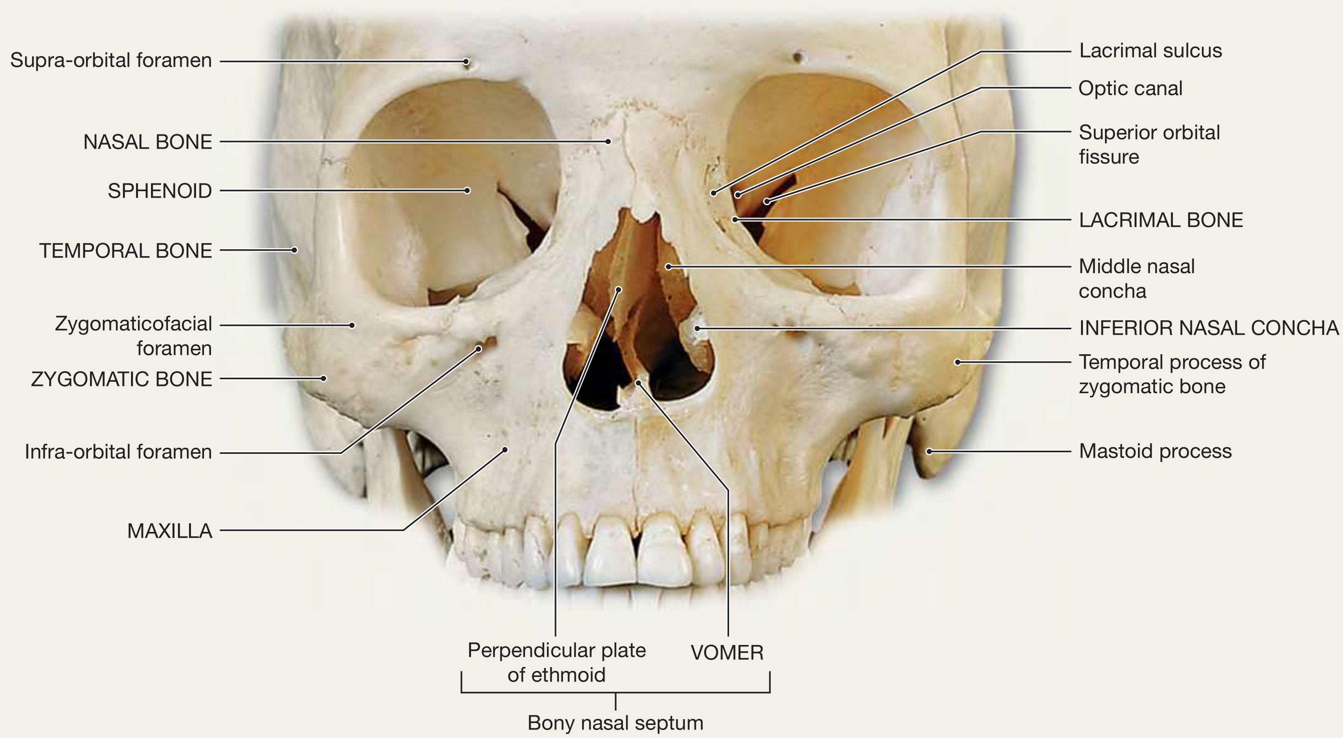
General Functions: The **nasal bones** support the superior portion of the bridge of the nose. They are connected to cartilages that support the distal portions of the nose. These flexible cartilages, and associated soft tissues, extend to the superior border of the **external nares** (NA-rēz; singular, *naris*), the entrances to the nasal cavity.

Articulations: The paired nasal bones articulate with one another, with the ethmoid, and with the frontal bone and maxillae (**Figures 7–3b–d** and **7–4a**).

The Vomer (Figure 7–11)

General Functions: The **vomer** forms the inferior portion of the bony nasal septum.

Figure 7–11 The Smaller Bones of the Face.



Articulations: The vomer articulates with the maxillae, sphenoid, ethmoid, and palatine bones, and with the cartilaginous part of the nasal septum, which extends into the fleshy part of the nose (**Figures 7–3d,e** and **7–4a**).

The Inferior Nasal Conchae (Figure 7–11)

General Functions: The **inferior nasal conchae** create turbulence in air passing through the nasal cavity, and increase the epithelial surface area to promote warming and humidification of inhaled air.

Articulations: The inferior nasal conchae articulate with the maxillae, ethmoid, palatine, and lacrimal bones (**Figure 7–3d**).

The Zygomatic Bones (Figure 7–11)

General Functions: The **zygomatic bones** contribute to the rim and lateral wall of the orbit and form part of the zygomatic arch.

Articulations: The zygomatic bones articulate with the maxillae, and the sphenoid, frontal, and temporal bones (**Figure 7–3b–e**).

Regions/Landmarks: The **temporal process** curves posteriorly to meet the zygomatic process of the temporal bone.

Foramina: The **zygomaticofacial foramen** on the anterior surface of each zygomatic bone carries a sensory nerve that innervates the cheek.

The Lacrimal Bones (Figure 7–11)

General Functions: The **lacrimal bones** form part of the medial wall of the orbit.

Articulations: The lacrimal bones—the smallest facial bones—articulate with the frontal bone and maxillae, and with the ethmoid (**Figure 7–3c,d**).

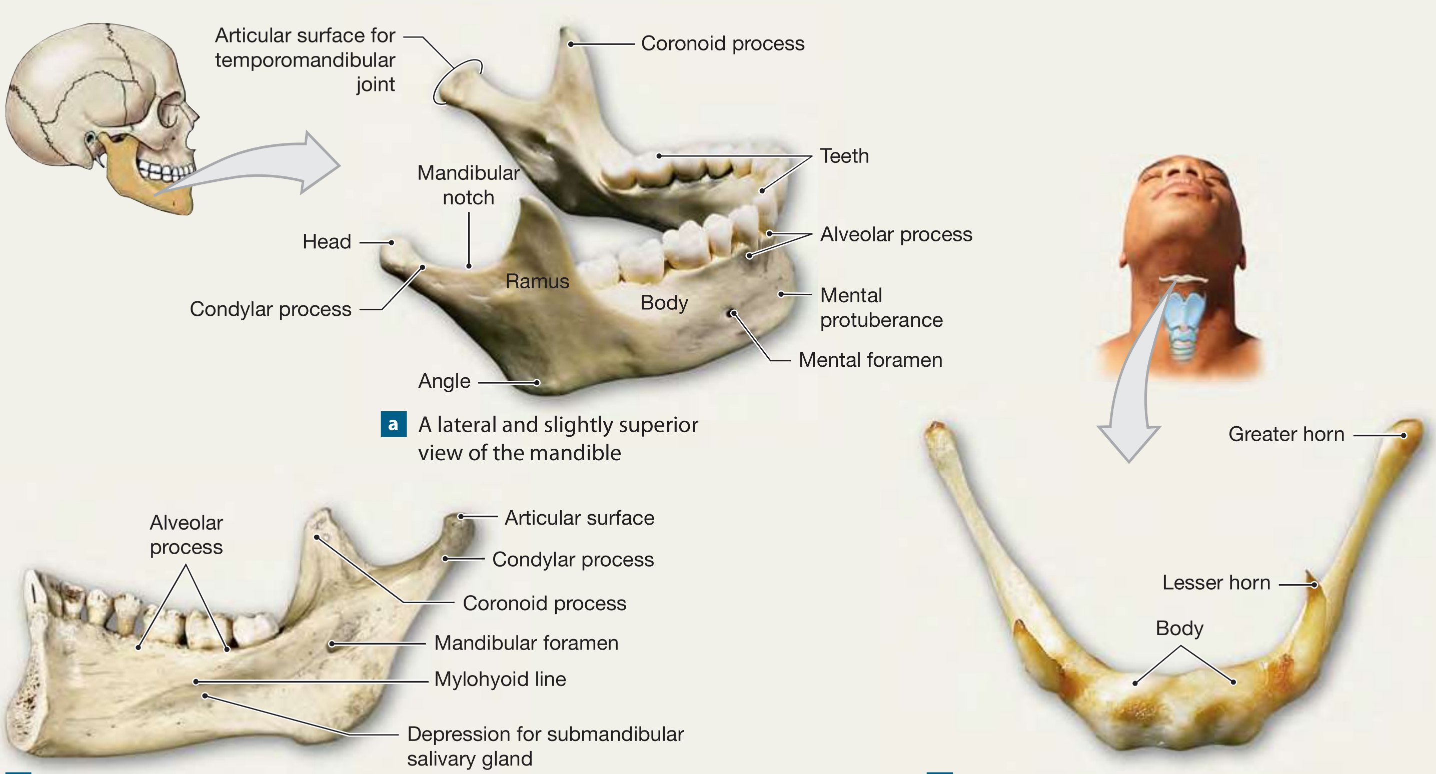
Regions/Landmarks: The **lacrimal sulcus**, a groove along the anterior, lateral surface of the lacrimal bone, marks the location of the lacrimal sac. The lacrimal sulcus leads to the nasolacrimal canal, which begins at the orbit and opens into the nasal cavity. As noted earlier, the lacrimal bone and the maxilla form this canal.

The Mandible (Figure 7–12a,b)

General Functions: The **mandible** forms the lower jaw.

Articulations: The mandible articulates with the mandibular fossae of the temporal bones (**Figures 7–3c,e** and **7–7a**).

Figure 7–12 The Mandible and Hyoid Bone.



a A lateral and slightly superior view of the mandible

b A medial view of the right mandible

c An anterior view of the hyoid bone

Regions/Landmarks: The **body** of the mandible is the horizontal portion of that bone.

The **alveolar process** supports the lower teeth.

The *mental protuberance* (*mentalis*, chin) is the attachment site for several facial muscles.

A prominent depression on the medial surface marks the position of the *submandibular salivary gland*.

The *mylohyoid line* marks the insertion of the *mylohyoid muscle*, which supports the floor of the mouth.

The **ramus** of the mandible is the ascending part that begins at the *mandibular angle* on either side. On each ramus:

1. The **condylar process** articulates with the temporal bone at the *temporomandibular joint*.
2. The **coronoid** (KOR-ō-noyd) **process** is the insertion point for the *temporalis muscle*, a powerful muscle that closes the jaws.
3. The **mandibular notch** is the depression that separates the condylar and coronoid processes.

Foramina: The **mental foramina** are openings for nerves that carry sensory information from the lips and chin to the brain.

The **mandibular foramen** is the entrance to the *mandibular canal*, a passageway for blood vessels and nerves that service the lower teeth. Dentists typically anesthetize the sensory nerve that enters this canal before they work on the lower teeth.

The Hyoid Bone (Figure 7–12c)

General Functions: The **hyoid bone** supports the larynx and is the attachment site for muscles of the larynx, pharynx, and tongue.

Articulations: *Stylohyoid ligaments* connect the *lesser horns* to the styloid processes of the temporal bones.

Regions/Processes: The **body** of the hyoid is an attachment site for muscles of the larynx, tongue, and pharynx.

The **greater horns,** or *greater cornua*, help support the larynx and are attached to muscles that move the tongue.

The **lesser horns,** or *lesser cornua*, are attached to the stylohyoid ligaments; from these ligaments, the hyoid and larynx hang beneath the skull like a child's swing from the limb of a tree.

Clinical Note

Temporomandibular Joint Syndrome The *temporomandibular joint (TMJ)*, between each temporal bone and the mandible, is quite mobile, allowing your jaw to move while you chew or talk. The disadvantage of such mobility is that your jaw can easily be dislocated by forceful forward or lateral displacement. The connective tissue sheath, or *capsule*, that surrounds the joint is relatively loose, and a pad of fibrocartilage separates the opposing bone surfaces. In **TMJ syndrome**, or *myofacial pain syndrome*, the mandible is pulled slightly out of alignment, generally by spasms in one of the jaw muscles. The individual experiences facial pain that radiates around the ear on the affected side and an inability to open the mouth fully. TMJ syndrome is a repeating cycle of muscle spasm → misalignment → pain → muscle spasm. It has been linked to involuntary behaviors, such as grinding of the teeth during sleep *(bruxism)*, and to emotional stress. Treatment focuses on breaking the cycle of muscle spasm and pain and, when necessary, providing emotional support. The application of heat to the affected joint, coupled with the use of anti-inflammatory drugs, local anesthetics, or both, may help. If teeth grinding is suspected, special mouth guards may be worn during sleep.

Checkpoint

3. In which bone is the foramen magnum located?
4. Tomás suffers a blow to the skull that fractures the right superior lateral surface of his cranium. Which bone is fractured?
5. Which bone contains the depression called the sella turcica? What is located in this depression?
6. Identify the facial bones.

See the blue Answers tab at the back of the book.

7-3 Foramina and fissures of the skull serve as passageways for nerves and vessels

Table 7–1 summarizes information about the foramina and fissures introduced thus far. This reference will be especially important to you in later chapters when you study the nervous and cardiovascular systems.

Table 7–1 Foramina and Fissures of the Skull

Bone	Major Structures Using Passageway		
	Foramen/Fissure	**Neural Tissue***	**Vessels and Other Structures**
OCCIPITAL BONE	Foramen magnum	Medulla oblongata (most caudal portion of brain) and accessory nerve (N XI), which provides motor control over several neck and back muscles	Vertebral arteries to brain; supporting membranes around central nervous system
	Hypoglossal canal	Hypoglossal nerve (N XII) provides motor control to muscles of the tongue	
With temporal bone	Jugular foramen	Glossopharyngeal nerve (N IX), vagus nerve (N X), accessory nerve (N XI). N IX provides taste sensation; N X is important for visceral functions; N XI innervates important muscles of the back and neck	Internal jugular vein; important vein returning blood from brain to heart
FRONTAL BONE	Supra-orbital foramen (or notch)	Supra-orbital nerve, sensory branch of ophthalmic nerve, innervating the eyebrow, eyelid, and frontal sinus	Supra-orbital artery delivers blood to same region
LACRIMAL BONE	Lacrimal sulcus, nasolacrimal canal (with maxilla)		Lacrimal sac and tear duct; drains into nasal cavity
TEMPORAL BONE	Stylomastoid foramen	Facial nerve (N VII) provides motor control of facial muscles	
	Carotid canal		Internal carotid artery supplies blood to brain
	External acoustic meatus		Air in meatus conducts sound to eardrum
	Internal acoustic meatus	Vestibulocochlear nerve (N VIII) from sense organs for hearing and balance. Facial nerve (N VII) enters here, exits at stylomastoid foramen	Internal acoustic artery supplies blood to inner ear
SPHENOID	Optic canal	Optic nerve (N II) brings information from the eye to the brain	Ophthalmic artery brings blood into orbit
	Superior orbital fissure	Oculomotor nerve (N III), trochlear nerve (N IV), ophthalmic branch of trigeminal nerve (N V), abducens nerve (N VI). Ophthalmic nerve provides sensory information about eye and orbit; other nerves control muscles that move the eye	Ophthalmic vein returns blood from orbit
	Foramen rotundum	Maxillary branch of trigeminal nerve (N V) provides sensation from the face	
	Foramen ovale	Mandibular branch of trigeminal nerve (N V) controls the muscles that move the lower jaw and provides sensory information from that area	
	Foramen spinosum		Vessels to membranes around central nervous system
With temporal and occipital bones	Foramen lacerum		Internal carotid artery after leaving carotid canal; auditory tube; small vessels; hyaline cartilage
With maxilla	Inferior orbital fissure	Maxillary branch of trigeminal nerve (N V); see *Foramen rotundum*	
ETHMOID	Olfactory foramina	Olfactory nerve (N I) provides sense of smell	
MAXILLA	Infra-orbital foramen	Infra-orbital nerve, maxillary branch of trigeminal nerve (N V) from the inferior orbital fissure to face	Infra-orbital artery with same distribution
MANDIBLE	Mental foramen	Mental nerve, sensory branch of the mandibular nerve, provides sensation from the chin and lips	Mental vessels to chin and lips
	Mandibular foramen	Inferior alveolar nerve, sensory branch of mandibular nerve, provides sensation from the gums, teeth	Inferior alveolar vessels supply same region
ZYGOMATIC BONE	Zygomaticofacial foramen	Zygomaticofacial nerve, sensory branch of maxillary nerve to cheek	

*Twelve pairs of cranial nerves, numbered N I–XII, exist. Their functions and distribution are detailed in Chapter 14.

7

Checkpoint

7. **Identify the bone containing the mental foramen, and list the structures using this passageway.**
8. **Identify the bone containing the optic canal, and cite the structures using this passageway.**
9. **Name the foramina found in the ethmoid bone.**

See the blue Answers tab at the back of the book.

7-4 Each orbital complex contains an eye, and the nasal complex encloses the nasal cavities

The facial bones not only protect and support the openings of the digestive and respiratory systems, but also protect the sense organs responsible for vision and smell. Together, certain cranial bones and facial bones form an *orbital complex*, which surrounds each eye, and the *nasal complex*, which surrounds the nasal cavities.

The Orbital Complexes

The **orbits** are the bony recesses that contain the eyes. Seven bones of the **orbital complex** form each orbit (**Figure 7–13**). The frontal bone forms the roof, and the maxilla provides most of the orbital floor. The orbital rim and the first portion of the medial wall are formed by the maxilla, the lacrimal bone, and the lateral mass of the ethmoid. The lateral mass articulates with the sphenoid and a small process of the palatine bone. Several prominent foramina and fissures penetrate the sphenoid or lie between it and the maxilla. Laterally, the sphenoid and maxilla articulate with the zygomatic bone, which forms the lateral wall and rim of the orbit.

The Nasal Complex

The **nasal complex** (**Figure 7–14**) includes the bones that enclose the nasal cavities and the *paranasal sinuses*, air-filled chambers connected to the nasal cavities. The frontal bone, sphenoid, and ethmoid form the superior wall of the nasal cavities. The lateral walls are formed by the maxillae and the lacrimal bones (not shown), the ethmoid (the superior and middle nasal conchae), and the inferior nasal conchae. Much of the anterior margin of the nasal cavity is formed by the soft tissues of the nose, but the bridge of the nose is supported by the maxillae and nasal bones.

The sphenoid, ethmoid, frontal bone, and paired palatine bones and maxillae contain the **paranasal sinuses. Figure 7–14a** shows the location of the frontal and sphenoidal sinuses. Ethmoidal air cells and maxillary sinuses are shown in **Figure 7–14b**. (The tiny palatine sinuses, not shown, generally open into the sphenoidal sinuses.) The paranasal sinuses lighten the skull bones and provide an extensive area of mucous epithelium. The mucous secretions are released into the nasal cavities. The ciliated epithelium passes the mucus back toward the throat, where it is eventually swallowed or expelled by coughing. Incoming air is humidified and warmed as it flows across this thick carpet of mucus. Foreign particulate matter, such as dust or microorganisms, becomes trapped in the sticky mucus

Figure 7–13 **The Orbital Complex.** The right orbital region. ATLAS: Plate 5f

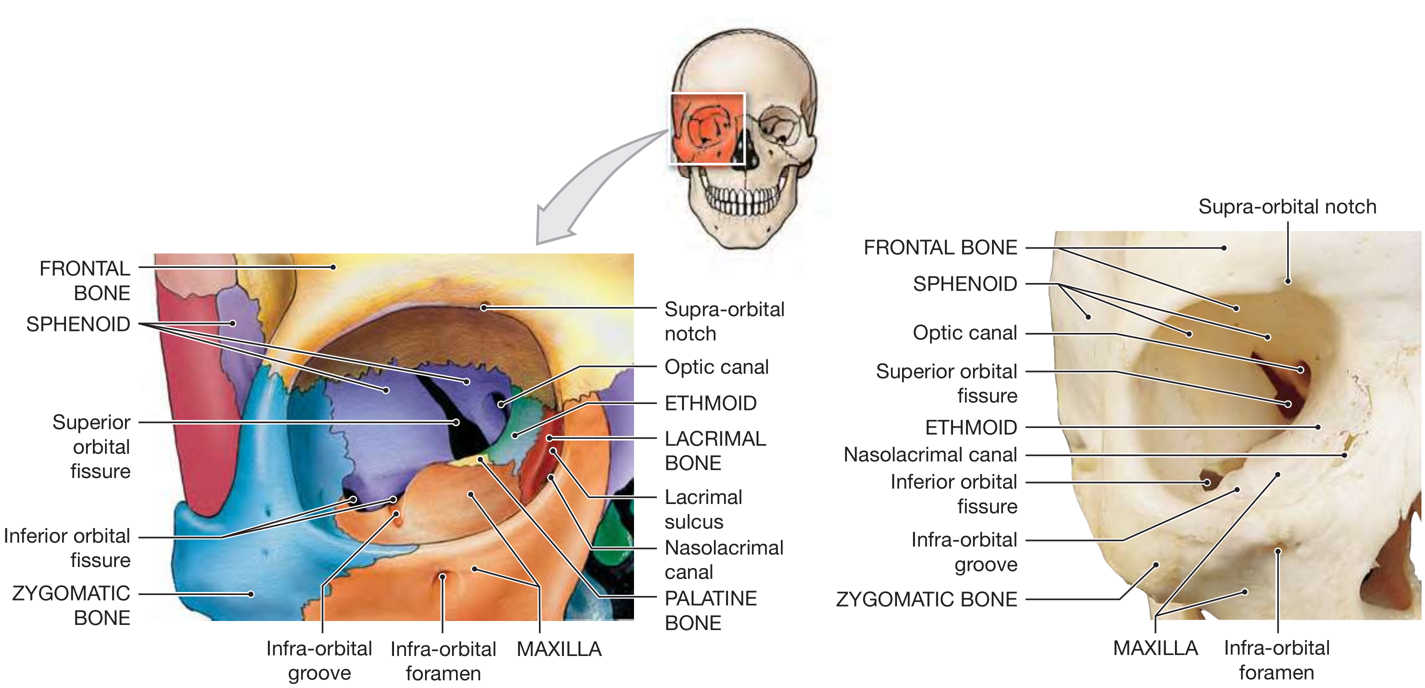
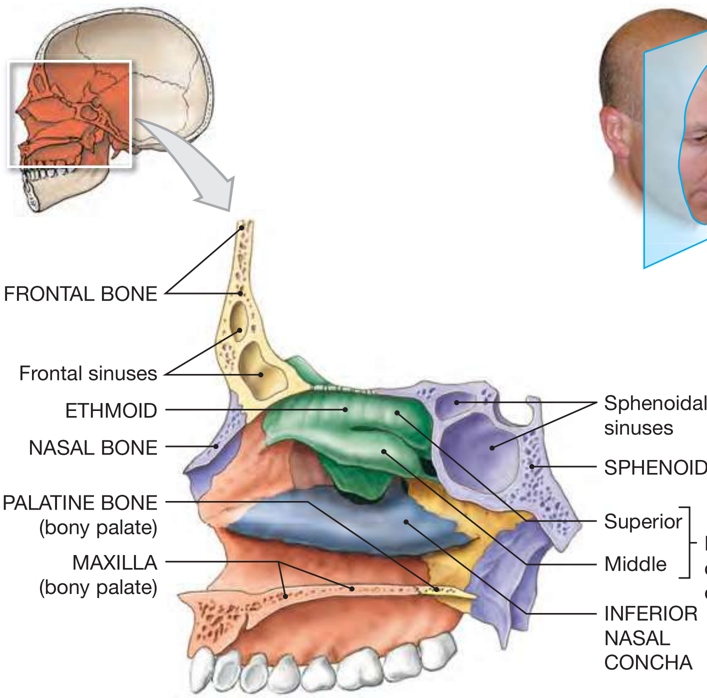
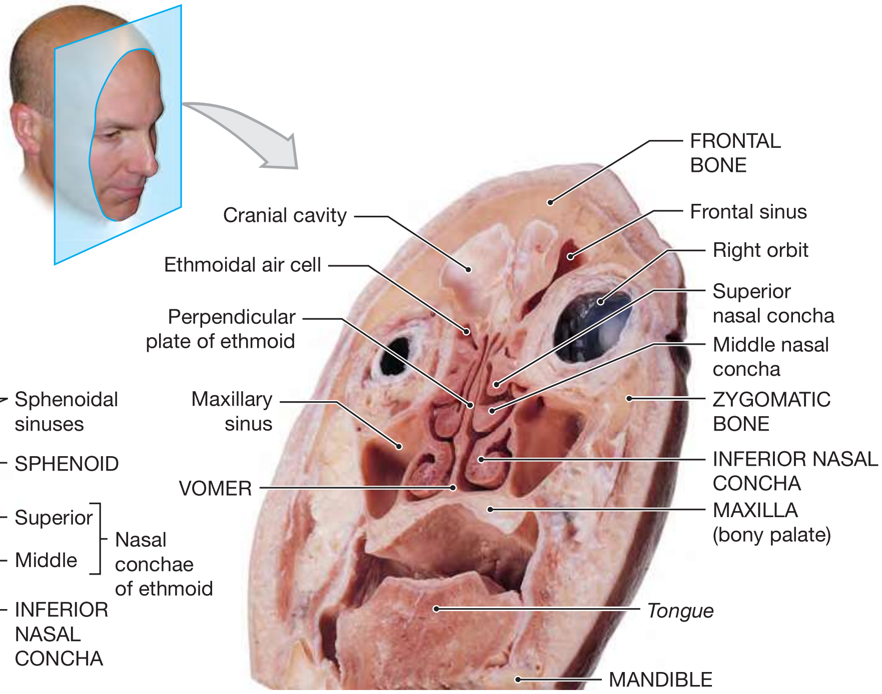


Figure 7–14 **The Nasal Complex.** ATLAS: Plates 11b; 12d; 13b,g



a A sagittal section through the skull, with the nasal septum removed to show major features of the wall of the right nasal cavity. The sphenoidal sinuses are visible.



b A frontal section through the ethmoidal air cells and maxillary sinuses, part of the paranasal sinuses.

7

and is then swallowed or expelled. This mechanism helps protect the more delicate portions of the respiratory tract.

Checkpoint

10. **Identify the bones of the orbital complex.**
11. **Identify the bones of the nasal complex.**
12. **Identify the bones containing the paranasal sinuses.**

See the blue Answers tab at the back of the book.

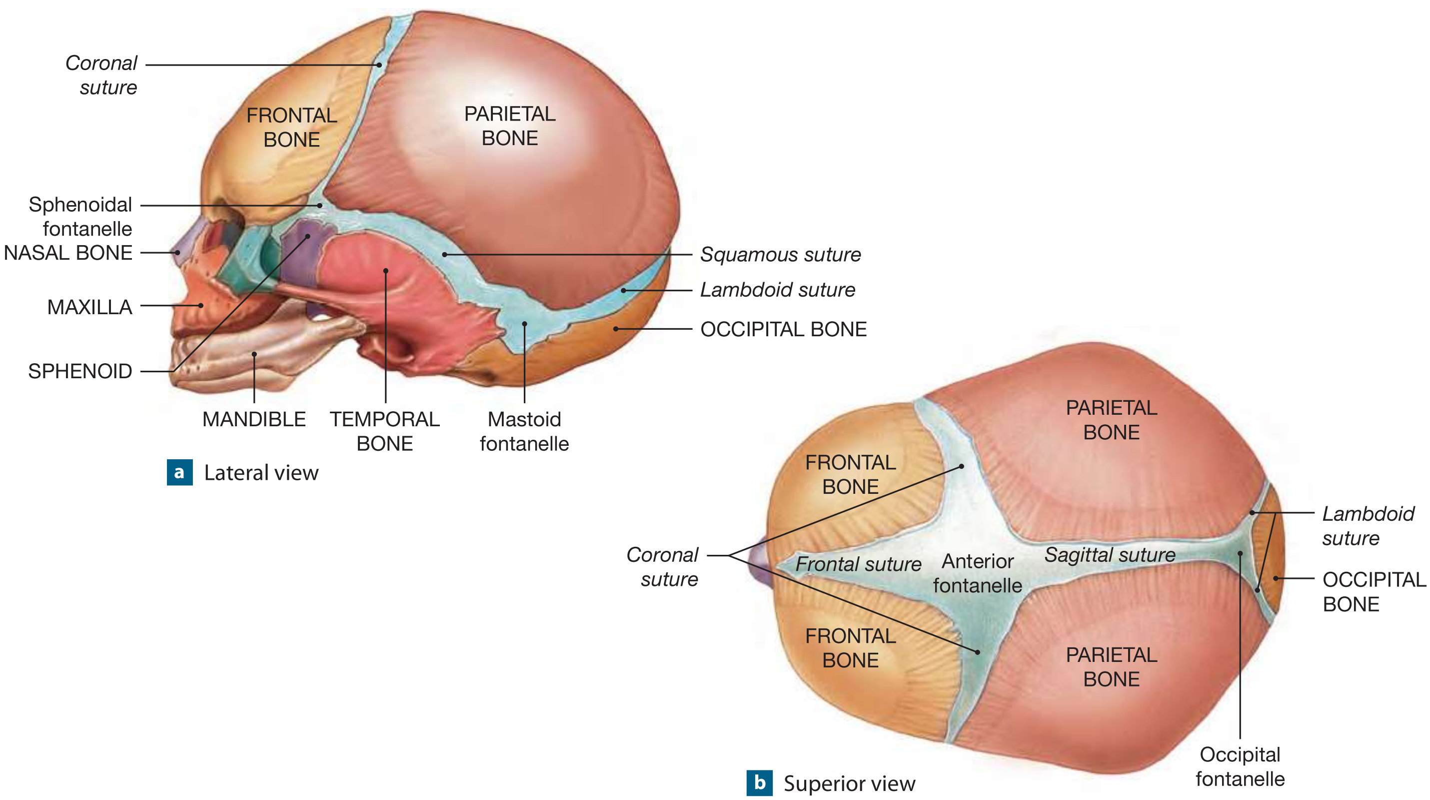
7-5 Fontanelles are non-ossified areas between cranial bones that allow for brain growth

Many different centers of ossification are involved in the formation of the skull. As development proceeds, the centers fuse, producing a smaller number of composite bones. For example, the sphenoid begins as 14 separate ossification centers. At birth, fusion has not been completed: There are two frontal bones, four occipital bones, and several sphenoid and temporal elements.

The skull organizes around the developing brain. As the time of birth approaches, the brain enlarges rapidly. Although the bones of the skull are also growing, they fail to keep pace. At birth, the cranial bones are connected by areas of fibrous connective tissue (**Figure 7–15**). The connections are quite flexible, so the skull can be distorted without damage. Such distortion normally occurs during delivery, and the changes in head shape ease the passage of the infant through the birth canal. The largest fibrous areas between the cranial bones are known as **fontanelles** (fon-tuh-NELZ; sometimes spelled *fontanels*):

- The *anterior fontanelle* is the largest fontanelle. It lies at the intersection of the frontal, sagittal, and coronal sutures in the anterior portion of the skull.
- The *occipital fontanelle* is at the junction between the lambdoid and sagittal sutures.
- The *sphenoidal fontanelles* are at the junctions between the squamous sutures and the coronal suture.
- The *mastoid fontanelles* are at the junctions between the squamous sutures and the lambdoid suture.

Figure 7–15 **The Skull of an Infant.**



The anterior fontanelle is often referred to as the "soft spot" on newborns, and is often the only fontanelle easily seen by new parents. Because it is composed of fibrous connective tissue and covers a major blood vessel, the anterior fontanelle pulses as the heart beats. This fontanelle is sometimes used to determine whether an infant is dehydrated, as the surface becomes indented when blood volume is low.

The occipital, sphenoidal, and mastoid fontanelles disappear within a month or two after birth. The anterior fontanelle generally persists until the child is nearly 2 years old. Even after the fontanelles disappear, the bones of the skull remain separated by fibrous connections.

The skulls of infants and adults differ in terms of the shape and structure of cranial elements. This difference accounts for variations in proportions as well as in size. The most significant growth in the skull occurs before age 5, because at that time the brain stops growing and the cranial sutures develop. As a result, the cranium of a young child, compared with the skull as a whole, is relatively larger than that of an adult. The growth of the cranium is generally coordinated with the expansion of the brain. If one or more sutures form before the brain stops growing, the skull will be abnormal in shape, size, or both.

Clinical Note

Craniostenosis Unusual distortions of the skull result from *craniostenosis* (krā-nē-ō-sten-Ō-sis; *stenosis*, narrowing), the premature closure of one or more fontanelles. As the brain continues to enlarge, the rest of the skull distorts to accommodate it. A long and narrow head is produced by early closure of the sagittal suture, whereas a very broad skull results if the coronal suture forms prematurely. Early closure of all cranial sutures restricts the development of the brain, and surgery must be performed to prevent brain damage. If brain enlargement stops due to genetic or developmental abnormalities, however, skull growth ceases as well. This condition, which results in an undersized head, is called *microcephaly* (mī-krō-SEF-uh-lē; *micro-*, small + *cephalon*, head).

Checkpoint

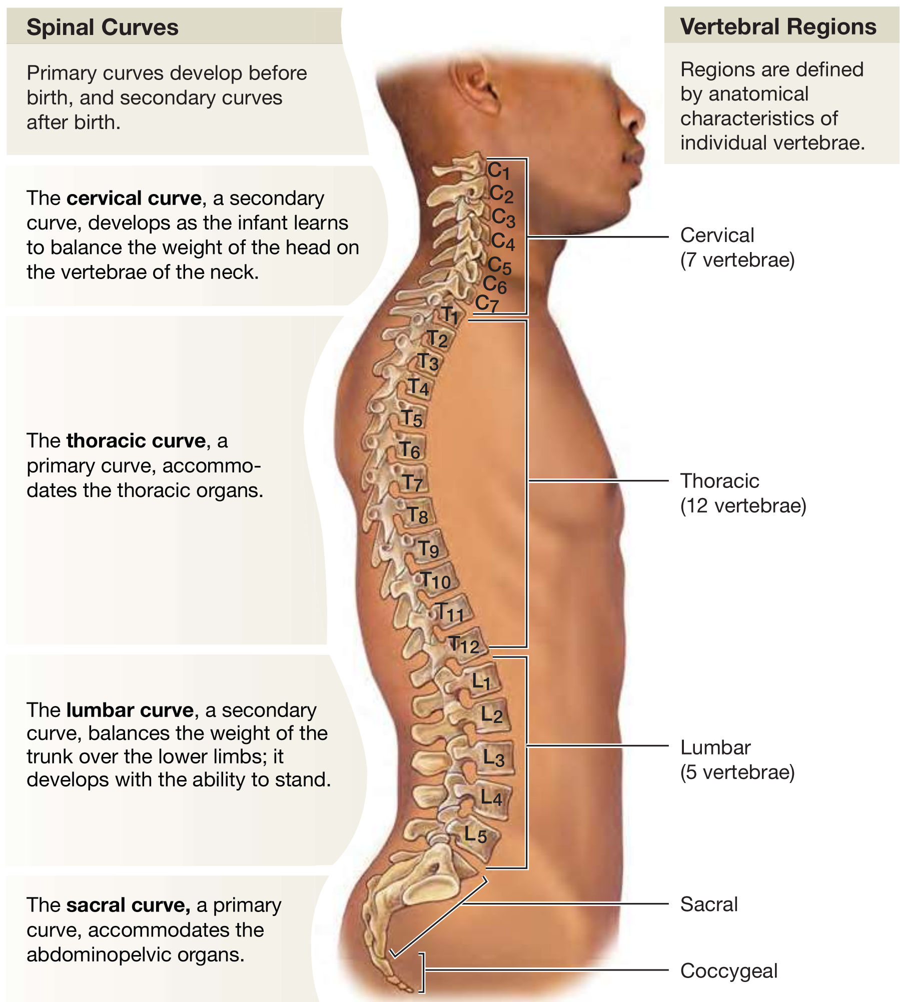
13. **Define fontanelle, and identify the major fontanelles.**
14. **What purpose does a fontanelle serve?**

See the blue Answers tab at the back of the book.

7-6 ◗ The vertebral column has four spinal curves

The rest of the axial skeleton consists of the vertebral column, ribs, and sternum. The adult **vertebral column,** or *spine*, consists of 26 bones: the **vertebrae** (24), the **sacrum,** and the **coccyx** (KOK-siks), or tailbone. The vertebrae provide a column of support, bearing the weight of the head, neck, and trunk and ultimately transferring the weight to the appendicular skeleton of the lower limbs. The vertebrae also protect the spinal cord and help maintain an upright body position, as in sitting or standing. The total length of the vertebral column of an adult averages 71 cm (28 in.). We begin this section by examining the curvature of the vertebral column; then we consider the basics of vertebral anatomy.

Figure 7–16 **The Vertebral Column.** ATLAS: Plate 2b



Spinal Curvature

The vertebral column is not straight and rigid. A lateral view shows four **spinal curves** (**Figure 7–16**): the (1) **cervical curve,** (2) **thoracic curve,** (3) **lumbar curve,** and (4) **sacral curve.**

You may have noticed that an infant's body axis forms a C-shape, with the back curving posteriorly. The C-shape results from the thoracic and sacral curves. These are called **primary curves,** because they appear late in fetal development, or **accommodation curves,** because they accommodate the thoracic and abdominopelvic viscera. The primary curves are present in the vertebral column at birth. The lumbar and cervical curves, known as **secondary curves,** do not appear until several months after birth. These curves are also called **compensation curves,** because they help shift the weight to permit an upright posture. The cervical and lumbar secondary curves become accentuated as the toddler learns to walk and run. All four curves are fully developed by age 10.

When you stand, the weight of your body must be transmitted through the vertebral column to the hips and ultimately to the lower limbs. Yet most of your body weight lies anterior to the vertebral column. The various curves bring that weight in line with the body axis. Consider what you do automatically when standing with a heavy object hugged to your chest. You avoid toppling forward by exaggerating the lumbar curve and by keeping the weight back toward the body axis. This posture can lead to discomfort at the base of the spinal column. For example, many women in the last three months of pregnancy develop chronic back pain from the changes in lumbar curvature that must adjust for the increasing weight of the fetus. In many parts of the world, people often balance heavy objects on their head. This practice increases the load on the vertebral column, but the spinal curves are not affected because the weight is aligned with the axis of the spine.

Vertebral Anatomy

Each vertebra consists of three basic parts: (1) a *vertebral body*, (2) a *vertebral arch*, and (3) *articular processes* (**Figure 7–18a**).

The **vertebral body,** or *centrum* (plural, *centra*), is the part of a vertebra that transfers weight along the axis of the vertebral column (**Figure 7–18a,b,e**). The bodies of adjacent vertebrae are interconnected by ligaments, but are separated by pads of fibrocartilage, the **intervertebral discs.**

The **vertebral arch** forms the posterior margin of each **vertebral foramen** (**Figure 7–18a,c**). The vertebral arch has walls, called **pedicles** (PED-i-kulz), and a roof, formed by flat

Humpback, **swayback**, and **crooked back**

The vertebral column must move, balance, and support the trunk and head. Conditions or events that damage the bones, muscles, and/or nerves can result in distorted shapes and impaired function. In **kyphosis** (kī-FŌ-sis; *kyphos*, humpbacked, bent), the normal thoracic curvature becomes exaggerated posteriorly, producing a "round-back" appearance (**Figure 7–17a**). This condition can be caused by (1) osteoporosis with compression fractures affecting the anterior portions of vertebral bodies, (2) chronic contractions in muscles that insert on the vertebrae, or (3) abnormal vertebral growth. In **lordosis** (lor-DŌ-sis; *lordosis*, a bending backward), or "swayback," both the abdomen and buttocks protrude abnormally (**Figure 7–17b**). The cause is an anterior exaggeration of the lumbar curvature. This may occur during pregnancy or result from abdominal obesity or weakness in the muscles of the abdominal wall. **Scoliosis** (skō-lē-Ō-sis; *scoliosis*, crookedness) is an abnormal lateral curvature of the spine (**Figure 7–17c**) in one or more of the movable vertebrae. Scoliosis is the most common distortion of the spinal curvature. This condition may result from developmental problems from damage to vertebral bodies, or from muscular paralysis affecting one side of the back (as in some cases of polio). In four out of five cases, the structural or functional cause of the abnormal spinal curvature is impossible to determine. This *idiopathic* (of no known cause) scoliosis generally appears in girls during adolescence, when periods of growth are most rapid. Small curves may later stabilize once growth is complete. For larger curves, bracing may prevent progression. Severe cases can be treated through surgical straightening with implanted metal rods or cables.

Figure 7–17 **Abnormal Curvatures of the Spine.**

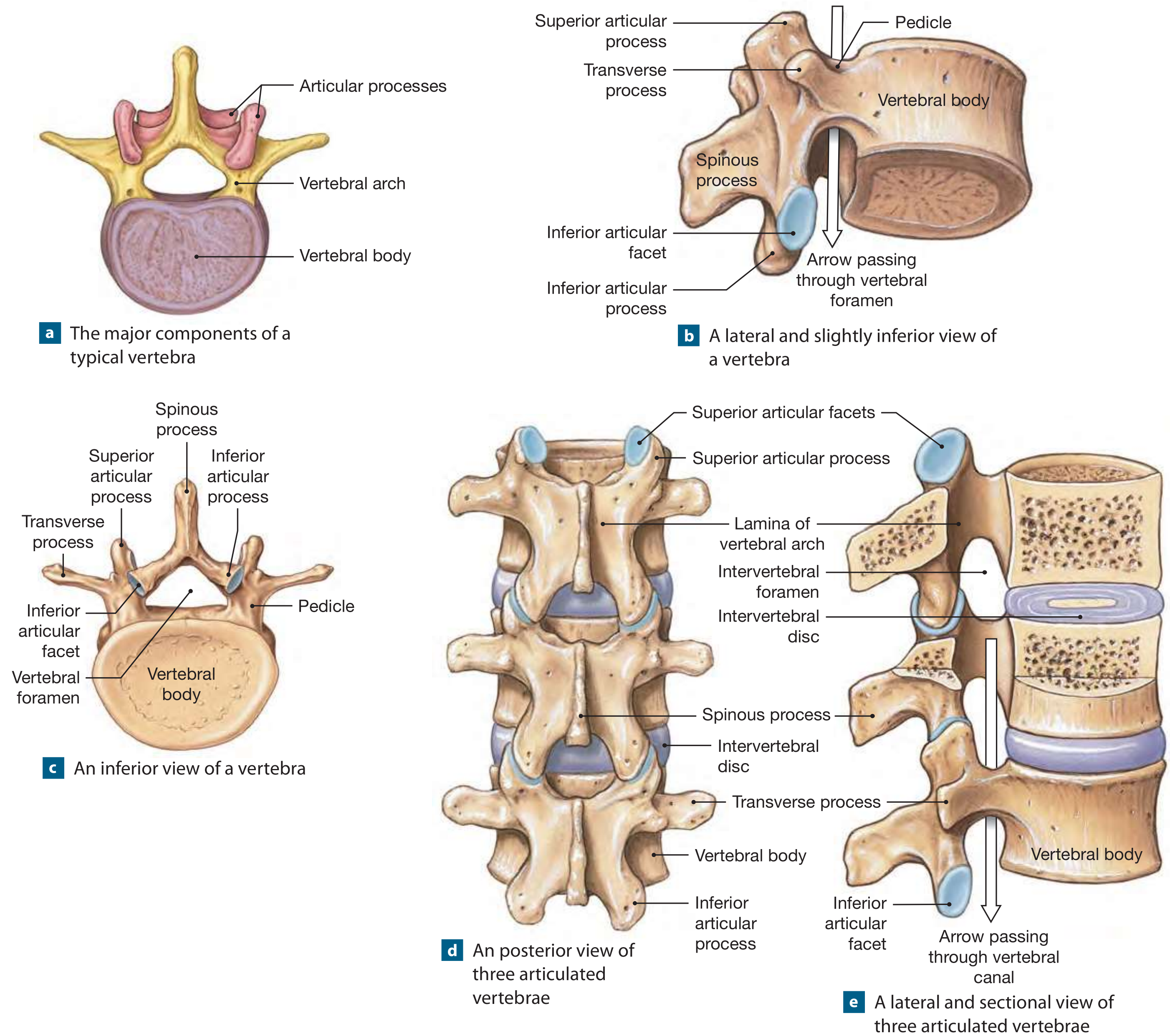
a Kyphosis **b** Lordosis **c** Scoliosis

layers called **laminae** (LAM-i-nē; singular, *lamina*, a thin plate). The pedicles arise along the posterior and lateral margins of the body. The laminae on either side extend dorsally and medially to complete the roof. Together, the vertebral foramina of successive vertebrae form the **vertebral canal,** which encloses the spinal cord (**Figure 7–18e**).

A **spinous process** projects posteriorly from the point where the vertebral laminae fuse to complete the vertebral arch. You can see—and feel—the spinous processes through the skin of the back when the spine is flexed. **Transverse processes** project laterally or dorsolaterally on both sides from the point where the laminae join the pedicles. These processes are sites of muscle attachment, and they may also articulate with the ribs.

Like the transverse processes, the **articular processes** arise at the junction between the pedicles and the laminae. A **superior** and an **inferior articular process** lie on each side of the vertebra. The superior articular processes articulate with the inferior articular processes of a more superior vertebra (or

Figure 7–18 Vertebral Anatomy.



the occipital condyles, in the case of the first cervical vertebra). The inferior articular processes articulate with the superior articular processes of a more inferior vertebra (or the sacrum, in the case of the last lumbar vertebra). Each articular process has a smooth concave surface called an **articular facet.** The superior processes have articular facets on their dorsal surfaces, whereas the inferior processes articulate along their ventral surfaces.

Intervertebral discs separate adjacent vertebral bodies, and gaps separate the pedicles of successive vertebrae. These gaps, called **intervertebral foramina,** permit the passage of nerves running to or from the enclosed spinal cord.

Checkpoint

15. **What is the importance of the secondary curves of the spine?**
16. **When you run your finger along a person's spine, what part of the vertebrae are you feeling just beneath the skin?**

See the blue Answers tab at the back of the book.

7

7

7-7 The five vertebral regions are the cervical, thoracic, lumbar, sacral, and coccygeal

As we saw in **Figure 7–16**, the vertebral column is divided into cervical, thoracic, lumbar, sacral, and coccygeal regions. Seven **cervical vertebrae** (C_1–C_7) constitute the neck and extend inferiorly to the trunk. Twelve **thoracic vertebrae** (T_1–T_{12}) form the superior portion of the back; each articulates with one or more pairs of ribs. Five **lumbar vertebrae** (L_1–L_5) form the inferior portion of the back; the fifth articulates with the sacrum, which in turn articulates with the coccyx. The cervical, thoracic, and lumbar regions consist of individual vertebrae. During development, the sacrum originates as a group of five vertebrae, and the coccyx begins as three to five very small vertebrae. In general, the vertebrae of the sacrum are completely fused by age 25–30. Ossification of the distal coccygeal vertebrae is not complete before puberty, and thereafter fusion occurs at a variable pace. ATLAS: Embryology Summary 7: The Development of the Vertebral Column

Note that when referring to a specific vertebra, we use a capital letter to indicate the vertebral region: C, T, L, S, and Co indicate the cervical, thoracic, lumbar, sacral, and coccygeal regions, respectively. In addition, we use a subscript number to indicate the relative position of the vertebra within that region, with 1 indicating the vertebra closest to the skull. For example, C_3 is the third cervical vertebra; C_1 is in contact with the skull. Similarly, L_4 is the fourth lumbar vertebra; L_1 is in contact with T_{12} (**Figure 7–16**). We will use this shorthand throughout the text.

Although each vertebra has characteristic markings and articulations, we will focus on the general characteristics of each region, and on how regional variations determine the vertebral group's function.

Cervical Vertebrae

Most mammals—whether giraffes, whales, mice, or humans—have seven cervical vertebrae (**Figure 7–19**). The cervical vertebrae are the smallest in the vertebral column and extend from the occipital bone of the skull to the thorax. The body of a cervical vertebra is small compared with the size of the vertebral foramen (**Figure 7–19b**). At this level, the spinal cord still contains most of the axons that connect the brain to the rest of the body. The diameter of the spinal cord decreases as you proceed caudally along the vertebral canal, and so does the diameter of the vertebral arch. However, cervical vertebrae support only the weight of the head, so the vertebral body can be relatively small and light. As you continue toward the sacrum, the loading increases and the vertebral bodies gradually enlarge.

In a typical cervical vertebra, the superior surface of the body is concave from side to side, and it slopes, with the anterior edge inferior to the posterior edge (**Figure 7–19c**). Vertebra C_1 has no spinous process. The spinous processes of the other cervical vertebrae are relatively stumpy, generally shorter than the diameter of the vertebral foramen. In the case of vertebrae C_2–C_6, the tip of each spinous process has a prominent notch (**Figure 7–19b**). A notched spinous process is said to be **bifid** (BĪ-fid).

Laterally, the transverse processes are fused to the **costal processes,** which originate near the ventrolateral portion of the vertebral body. The costal and transverse processes encircle prominent, round **transverse foramina.** These passageways protect the *vertebral arteries* and *vertebral veins*, important blood vessels that service the brain.

The preceding description is adequate for identifying the cervical vertebrae C_3–C_6. The first two cervical vertebrae are unique, and the seventh is modified; these vertebrae are described shortly. The interlocking bodies of articulated C_3–C_7 permit more flexibility than do those of other regions. **Table 7–2** includes a summary of the features of these cervical vertebrae.

Compared with the cervical vertebrae, your head is relatively massive. It sits atop the cervical vertebrae like a soup bowl on the tip of a finger. With this arrangement, small muscles can produce significant effects by tipping the balance one way or another. But if you change position suddenly, as in a fall or during rapid acceleration (a jet takeoff) or deceleration (a car crash), the balancing muscles are not strong enough to stabilize the head. A dangerous partial or complete dislocation of the cervical vertebrae can result, with injury to muscles and ligaments and potential injury to the spinal cord. The term **whiplash** is used to describe such an injury, because the movement of the head resembles the cracking of a whip.

The Atlas (C_1)

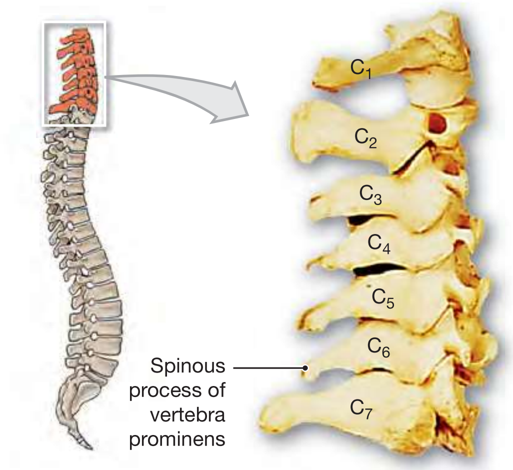
The **atlas,** cervical vertebra C_1 (**Figure 7–19d**), holds up the head, articulating with the occipital condyles of the skull. This vertebra is named after Atlas, who, according to Greek myth, holds the world on his shoulders. The articulation between the occipital condyles and the atlas is a joint that permits you to nod (such as when you indicate "yes"). The atlas can easily be distinguished from other vertebrae by (1) the lack of a body and spinous process and (2) the presence of a large, round vertebral foramen bounded by **anterior** and **posterior arches.**

The atlas articulates with the second cervical vertebra, the *axis*. This articulation permits rotation (as when you shake your head to indicate "no").

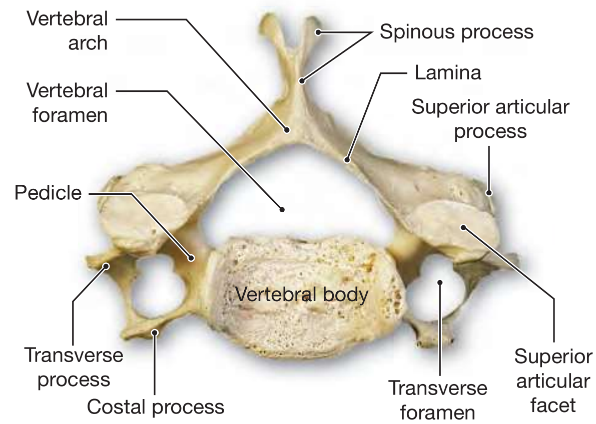
The Axis (C_2)

During development, the body of the atlas fuses to the body of the second cervical vertebra, called the **axis** (C_2) (**Figure 7–19d**). This fusion creates the prominent **dens** (DENZ; *dens*, tooth), or *odontoid* (ō-DON-toyd; *odontos*, tooth) *process*, of the axis. A transverse ligament binds the dens to the inner surface of the atlas, forming a pivot for rotation of the atlas and skull. Important muscles controlling the position of the head and neck attach to the especially robust spinous process of the axis.

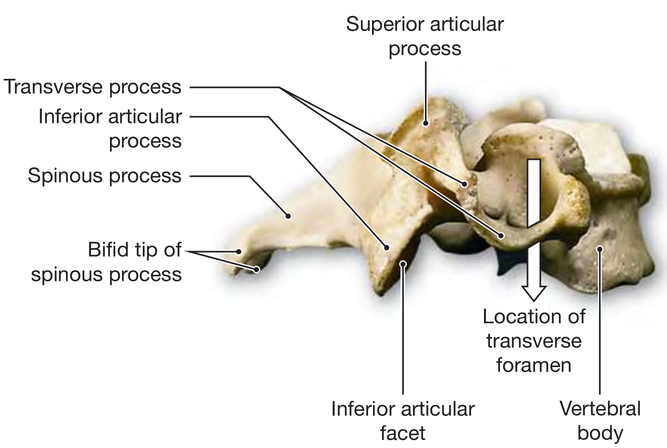
Figure 7–19 **The Cervical Vertebrae.** ATLAS: Plates 20b; 21a–e



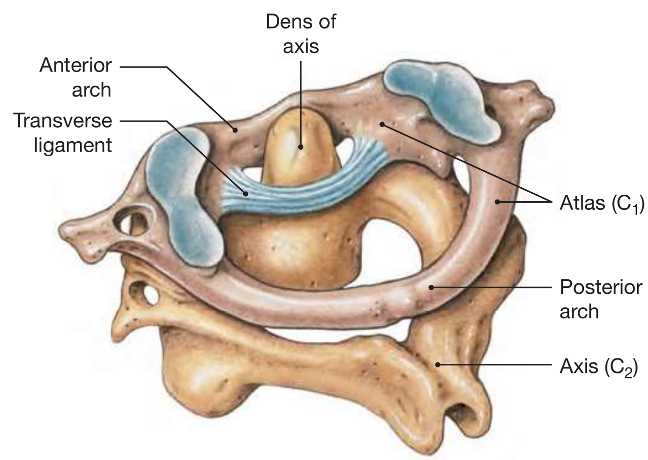
a A lateral view of the cervical vertebrae, C_1–C_7.



b A superior view of a representative cervical vertebra showing characteristics of C_3–C_6. Notice the typical features listed in *Table 7–2*.



c A lateral view of the same vertebra as in b.



d The atlas (C_1) and axis (C_2).

7

In children, the fusion between the dens and axis is incomplete. Impacts or even severe shaking can cause dislocation of the dens and severe damage to the spinal cord. In adults, a hit to the base of the skull can be equally dangerous, because a dislocation of the atlas–axis joint can force the dens into the base of the brain, with fatal results.

Tips & Tricks

To remember the difference between the atlas and the axis and their respective movements, consider Greek mythology and the Earth. In this case, the head (Earth) is held up by Atlas and is capable of nodding "yes" movements; the Earth rotates on its axis, and the axis allows for us to shake our heads in a "no" movement.

The Vertebra Prominens (C_7)

The transition from one vertebral region to another is not abrupt, and the last vertebra of one region generally resembles the first vertebra of the next. The **vertebra prominens,** or seventh cervical vertebra (C_7), has a long, slender spinous process (**Figure 7–19a**) that ends in a broad tubercle that you can feel through the skin at the base of the neck. This vertebra is the interface between the cervical curve, which arches anteriorly, and the thoracic curve, which arches posteriorly (**Figure 7–16**). The transverse processes of C_7 are large, providing additional surface area for muscle attachment. The **ligamentum nuchae** (lig-uh-MEN-tum NOO-kē; *nucha*, nape), a stout elastic ligament, begins at the vertebra prominens and extends to an insertion along the occipital crest of the skull. Along the way, it

Table 7–2 Regional Differences in Vertebral Structure and Function

Feature	Type (Number)		
	Cervical Vertebrae (7)	**Thoracic Vertebrae (12)**	**Lumbar Vertebrae (5)**
Location	Neck	Chest	Inferior portion of back
Body	Small, oval, curved faces	Medium, heart-shaped, flat faces; facets for rib articulations	Massive, oval, flat faces
Vertebral foramen	Large	Medium	Small
Spinous process	Long; split tip; points inferiorly	Long, slender; not split; points inferiorly	Blunt, broad; points posteriorly
Transverse processes	Have transverse foramina	All but two (T_{11}, T_{12}) have facets for rib articulations	Short; no articular facets or transverse foramina
Functions	Support skull, stabilize relative positions of brain and spinal cord, and allow controlled head movement	Support weight of head, neck, upper limbs, and chest; articulate with ribs to allow changes in volume of thoracic cage	Support weight of head, neck, upper limbs, and trunk

Typical appearance (superior view)

7

attaches to the spinous processes of the other cervical vertebrae. When your head is upright, this ligament acts like the string on a bow, maintaining the cervical curvature without muscular effort. If you have bent your neck forward, the elasticity in the ligamentum nuchae helps return your head to an upright position.

Thoracic Vertebrae

There are 12 thoracic vertebrae (**Figure 7–20**). A typical thoracic vertebra has a distinctive heart-shaped body that is more massive than that of a cervical vertebra. The vertebral foramen is relatively smaller, and the long, slender spinous process projects posteriorly and inferiorly. The spinous processes of T_{10}, T_{11}, and T_{12} increasingly resemble those of the lumbar region as the transition between the thoracic and lumbar curves approaches. Because the inferior thoracic and lumbar vertebrae carry so much weight, the transition between the thoracic and lumbar curves is difficult to stabilize. As a result, compression fractures or compression–dislocation fractures incurred after a hard fall tend to involve the last thoracic and first two lumbar vertebrae.

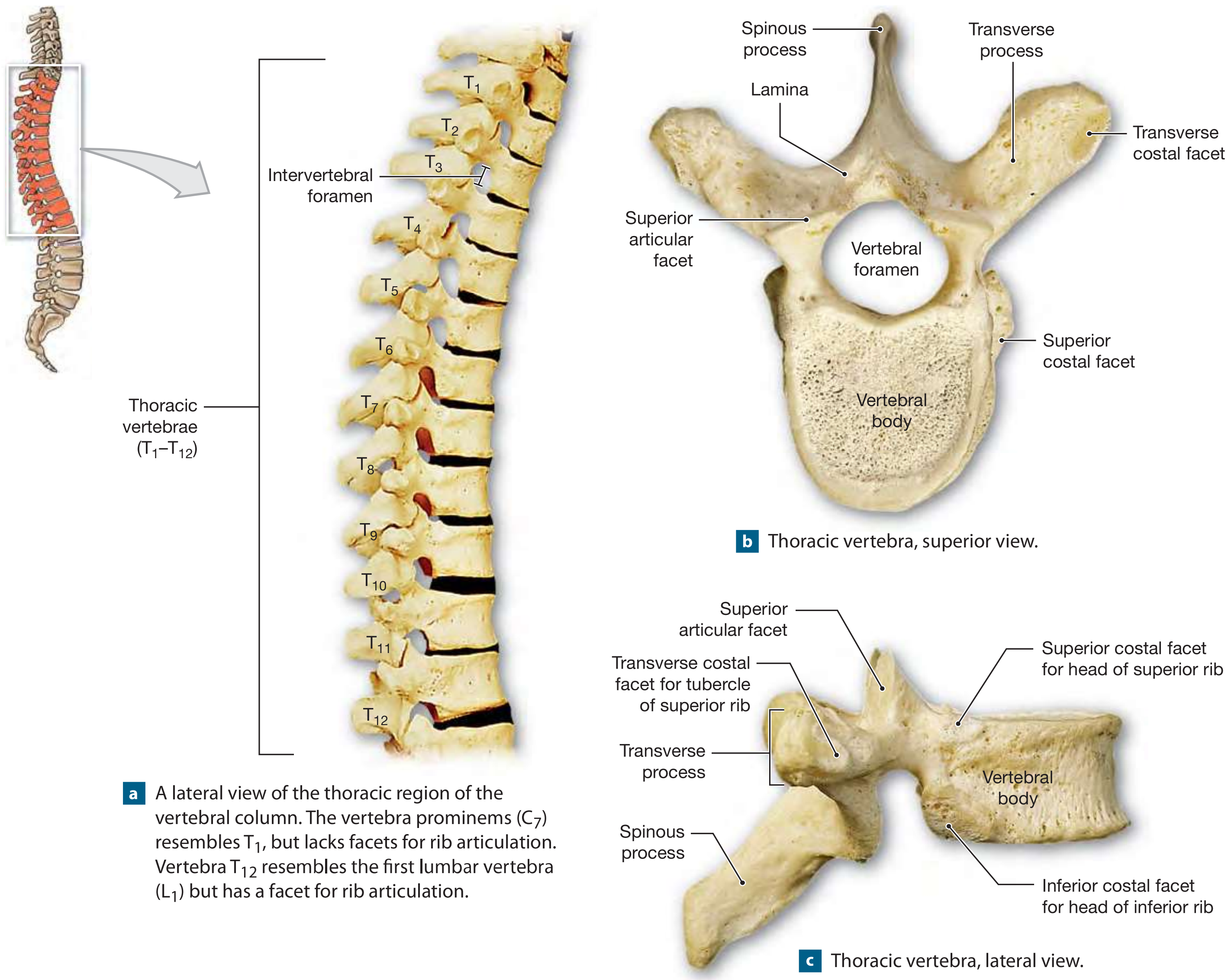
Each thoracic vertebra articulates with ribs along the dorsolateral surfaces of the body. The **costal facets** on the vertebral bodies articulate with the heads of the ribs. The location and structure of the articulations vary somewhat among thoracic vertebrae (**Figure 7–20a**). Vertebrae T_1–T_8 each articulate with two pairs of ribs, so their vertebral bodies have two costal facets (*superior* and *inferior*) on each side. Vertebrae T_9–T_{11} have a single costal facet on each side, and each vertebra articulates with a single pair of ribs.

The transverse processes of vertebrae T_1–T_{10} are relatively thick and contain **transverse costal facets** for rib articulation (**Figure 7–20b,c**). Thus, rib pairs 1 through 10 contact their vertebrae at two points: a costal facet and a transverse costal facet. **Table 7–2** summarizes the features of thoracic vertebrae.

Lumbar Vertebrae

The five lumbar vertebrae are the largest vertebrae. The body of a typical lumbar vertebra (**Figure 7–21**) is thicker than that of a thoracic vertebra, and the superior and inferior surfaces are oval rather than heart shaped. Other noteworthy features are that (1) lumbar vertebrae do not have costal facets; (2) the slender transverse processes, which lack transverse costal facets, project dorsolaterally; (3) the vertebral foramen is triangular;

Figure 7–20 The Thoracic Vertebrae. Notice the characteristic features listed in *Table 7–2*. ATLAS: Plates 22a–c



a A lateral view of the thoracic region of the vertebral column. The vertebra prominens (C_7) resembles T_1, but lacks facets for rib articulation. Vertebra T_{12} resembles the first lumbar vertebra (L_1) but has a facet for rib articulation.

b Thoracic vertebra, superior view.

c Thoracic vertebra, lateral view.

(4) the stumpy spinous processes project dorsally; (5) the superior articular processes face medially ("up and in"); and (6) the inferior articular processes face laterally ("down and out").

The lumbar vertebrae withstand the most weight. Their massive spinous processes provide surface area for the attachment of lower back muscles that reinforce or adjust the lumbar curve. **Table 7–2** summarizes the characteristics of lumbar vertebrae.

Tips & Tricks

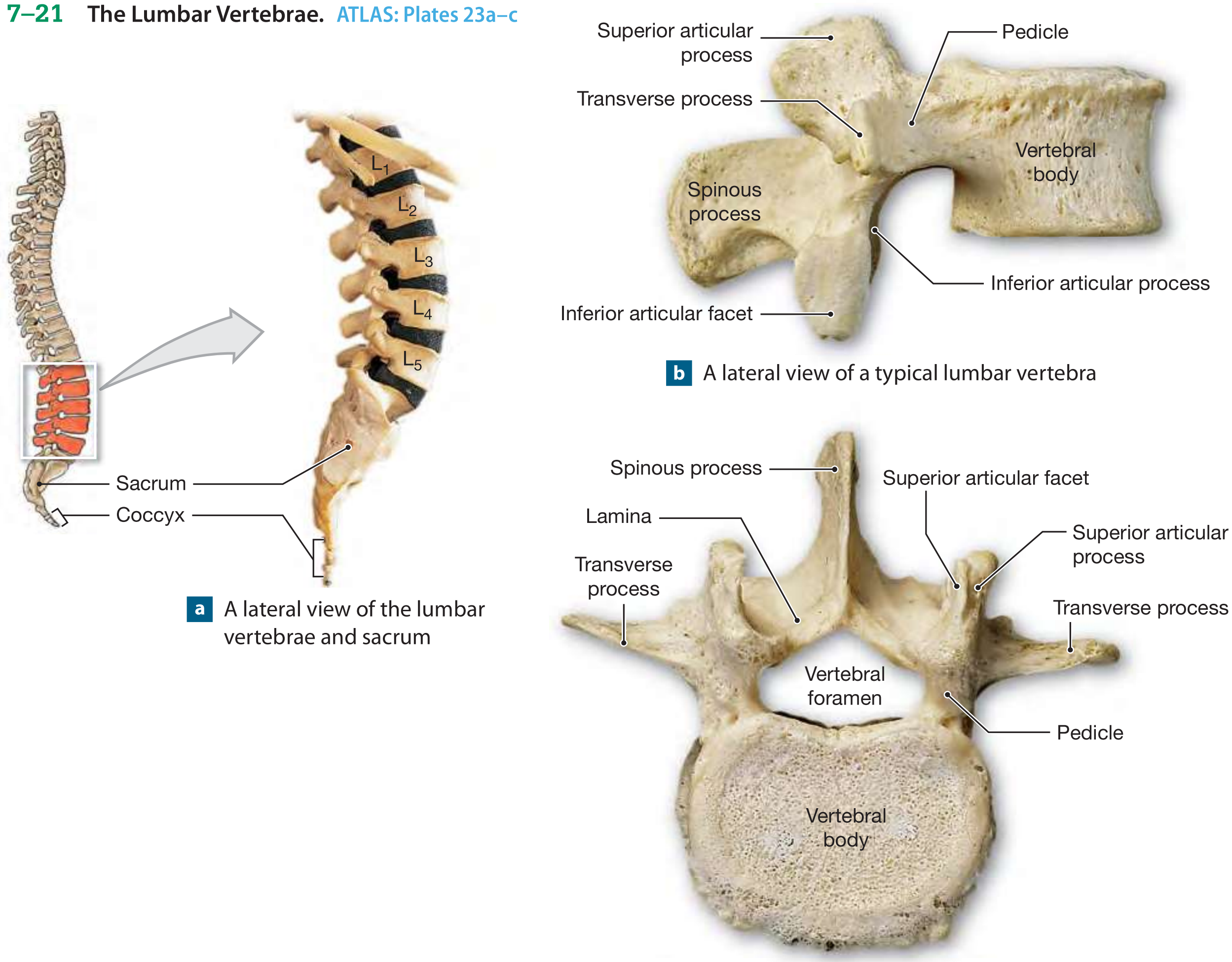
To remember the number of bones in the first three spinal curves, think about mealtimes. You eat breakfast at 7 a.m. (7 cervical vertebrae), lunch at 12 p.m. (12 thoracic vertebrae), and dinner at 5 p.m. (5 lumbar vertebrae).

The Sacrum

The sacrum consists of the fused components of five sacral vertebrae. These vertebrae begin fusing shortly after puberty and, in general, are completely fused at age 25–30. The sacrum protects the reproductive, digestive, and urinary organs and, through paired articulations, attaches the axial skeleton to the pelvic girdle of the appendicular skeleton (**Figure 7–1a**).

The broad posterior surface of the sacrum (**Figure 7–22a**) provides an extensive area for the attachment of muscles, especially those that move the thigh. The superior articular processes of the first sacral vertebra articulate with the last lumbar vertebra. The **sacral canal** is a passageway that begins between these articular processes and extends the length of the

Figure 7–21 **The Lumbar Vertebrae.** ATLAS: Plates 23a–c

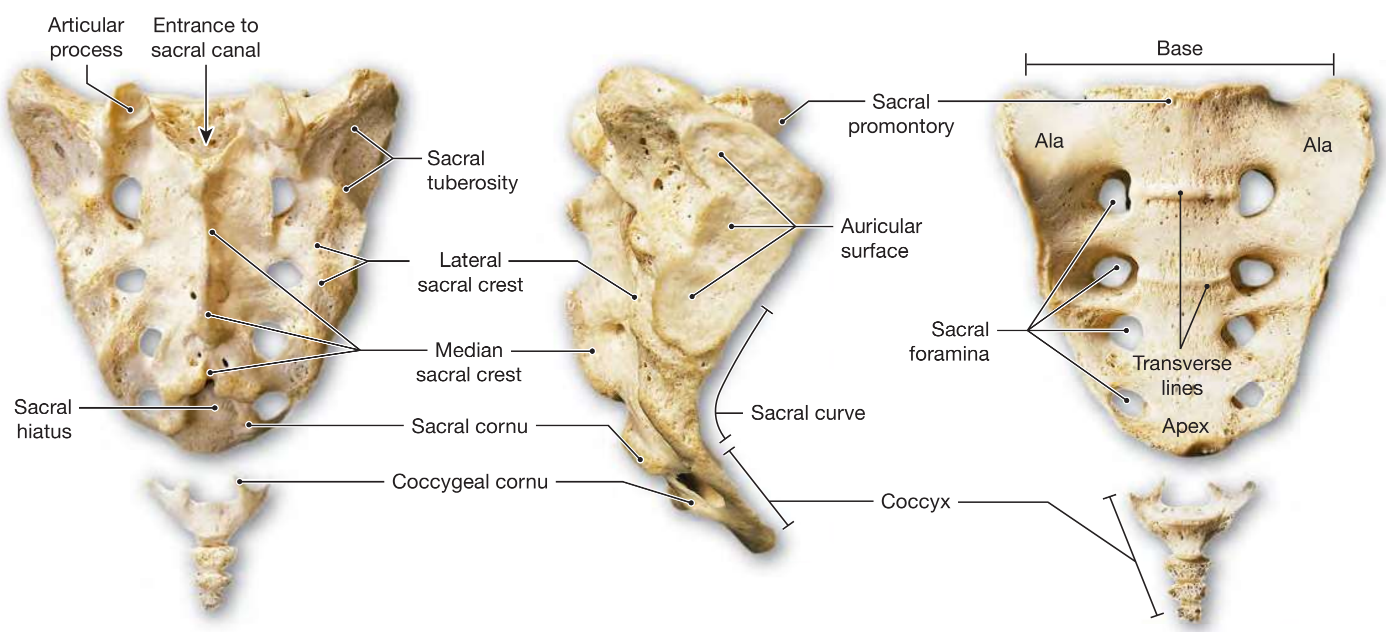


a A lateral view of the lumbar vertebrae and sacrum

b A lateral view of a typical lumbar vertebra

c A superior view of the same vertebra shown in part b

Figure 7–22 **The Sacrum and Coccyx.**



a A posterior view

b A lateral view from the right side

c An anterior view

sacrum. Nerves and membranes that line the vertebral canal in the spinal cord continue into the sacral canal.

The **median sacral crest** is a ridge formed by the fused spinous processes of the sacral vertebrae. The laminae of the fifth sacral vertebra fail to contact one another at the midline; they form the **sacral cornua** (KOR-nū-uh; singular, *cornu*; *cornua*, horns). These ridges form the margins of the **sacral hiatus** (hī-Ā-tus), the opening at the inferior end of the sacral canal. This opening is covered by connective tissues. Four pairs of **sacral foramina** open on either side of the median sacral crest. The intervertebral foramina of the fused sacral vertebrae open into these passageways. The **lateral sacral crest** on each side is a ridge that represents the fused transverse processes of the sacral vertebrae. The sacral crests provide surface area for the attachment of muscles.

The sacrum is curved, with a convex posterior surface (**Figure 7–22b**). The degree of curvature is more pronounced in males than in females. The **auricular surface** is a thickened, flattened area lateral and anterior to the superior portion of the lateral sacral crest. The auricular surface is the site of articulation with the pelvic girdle (the *sacroiliac joint*). The **sacral tuberosity** is a roughened area between the lateral sacral crest and the auricular surface. It marks the attachment site of ligaments that stabilize the sacroiliac joint.

The subdivisions of the sacrum are most clearly seen in anterior view (**Figure 7–22c**). The narrow, inferior portion is the sacral **apex,** whereas the broad superior surface forms the **base.** The **sacral promontory,** a prominent bulge at the anterior tip of the base, is an important landmark in females during pelvic examinations and during labor and delivery. Prominent *transverse lines* mark the former boundaries of individual vertebrae that fuse during the formation of the sacrum. At the base of the sacrum, a broad sacral **ala,** or *wing*, extends on either side. The anterior and superior surfaces of each ala provide an extensive area for muscle attachment. At the apex, a flattened area marks the site of articulation with the coccyx.

The Coccyx

The small coccyx consists of three to five (typically, four) coccygeal vertebrae that have generally begun fusing by age 26 (**Figure 7–22**). The coccyx provides an attachment site for a number of ligaments and for a muscle that constricts the anal opening. The first two coccygeal vertebrae have transverse processes and unfused vertebral arches. The prominent laminae of the first coccygeal vertebrae are known as the **coccygeal cornua.** These laminae curve to meet the sacral cornua. The coccygeal vertebrae do not fuse completely until late in adulthood. In very old persons, the coccyx may fuse with the sacrum.

Checkpoint

17. **Why does the vertebral column of an adult have fewer vertebrae than that of a newborn?**
18. **Joe suffered a hairline fracture at the base of the dens. Which bone is fractured, and where is it located?**
19. **Examining a human vertebra, you notice that, in addition to the large foramen for the spinal cord, two smaller foramina are on either side of the bone in the region of the transverse processes. From which region of the vertebral column is this vertebra?**
20. **Why are the bodies of the lumbar vertebrae so large?**

See the blue Answers tab at the back of the book.

7

7-8 The thoracic cage protects organs in the chest and provides sites for muscle attachment

The skeleton of the chest, or **thoracic cage** (**Figure 7–23**), provides bony support to the walls of the thoracic cavity. It consists of the thoracic vertebrae, the ribs, and the sternum (breastbone). The ribs and the sternum form the *rib cage*, whose movements are important in respiration. The thoracic cage as a whole serves two functions:

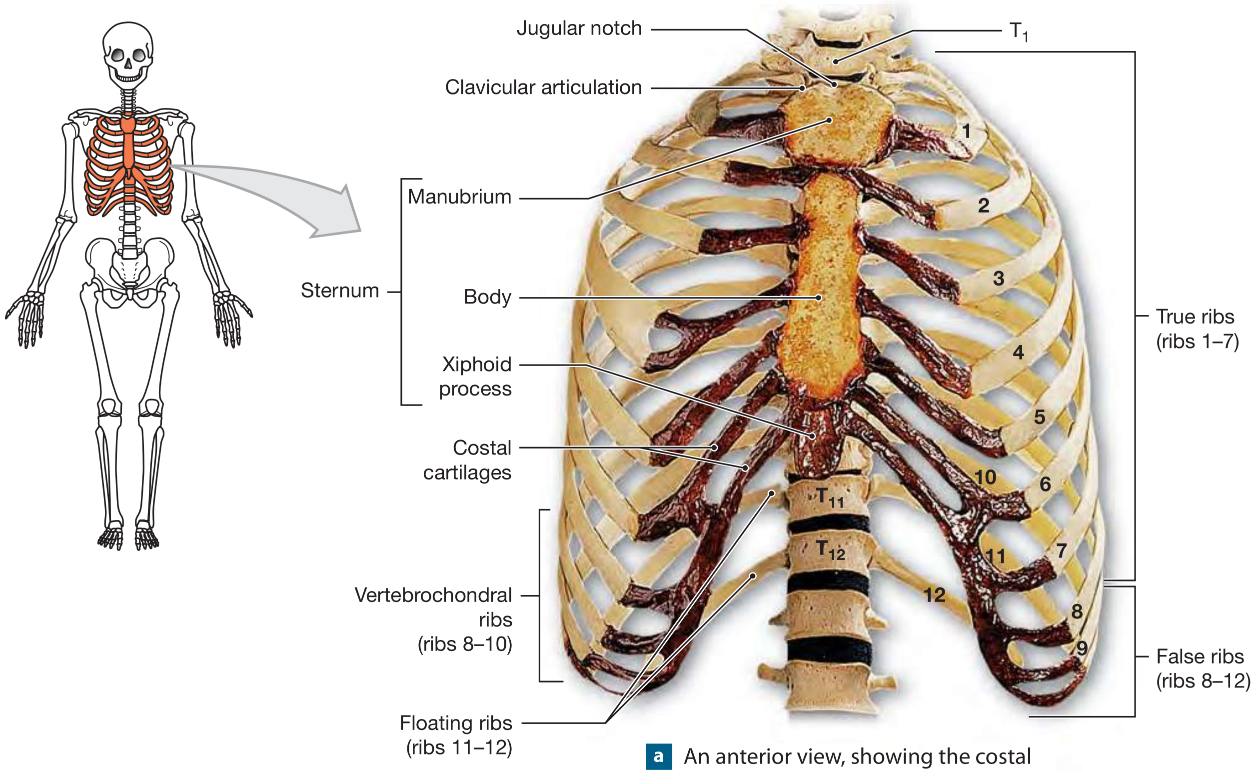
1. It protects the heart, lungs, thymus, and other structures in the thoracic cavity.
2. It serves as an attachment point for muscles involved in (1) respiration, (2) maintenance of the position of the vertebral column, and (3) movements of the pectoral girdle and upper limbs.

The Ribs

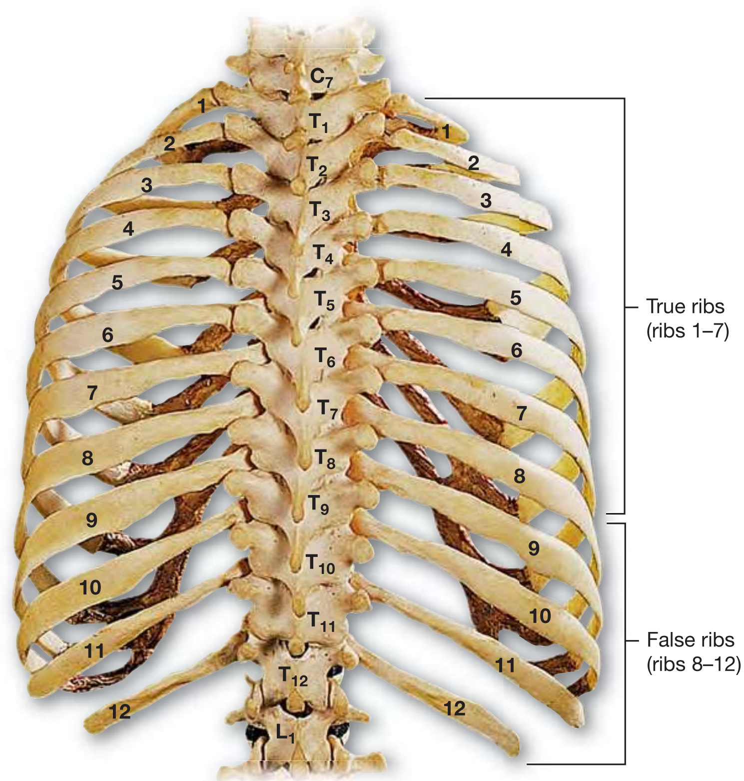
Ribs, or *costae*, are elongate, curved, flattened bones that originate on or between the thoracic vertebrae and end in the wall of the thoracic cavity. Each of us, regardless of sex, has 12 pairs of ribs (**Figure 7–23**). The first seven pairs are called **true ribs,** or *vertebrosternal ribs*. They reach the anterior body wall and are connected to the sternum by separate cartilaginous extensions, the **costal cartilages.** Beginning with the first rib, the vertebrosternal ribs gradually increase in length and in radius of curvature.

Ribs 8–12 are called **false ribs,** because they do not attach directly to the sternum. The costal cartilages of ribs 8–10, the *vertebrochondral ribs*, fuse together and merge with the cartilages of rib pair 7 before they reach the sternum (**Figure 7–23a**). The last two pairs of ribs (11 and 12) are called *floating ribs*, because they have no connection with the sternum, or *vertebral ribs*,

Figure 7–23 **The Thoracic Cage.** ATLAS: Plate 22b



a An anterior view, showing the costal cartilages and the sternum



b A posterior view, showing the articulations of the ribs and vertebrae because they are attached only to the vertebrae (**Figure 7–23b**) and muscles of the body wall.

Figure 7–24a shows the superior surface of a typical rib. The *vertebral end* of the rib articulates with the vertebral column at the **head,** or *capitulum* (ka-PIT-ū-lum). A ridge divides the articular surface of the head into superior and inferior articular facets (**Figure 7–24b**). From the head, a short **neck** leads to the **tubercle,** a small elevation that projects dorsally. The inferior portion of the tubercle contains an articular facet that contacts the transverse process of the thoracic vertebra. Ribs 1 and 10 originate at costal facets on vertebrae T_1 and T_{10}, respectively, and their tubercular facets articulate with the transverse costal facets on those vertebrae. The heads of ribs 2–9 articulate with costal facets on two adjacent vertebrae; their tubercular facets articulate with the transverse costal facets of the inferior member of the vertebral pair. Ribs 11 and 12, which originate at T_{11} and T_{12}, do not have tubercular facets and do not contact the transverse processes of T_{11} or T_{12}. The difference in rib orientation can be seen by comparing **Figure 7–20a** with **Figure 7–23b**.

The bend, or *angle*, of the rib is the site where the tubular **body,** or *shaft*, begins curving toward the sternum. The internal rib surface is concave, and a prominent *costal groove* along its inferior border marks the path of nerves and blood vessels. The superficial surface is convex and provides an attachment site for muscles of the pectoral girdle and trunk. The *intercostal muscles*, which move the ribs, are attached to the superior and inferior surfaces.

With their complex musculature, dual articulations at the vertebrae, and flexible connection to the sternum, the ribs are quite mobile. Note how the ribs curve away from the vertebral column to angle inferiorly (**Figure 7–23**). A typical rib acts like the handle on a bucket, lying just below the horizontal plane. Pushing the handle down forces it inward; pulling it up swings it outward (**Figure 7–24c**). In addition, because of the curvature of the ribs, the same movements change the position of the sternum. Depression of the ribs pulls the sternum inward, whereas elevation moves it outward. As a result, movements of the ribs affect both the width and the depth of the thoracic cage, increasing or decreasing its volume accordingly. The role of these movements in breathing will be discussed further in Chapter 23.

The ribs can bend and move to cushion shocks and absorb hits, but severe or sudden impacts can cause painful rib fractures. Because the ribs are tightly bound in connective tissues, a cracked rib can heal without a cast or splint. But compound fractures of the ribs can send bone splinters or

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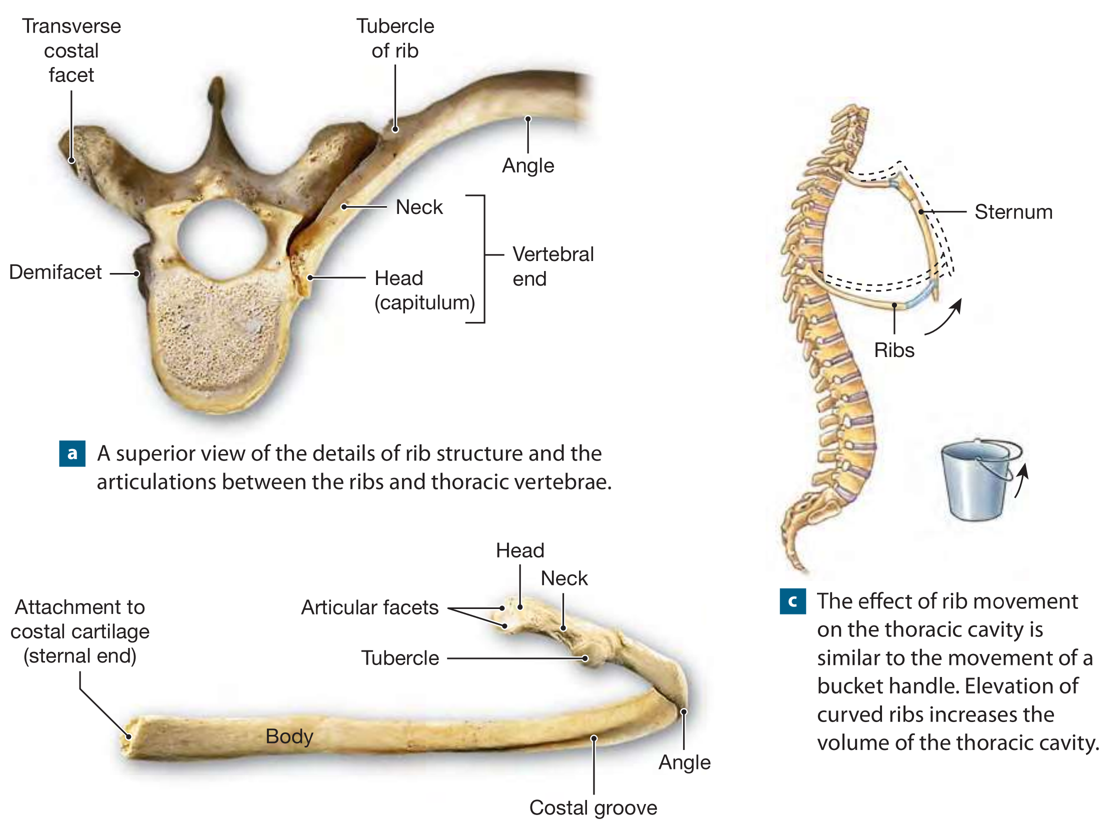
Figure 7–24 The Ribs. ATLAS: Plates 22a,b



a A superior view of the details of rib structure and the articulations between the ribs and thoracic vertebrae.

b A posterior view of the head of a representative rib from the right side (ribs 2–9).

c The effect of rib movement on the thoracic cavity is similar to the movement of a bucket handle. Elevation of curved ribs increases the volume of the thoracic cavity.

fragments into the thoracic cavity, with potential damage to internal organs.

Surgery on the heart, lungs, or other organs in the thorax typically involves entering the thoracic cavity. The mobility of the ribs and the cartilaginous connections with the sternum allow the ribs to be temporarily moved out of the way. "Rib spreaders" are used to push the ribs apart in much the same way that a jack lifts a car off the ground for a tire change. If more extensive access is required, the cartilages of the sternum can be cut and the entire sternum folded out of the way. Once the sternum is replaced, scar tissue reunites the cartilages, and the ribs heal fairly rapidly.

The Sternum

The adult **sternum,** or breastbone, is a flat bone that forms in the anterior midline of the thoracic wall (**Figure 7–23a**). The sternum has three components:

1. The broad, triangular **manubrium** (ma-NOO-brē-um) articulates with the *clavicles* (collarbones) and the cartilages of the first pair of ribs. The manubrium is the widest and most superior portion of the sternum. Only the first pair of ribs is attached by cartilage to this portion of the sternum. The **jugular notch,** located between the clavicular articulations, is a shallow indentation on the superior surface of the manubrium.
2. The tongue-shaped **body** attaches to the inferior surface of the manubrium and extends inferiorly along the midline. Individual costal cartilages from rib pairs 2–7 are attached to this portion of the sternum.
3. The **xiphoid** (ZI-foyd) **process,** the smallest part of the sternum, is attached to the inferior surface of the body. The muscular *diaphragm* and *rectus abdominis muscles* attach to the xiphoid process. Ossification of the sternum begins at 6 to 10 ossification centers, and fusion is not complete until at least age 25. Before that age, the sternal body consists of four separate bones. In adults, their boundaries appear as a series of transverse lines crossing the sternum. The xiphoid process is generally the last part to ossify and fuse. Its connection to the sternal body can be broken by impact or by strong pressure, creating a spear of bone that can severely damage the liver. The xiphoid process is used as a palpable landmark during the administration of cardiopulmonary resuscitation (CPR), and CPR training strongly emphasizes proper hand positioning to reduce the chances of breaking ribs or the xiphoid process.

Checkpoint

21. **How are true ribs distinguished from false ribs?**
22. **Improper administration of cardiopulmonary resuscitation (CPR) can result in a fracture of which bones?**
23. **What are the main differences between vertebrosternal ribs and vertebrochondral ribs?**

See the blue Answers tab at the back of the book.

Related Clinical Terms

craniotomy: The surgical removal of a section of bone (bone flap) from the skull for the purpose of operating on the underlying tissues.

deviated nasal septum: A bent nasal septum (cartilaginous structure dividing the left and right nasal cavities) that slows or prevents sinus drainage.

herniated disc: A disc (fibrocartilaginous pad) that slips out of place or ruptures; if it presses on a nerve, it can cause back pain or sciatica.

laminectomy: A surgical operation to remove the posterior vertebral arch on a vertebra, usually to give access to the spinal cord or to relieve pressure on nerves.

sinusitis: Inflammation and congestion of the sinuses (air-filled cavities in the skull).

spina bifida: A condition resulting from the failure of the vertebral laminae to unite during development; commonly associated with developmental abnormalities of the brain and spinal cord.

spinal fusion: A surgical procedure that stabilizes the spine by joining together (fusing) two or more vertebrae using bone grafts, metal rods, or screws.

Chapter Review

Study Outline

7-1 ◗ The 80 bones of the head and trunk make up the axial skeleton p. 198

1. The skeletal system consists of the **axial skeleton** and the appendicular skeleton. The axial skeleton can be divided into the **skull,** the **auditory ossicles** and **hyoid bone,** the **vertebral column,** and the **thoracic cage.** *(Figure 7–1)*
2. The **appendicular skeleton** includes the pectoral and pelvic girdles, which support the upper and lower limbs.

7-2 ◗ The skull is composed of 8 cranial bones and 14 facial bones p. 198

3. The **skull** consists of the **cranium** and the bones of the face. The cranium, composed of **cranial bones,** encloses the **cranial cavity.** The **facial bones** protect and support the entrances to the digestive and respiratory tracts. *(Figure 7–2)*
4. Prominent superficial landmarks on the skull include the **lambdoid, coronal, sagittal,** and **squamous sutures.** *(Figure 7–3)*
5. The bones of the cranium are the **occipital bone,** the two **parietal bones,** the **frontal bone,** the two **temporal bones,** the **sphenoid,** and the **ethmoid.** *(Figures 7–2 to 7–9)*
6. The occipital bone surrounds the **foramen magnum.** *(Figures 7–3 to 7–5)*
7. The frontal bone contains the **frontal sinuses.** *(Figures 7–4, 7–6)*
8. The **auditory ossicles** are located in a cavity within the temporal bone. *(Figure 7–7)*
9. The bones of the face are the **maxillae,** the **palatine bones,** the **nasal bones,** the **vomer,** the **inferior nasal conchae,** the **zygomatic bones,** the **lacrimal bones,** and the **mandible.** *(Figures 7–2 to 7–4, 7–10 to 7–12)*
10. The left and right maxillae, or *maxillary bones*, are the largest facial bones; they form the upper jaw and most of the **hard palate.** *(Figures 7–3, 7–4, 7–10)*
11. The palatine bones are small L-shaped bones that form the posterior portions of the hard palate and contribute to the floor of the orbital cavities. *(Figures 7–3, 7–4, 7–10)*
12. The paired nasal bones extend to the superior border of the **external nares.** *(Figures 7–3, 7–4, 7–11)*
13. The vomer forms the inferior portion of the **nasal septum.** *(Figures 7–3, 7–4, 7–11)*
14. The **temporal process** of the zygomatic bone articulates with the **zygomatic process** of the temporal bone to form the **zygomatic arch.** *(Figures 7–3, 7–7, 7–11)*
15. The paired lacrimal bones, the smallest bones of the face, are situated medially in each **orbit.** *(Figures 7–3, 7–11)*
16. The mandible is the bone of the lower jaw. *(Figures 7–3, 7–4, 7–12)*
17. The **hyoid bone,** suspended by *stylohyoid ligaments*, supports the larynx. *(Figure 7–12)*

7-3 ◗ Foramina and fissures of the skull serve as passageways for nerves and vessels p. 212

18. The foramina and fissures of the adult skull are summarized in *Table 7–1*.

7-4 ◗ Each orbital complex contains an eye, and the nasal complex encloses the nasal cavities p. 214

19. Seven bones form each **orbital complex.** *(Figure 7–13)*
20. The **nasal complex** includes the bones that enclose the nasal cavities and the **paranasal sinuses,** hollow airways that connect with the nasal passages. *(Figure 7–14)*

7-5 ◗ Fontanelles are non-ossified fibrous areas between cranial bones that allow for brain growth p. 215

21. Fibrous connective tissue **fontanelles** permit the skulls of infants and children to continue growing after birth. *(Figure 7–15)*

7-6 ◗ The vertebral column has four spinal curves p. 217

22. The **vertebral column** consists of the vertebrae, sacrum, and coccyx. We have 7 **cervical vertebrae** (the first articulates with the skull), 12 **thoracic vertebrae** (which articulate with the ribs), and 5 **lumbar vertebrae** (the last articulates with the sacrum). The **sacrum** and **coccyx** consist of fused vertebrae. *(Figure 7–16)*
23. The spinal column has four **spinal curves.** The **thoracic** and **sacral curves** are called **primary** or **accommodation curves;** the **lumbar** and **cervical curves** are known as **secondary** or **compensation curves.** *(Figure 7–16)*
24. A typical vertebra has a **vertebral body** and a **vertebral arch,** and articulates with adjacent vertebrae at the **superior** and **inferior articular processes.** *(Figure 7–18)*
25. **Intervertebral discs** separate adjacent vertebrae. Spaces between successive **pedicles** form the **intervertebral foramina**. *(Figure 7–18)*

7-7 ◗ The five vertebral regions are the cervical, thoracic, lumbar, sacral, and coccygeal p. 220

26. Cervical vertebrae are distinguished by the shape of the body, the relative size of the vertebral foramen, the presence of **costal processes** with **transverse foramina,** and notched **spinous processes.** These vertebrae include the **atlas, axis,** and **vertebra prominens.** *(Figure 7–19; Table 7–2)*
27. Thoracic vertebrae have a distinctive heart-shaped body; long, slender spinous processes; and articulations for the ribs. *(Figures 7–20, 7–23; Table 7–2)*
28. The lumbar vertebrae are the most massive and least mobile of the vertebrae; they are subjected to the greatest strains. *(Figure 7–21; Table 7–2)*
29. The sacrum protects reproductive, digestive, and urinary organs and articulates with the pelvic girdle and with the fused elements of the coccyx. *(Figure 7–22)*

7-8 ◗ The thoracic cage protects organs in the chest and provides sites for muscle attachment p. 225

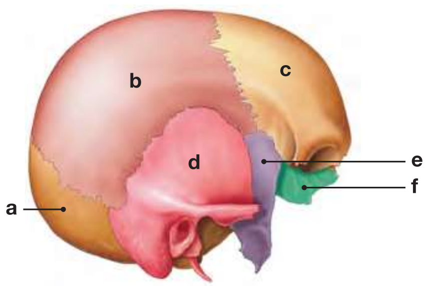
30. The skeleton of the **thoracic cage** consists of the thoracic vertebrae, the ribs, and the sternum. The **ribs** and **sternum** form the *rib cage*. *(Figure 7–23)*
31. Ribs 1–7 are **true ribs,** or *vertebrosternal ribs*. Ribs 8–12 are called **false ribs;** they include the *vertebrochondral ribs* (ribs 8–10) and two pairs of *floating (vertebral) ribs* (ribs 11–12). A typical rib has a **head,** or *capitulum*; a **neck;** a **tubercle;** an *angle*; and a **body,** or *shaft*. A *costal groove* marks the path of nerves and blood vessels. *(Figures 7–23, 7–24)*
32. The sternum consists of the **manubrium, body,** and **xiphoid process.** *(Figure 7–23)*

Review Questions

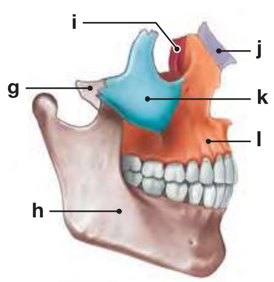
See the blue Answers tab at the back of the book.

LEVEL 1 Reviewing Facts and Terms

1. Identify the cranial and facial bones in the diagram below.



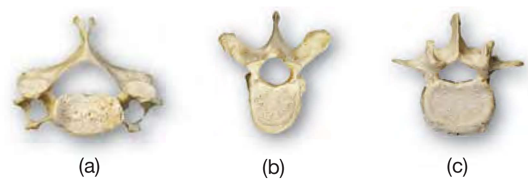
Cranial bones



Facial bones

(a) ______________________________
(b) ______________________________
(c) ______________________________
(d) ______________________________
(e) ______________________________
(f) ______________________________
(g) ______________________________
(h) ______________________________
(i) ______________________________
(j) ______________________________
(k) ______________________________
(l) ______________________________

2. Which of the following lists contains *only* facial bones?
   (a) mandible, maxilla, nasal, zygomatic
   (b) frontal, occipital, zygomatic, parietal
   (c) occipital, sphenoid, temporal, lacrimal
   (d) frontal, parietal, occipital, sphenoid
3. The unpaired facial bones include the
   (a) lacrimal and nasal.
   (b) vomer and mandible.
   (c) maxilla and mandible.
   (d) zygomatic and palatine.
4. The boundaries between skull bones are immovable joints called
   (a) foramina.
   (b) fontanelles.
   (c) lacunae.
   (d) sutures.
5. The joint between the frontal and parietal bones is correctly called the __________ suture.
   (a) parietal
   (b) lambdoid
   (c) squamous
   (d) coronal
6. Blood vessels that drain blood from the head pass through the
   (a) jugular foramina.
   (b) hypoglossal canals.
   (c) stylomastoid foramina.
   (d) mental foramina.
   (e) lateral canals.
7. For each of the following vertebrae, indicate its vertebral region.



   (a) ______________________________
   (b) ______________________________
   (c) ______________________________
8. Cervical vertebrae can usually be distinguished from other vertebrae by the presence of
   (a) transverse processes.
   (b) transverse foramina.
   (c) demifacets on the centrum.
   (d) the vertebra prominens.
   (e) large spinous processes.
9. The side walls of the vertebral foramen are formed by the
   (a) centrum of the vertebra.
   (b) spinous process.
   (c) pedicles.
   (d) laminae.
   (e) transverse processes.
10. The part of the vertebra that transfers weight along the axis of the vertebral column is the
   (a) vertebral arch.
   (b) lamina.
   (c) pedicles.
   (d) body.
11. Which eight bones make up the cranium?
12. What seven bones constitute the orbital complex?
13. What is the primary function of the vomer?
14. In addition to the spinal curves, what skeletal element contributes to the flexibility of the vertebral column?

LEVEL 2 Reviewing Concepts

15. What is the relationship between the temporal bone and the ear?
16. What is the relationship between the ethmoid and the nasal cavity?
17. Describe how ribs function in breathing.

18. Why is it important to keep your back straight when you lift a heavy object?
19. The atlas (C_1) can be distinguished from the other vertebrae by
    (a) the presence of anterior and posterior vertebral arches.
    (b) the lack of a body.
    (c) the presence of superior facets and inferior articular facets.
    (d) all of these.
20. What purpose do the fontanelles serve during birth?
21. The secondary spinal curves
    (a) help position the body weight over the legs.
    (b) accommodate the thoracic and abdominopelvic viscera.
    (c) include the thoracic curvature.
    (d) do all of these.
    (e) do only a and c.
22. When you rotate your head to look to one side,
    (a) the atlas rotates on the occipital condyles.
    (b) C_1 and C_2 rotate on the other cervical vertebrae.
    (c) the atlas rotates on the dens of the axis.
    (d) the skull rotates the atlas.
    (e) all cervical vertebrae rotate.
23. Improper administration of CPR (cardiopulmonary resuscitation) can force the ___________ into the liver.
    (a) floating ribs
    (b) lumbar vertebrae
    (c) manubrium of the sternum
    (d) costal cartilage
    (e) xiphoid process

LEVEL 3 Critical Thinking and Clinical Applications

24. Jane has an upper respiratory infection and begins to feel pain in her teeth. This is a good indication that the infection is located in the
    (a) frontal sinuses.
    (b) sphenoid bone.
    (c) temporal bone.
    (d) maxillary sinuses.
    (e) zygomatic bones.
25. While working at an excavation, an archaeologist finds several small skull bones. She examines the frontal, parietal, and occipital bones and concludes that the skulls are those of children not yet 1 year old. How can she tell their ages from an examination of these bones?
26. Mary is in her last month of pregnancy and is suffering from lower back pains. Since she is carrying excess weight in front of her, she wonders why her back hurts. What would you tell her?

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