EXPLORATIONS: AN OPEN INVITATION TO BIOLOGICAL ANTHROPOLOGY, 2ND EDITION

BETH SHOOK, PH.D.; LARA BRAFF, PH.D.; KATIE NELSON, PH.D.; AND KELSIE AGUILERA, M.A.

American Anthropological Association
Arlington

Explorations: An Open Invitation to Biological Anthropology, 2nd Edition Copyright © 2023 by Beth Shook, Ph.D.; Lara Braff, Ph.D.; Katie Nelson, Ph.D.; and Kelsie Aguilera, M.A. is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, except where otherwise noted.

(CC BY-NC 4.0) Except where otherwise noted, content in Explorations: An Open Invitation to Biological Anthropology is licensed under a Creative Commons Attribution-Noncommercial 4.0 International license.

Disclaimer: The ebook version of this edition adheres to the strictest accessible standards and should be considered the final version of the book. While this PDF document is available to users, we recommend users connect with their institutions for a full accessibility review prior to student distribution.

Appendix A

Jason M. Organ, Ph.D., Indiana University School of Medicine
Jessica N. Byram, Ph.D., Indiana University School of Medicine

This chapter is a revision from "Appendix A: Osteology" by Jason M. Organ and Jessica N. Byram. In Explorations: An Open Invitation to Biological Anthropology, first edition, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff, which is licensed under CC BY-NC 4.0.

Learning Objectives

- Identify anatomical position and anatomical planes, and use directional terms to describe relative positions of bones and teeth.
- Describe the different regions of the human skeleton and identify (by name) all of the bones within them.
- Distinguish major bony features of the human skeleton like muscle attachment sites and passages for nerves and/or arteries and veins.
- Identify the bony features relevant to estimating age and sex in forensic and bioarchaeological contexts.

Introduction to Osteology

Osteology, or the study of bones, is central to biological anthropology because every person's skeleton tells a story of how that person has lived. Bones from archaeological sites can be used to understand what animals people ate, how stressful and strenuous their lives were, and how they died—by natural or unnatural causes. This appendix introduces the basics of anatomical terminology and describes the different regions and bones of the skeleton. It also highlights some skeletal features that are used frequently by forensic anthropologists to estimate the age and sex of recovered remains. The authors note that sex is not binary but exists on a spectrum based on influences of chromosomes, genes, and hormones. These biological influences affect the size and shape of bone, which is sometimes useful in classifying skeletal remains into one of the two most common sex categories: female and male.

Bone Structure and Function

Bone is a composite of organic collagen and an inorganic mineral (hydroxyapatite, a calcium phosphate salt), which help make it strong enough to support the body under the force of gravity without collapsing. When bone is mature (fully mineralized as in adults), it comprises an outer dense region of bone called **cortical (or compact) bone** and an inner spongy region of bone called **cancellous (or trabecular) bone** (Figure A.1).

Bone performs both metabolic and mechanical functions for the body. On the metabolic side, bone is required to maintain mineral (i.e., calcium) homeostasis and for the production of red and white blood cells (Figure A.2), which develop in the diaphyseal marrow cavity and the cancellous region of the metaphysis and epiphysis. But it is undeniable that the mechanical functions of bone are primary because bone is critically responsible for protecting internal organs, providing support against the force of gravity, and serving as a network of rigid levers for muscles to act upon during movement.

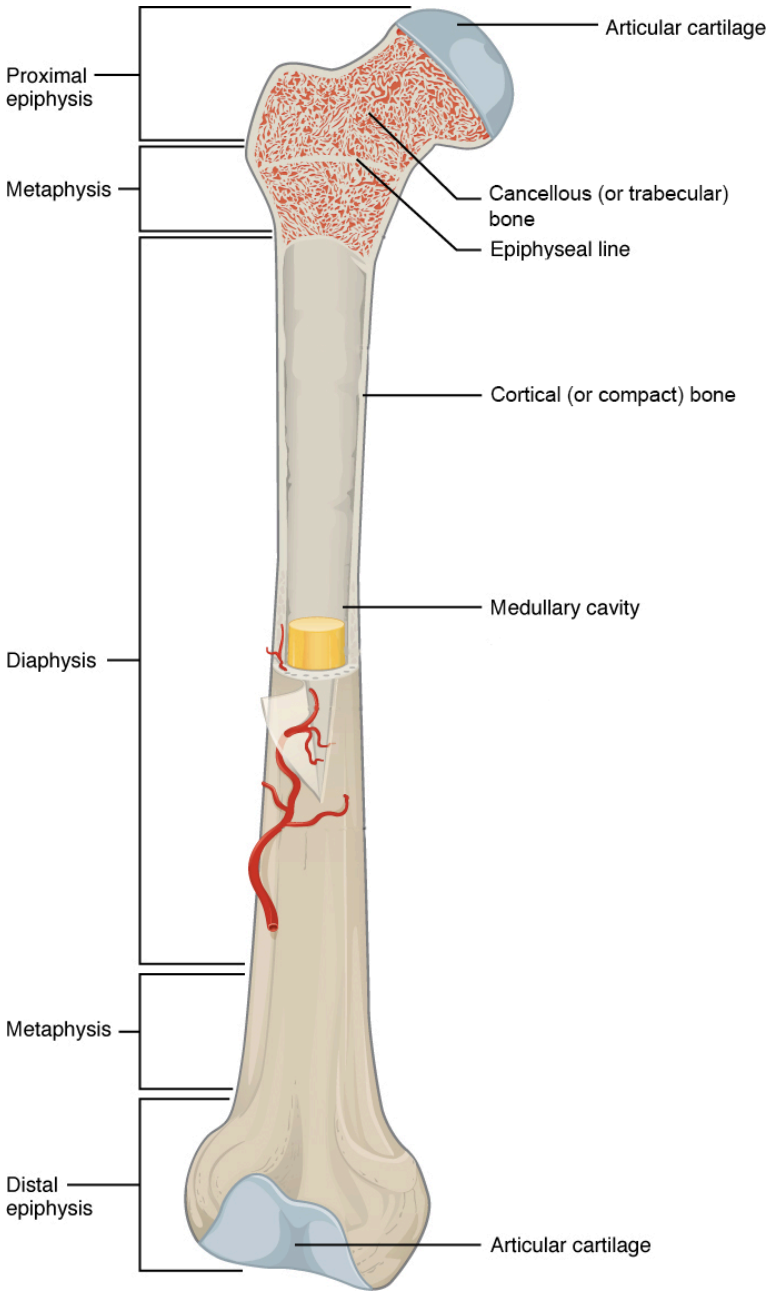

Figure A.1: A typical long bone shows the gross anatomical characteristics of bone. A full text description of this image is available. Credit: Anatomy of a Long Bone (Anatomy & Physiology, Figure 6.7) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Bone Shape

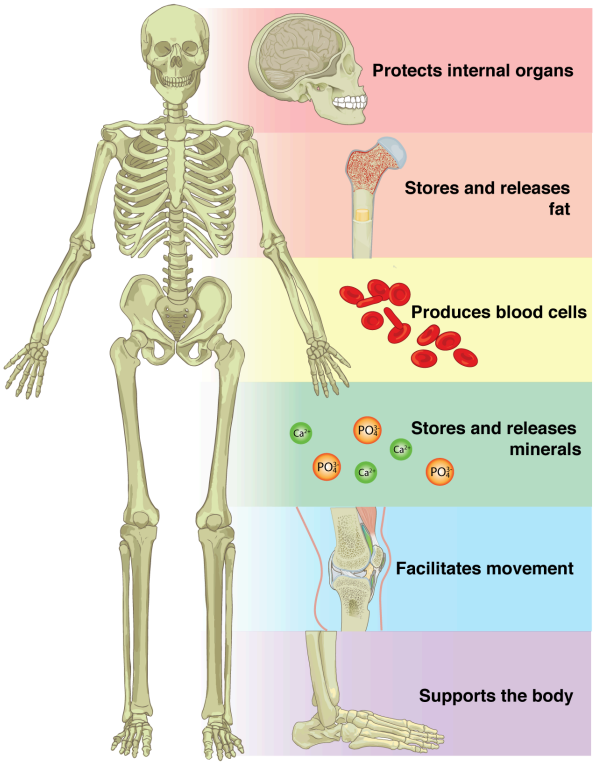

Figure A.2: Functions of the skeletal system include support and protection, storage and release of fat, production of red blood cells, storage and release of calcium and phosphates, and facilitating movement. A full text description of this image is available. Credit: Functions of the Skeletal System (Anatomy & Physiology, Figure 6.1.1) by Open Oregon State is under a CC BY 4.0 License.

Bones have different shapes that largely relate to their specific function within the skeletal system. Additionally, the ratio of cortical to cancellous bone, and which muscles are attached to the bone and how, affect the shape of the whole bone. Generally there are five recognized bone shapes: long bones, short bones, flat bones, sesamoid bones, and irregular bones. **Long bones** are longer than they are wide and consist of three sections: diaphysis, epiphysis, and metaphysis (see Figure A.1). The **diaphysis** of a long bone is simply the shaft of the bone, and it comprises mostly cortical bone with a thin veneer of internal cancellous bone lining a **medullary cavity**. At both the proximal and distal ends of every long bone, there is an **epiphysis**, which consists of a thin shell of cortical bone surrounding a high concentration of cancellous bone. The epiphysis is usually coated with cartilage to facilitate joint articulation with other bones. The junction between diaphysis and epiphysis is the **metaphysis**, which has a more equal ratio of cortical to cancellous bone. Examples of long bones are the humerus, the femur, and the metacarpals and metatarsals.

The other three bone shapes are simpler. **Short bones** are defined as being equal in length and width, and they possess a mix of cortical and cancellous bone (Figure A.3). They are usually involved in forming movable joints with adjacent bones and therefore often have surfaces covered with cartilage. Examples of short bones are the carpals of the wrist and the tarsals of the ankle. **Flat bones** are flat and consist of two layers of thick cortical bone with an intermediate layer of cancellous bone referred to as diploë. Most of the bones of the skull are flat bones, such as the frontal and parietal bones, as well as all parts of the sternum (Figure A.3). Sometimes bones develop within the tendon of a muscle in order to reduce friction on the joint surface and to increase leverage of the muscle to move a joint. These types of bones are called **sesamoid bones**, and these include the patella (or knee cap) and the pisiform (a bone of the wrist). **Irregular bones** are bones that don't fit into any of the other four categories. The shapes of these bones are often more complex than the others, and examples include the vertebrae and certain bones of the skull, like the ethmoid and sphenoid bones (Figure A.3).

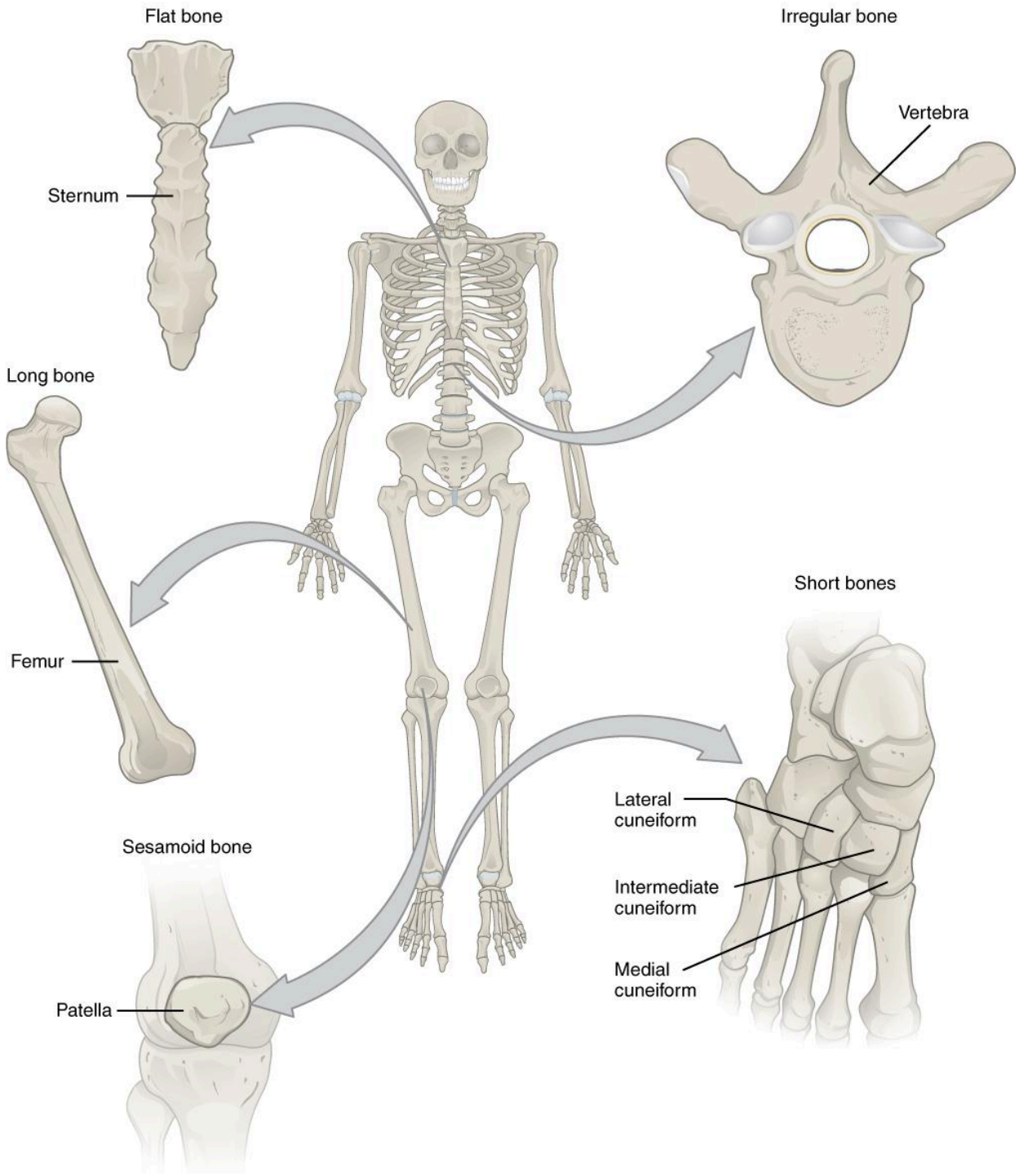

Figure A.3: Bones are classified according to their shape and include long, short, flat, sesamoid, and irregular bones. A full text description of this image is available. Credit: Classifications of Bones (Anatomy & Physiology, Figure 6.6) by OpenStax is under a CC BY 4.0 License.

Dig Deeper: Bone Functional Adaptation

Each time we move our muscles, we bend, twist, compress, and tense our bones, and this causes them to develop microscopic cracks that weaken them. These may even lead to a bone fracture. Bone cells called **osteocytes** can sense when these microcracks form. Osteocytes then signal **osteoclasts** to remove the cracked bone and **osteoblasts** to lay down new bone—a process known as skeletal remodeling. **Osteogenic cells** are stem cells that are able to differentiate into osteoblasts and osteocytes (Figure A.4).

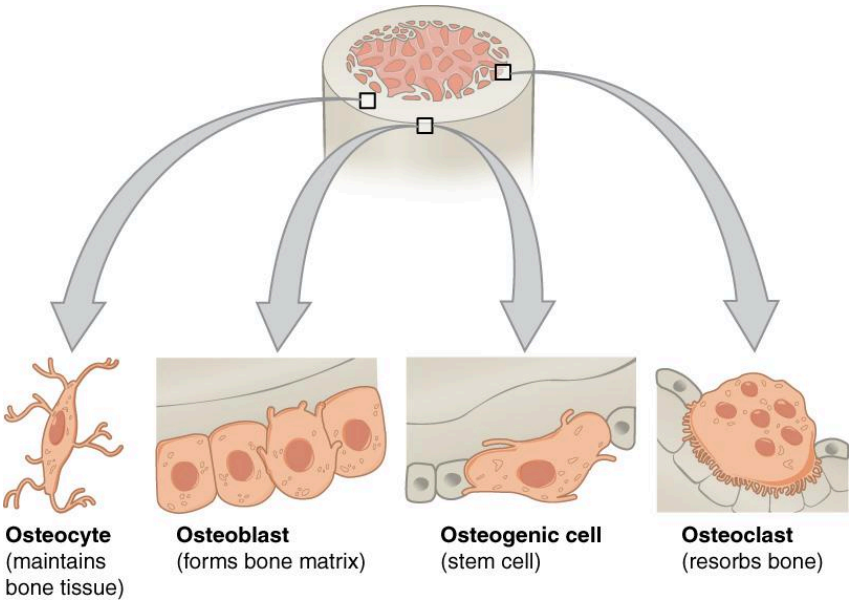

Figure A.4: Four types of cells are found within bone tissue. Osteogenic cells are stem cells that develop into osteoblasts. Osteoblasts lay down new bone while osteoclasts remove bone. Osteoblasts that get trapped in calcified matrix become osteocytes. A full text description of this image is available. Credit: Bone Cells (Anatomy & Physiology, Figure 6.11) by OpenStax is under a CC BY 4.0 License.

Did Deeper: How Do Bones Develop?

Bones develop via one of two mechanisms: intramembranous or endochondral bone formation. During **intramembranous bone formation** connective tissue (mesenchymal) stem cells form a tissue layer and then differentiate into osteoblasts, which begin to synthesize new bone along the tissue layer (Figure A.5). Only a few bones develop through intramembranous bone formation, mostly bones of the skull and the clavicle (collar bone). In **endochondral bone formation**, instead of developing directly from connective tissue stem cells, osteoblasts develop from an intermediate cartilage "model" that is then replaced by synthesized new bone (Figure A.6). Most bones of the skeleton develop through endochondral bone formation (Burr and Organ 2017).

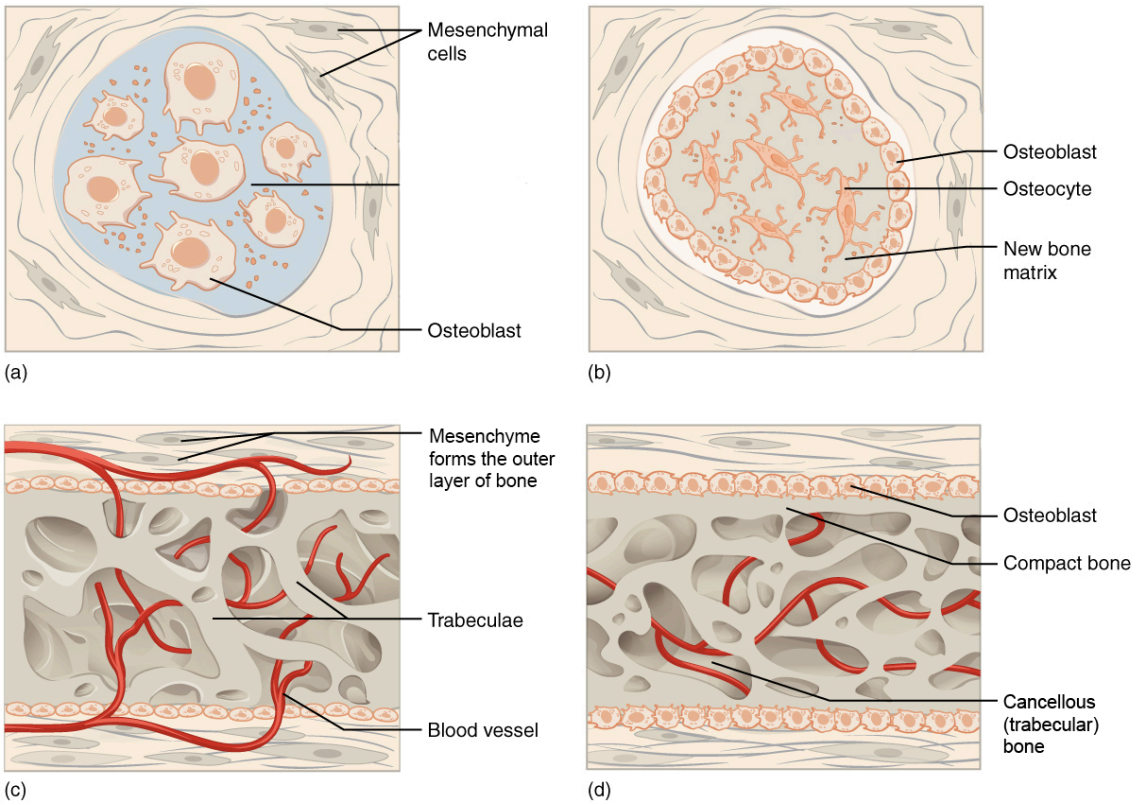

Figure A.5: Intramembranous ossification begins when mesenchymal stem cells group into clusters. These clusters contain osteoblasts, which lay down the initial trabecular bone. Compact bone develops superficial to the trabecular bone, and the initial structure of the bone is complete. A full text description of this image is available. Credit: Intramembranous Ossification (Anatomy & Physiology, Figure 6.16) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

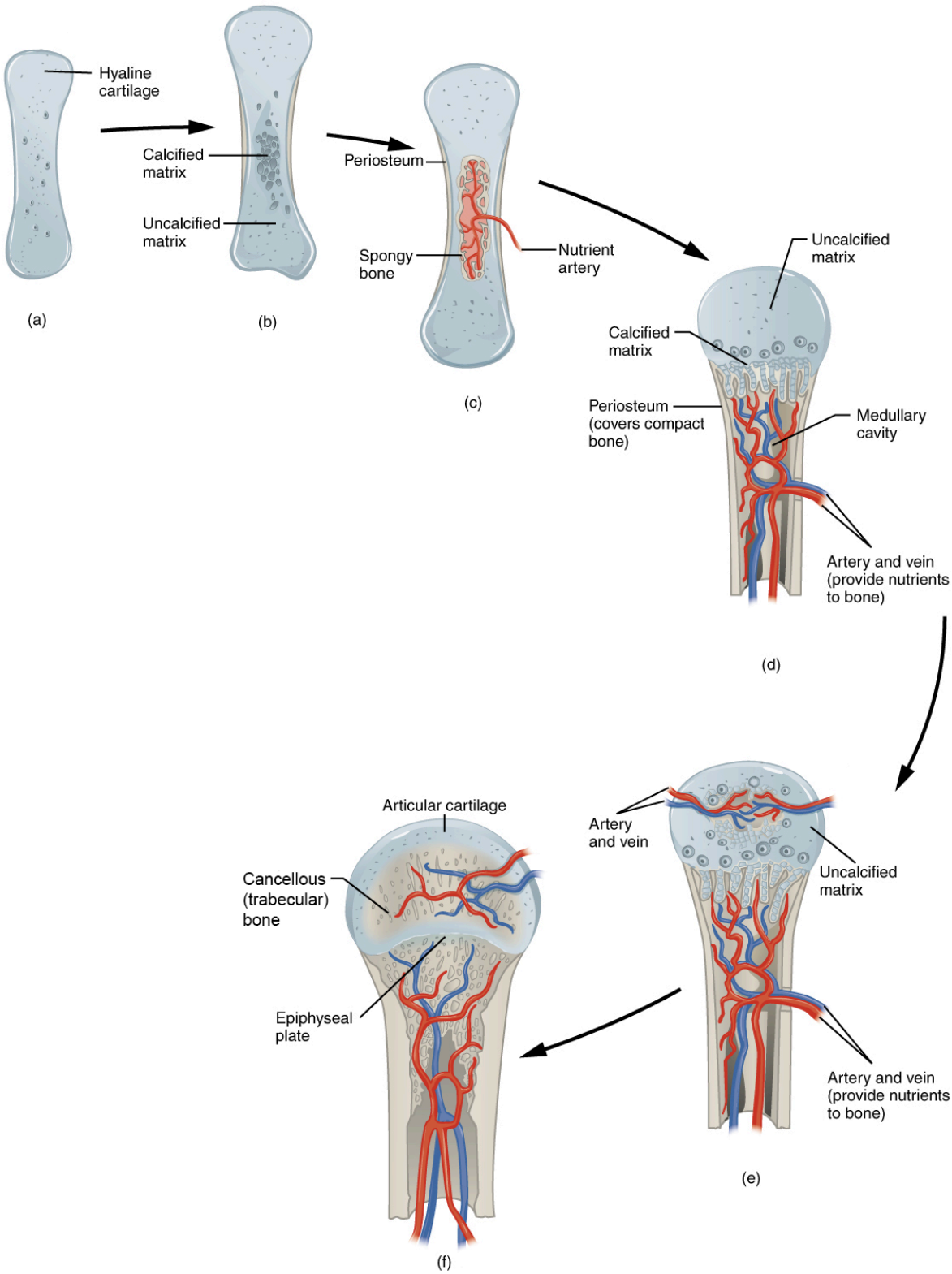

Figure A.6: Endochondral ossification begins when mesenchymal cells differentiate into cartilage cells, which lay down a cartilage model of the

future bony skeleton. Cartilage is then replaced by bone, except at the (epiphyseal) growth plates (which fuse at the end of postnatal growth) and the hyaline (articular) cartilage on the joint surface. A full text description of this image is available. Credit: Endochondral Ossification (Anatomy & Physiology, Figure 6.17) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Anatomical Terminology

Anatomical Planes

A body in **anatomical position** is situated as if the individual is standing upright; with head, eyes, and feet pointing forward; and with arms at the side and palms facing forward. In anatomical position, the bones of the forearm are not crossed (Figure A.7).

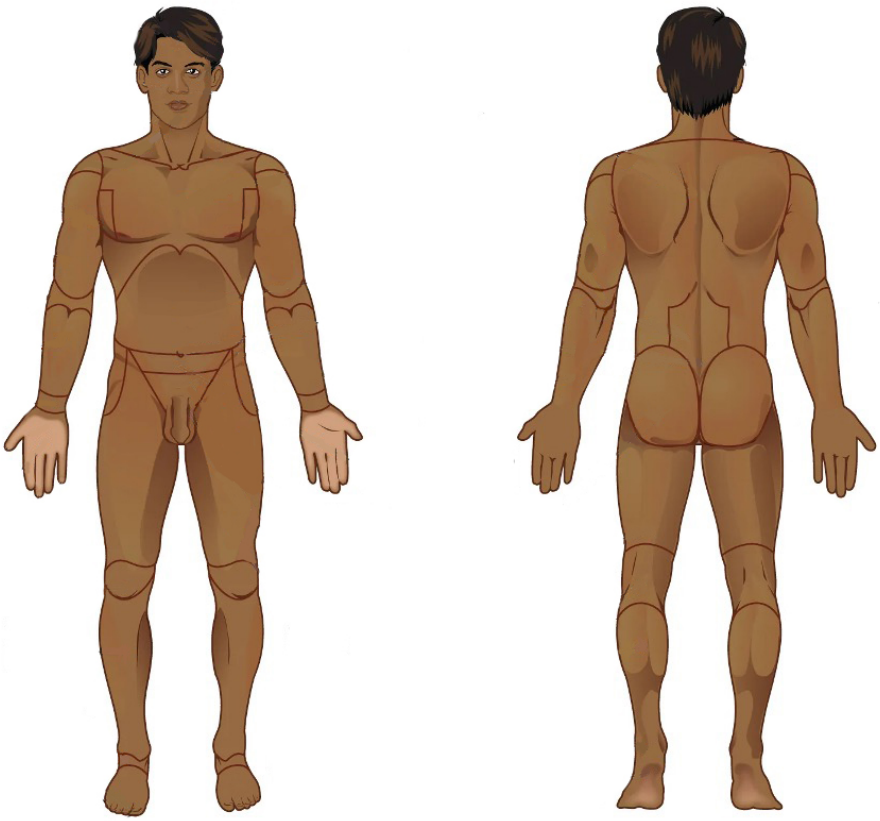

Figure A.7: A human body is shown in anatomical position in an (left) anterior view and a (right) posterior view. A full text description of this image is available. Credit: Regions of the Human Body (Anatomy & Physiology, Figure 1.12) by OpenStax has been modified (labels removed) and is under a CC BY 4.0 License.

In anatomical position, specific organs are situated within specific anatomical planes (Figure A.8). These imaginary planes divide the body into equal or subequal halves, depending on which plane is described. **Coronal (frontal) planes** divide the body vertically into anterior (front) and posterior (back) halves. **Transverse planes** divide the body horizontally into superior (upper) and inferior (lower) halves. **Sagittal planes** divide the body vertically into left and right halves. The plane that divides the body vertically into equal left and right halves is called the **midsagittal plane**. The midsagittal plane is also called the median plane because it is in the midline of the body. Every other sagittal plane divides the body into unequal right and left halves; these planes are called **parasagittal planes**.

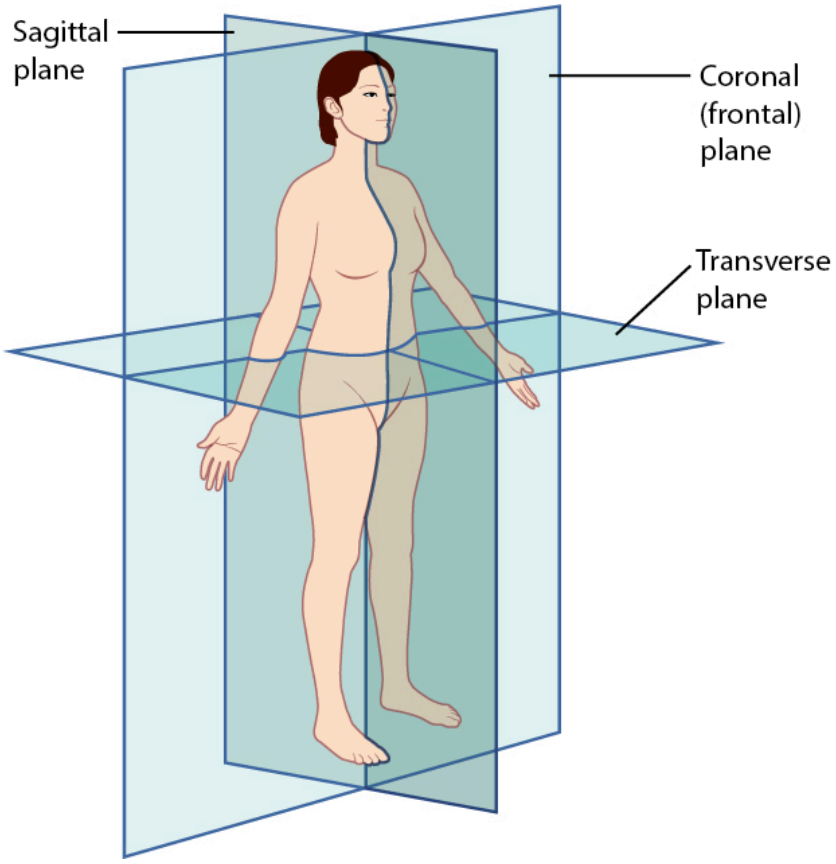

Figure A.8: The three planes most commonly used in anatomical and medical imaging are the sagittal, coronal (or frontal), and transverse planes. A full text description of this image is available. A full text description of this image is available. Credit: Planes of the Body (Anatomy & Physiology, Figure 1.14) by OpenStax has been modified (some labels modified) and is under a CC BY 4.0 License.

Directional Terms

An anatomical feature that is **anterior (or ventral)** is located toward the front of the body, and a bone that is **posterior (or dorsal)** is located toward the back of the body (Figure A.9). For example, the sternum (breastbone) is anterior to the vertebral column ("backbone"). A feature that is **medial** is located closer to the midline (midsagittal plane) than a feature that is **lateral**, or located further from the midline. For example, the thumb is lateral to the index finger. A structure that is **proximal** is closer to the trunk of the body (usually referring to limb bones) than a **distal** structure, which is further from the trunk of the body. For example, the femur (thigh bone) is proximal to the tibia (leg bone). Finally, a structure that is **superior (or cranial)** is located closer to the head than a structure that is **inferior (or caudal)**. For example, the rib cage is superior to the pelvis, and the foot is inferior to the knee.

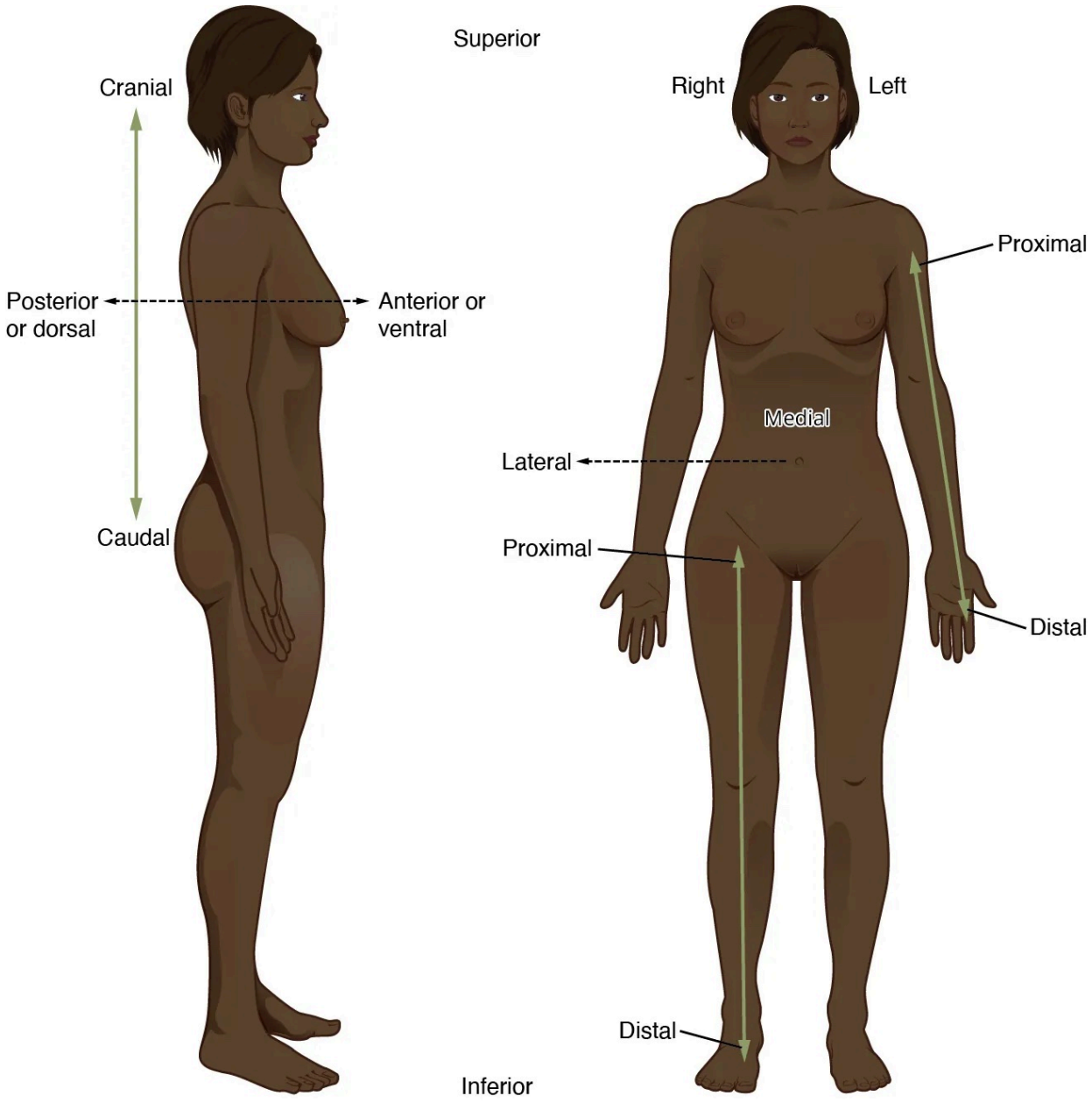

Figure A.9: Paired directional terms are shown as applied to a human body. A full text description of this image is available. Credit: Directional Terms Applied to the Human Body (Anatomy & Physiology, Figure 1.13) by OpenStax is under a CC BY 4.0 License.

Human Skeletal System

The skeletal system is divided into two regions: axial and appendicular (Figure A.10). The **axial skeleton** consists of the skull, vertebral column, and the thoracic cage formed by the ribs and sternum (breastbone). The **appendicular skeleton** comprises the pectoral girdle, the pelvic girdle, and all the bones of the upper and lower limbs.

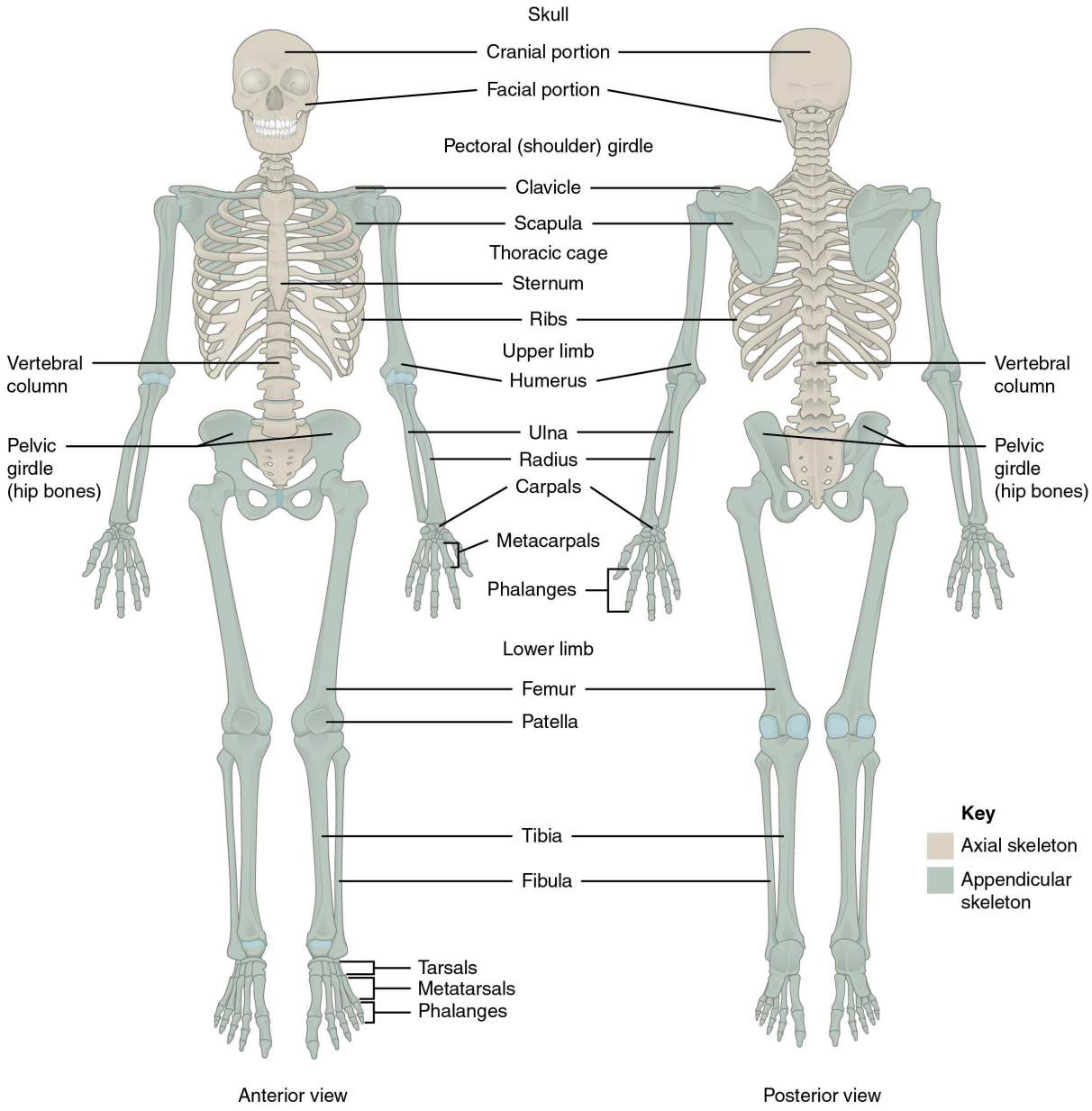

Figure A.10: The axial skeleton consists of the skull, vertebral column, and the thoracic cage. The appendicular skeleton is made up of all bones of the upper and lower limbs. A full text description of this image is available. Credit: Axial and Appendicular Skeleton (Anatomy & Physiology, Figure 7.2) by OpenStax is under a CC BY 4.0 License.

Axial Skeleton

Skull

The skull comprises numerous bones (some paired and others that are unpaired) and is divided into two major portions: the **mandible** (or lower jaw) and the **cranium** (the remainder of the skull). The cranium is further subdivided into the **neurocranium** (or cranial vault), which houses the brain, and the **viscerocranium** (or facial skeleton; Figure A.11), which houses the organs responsible for special senses like sight, smell, taste, hearing, and balance.

Where two bones of the cranium come together, they form articulations called **cranial sutures**, which fuse (or close) with increasing age. Degree of suture closure can be used to broadly estimate age at death (Boldsen et al. 2002; Meindl and Lovejoy 1985).

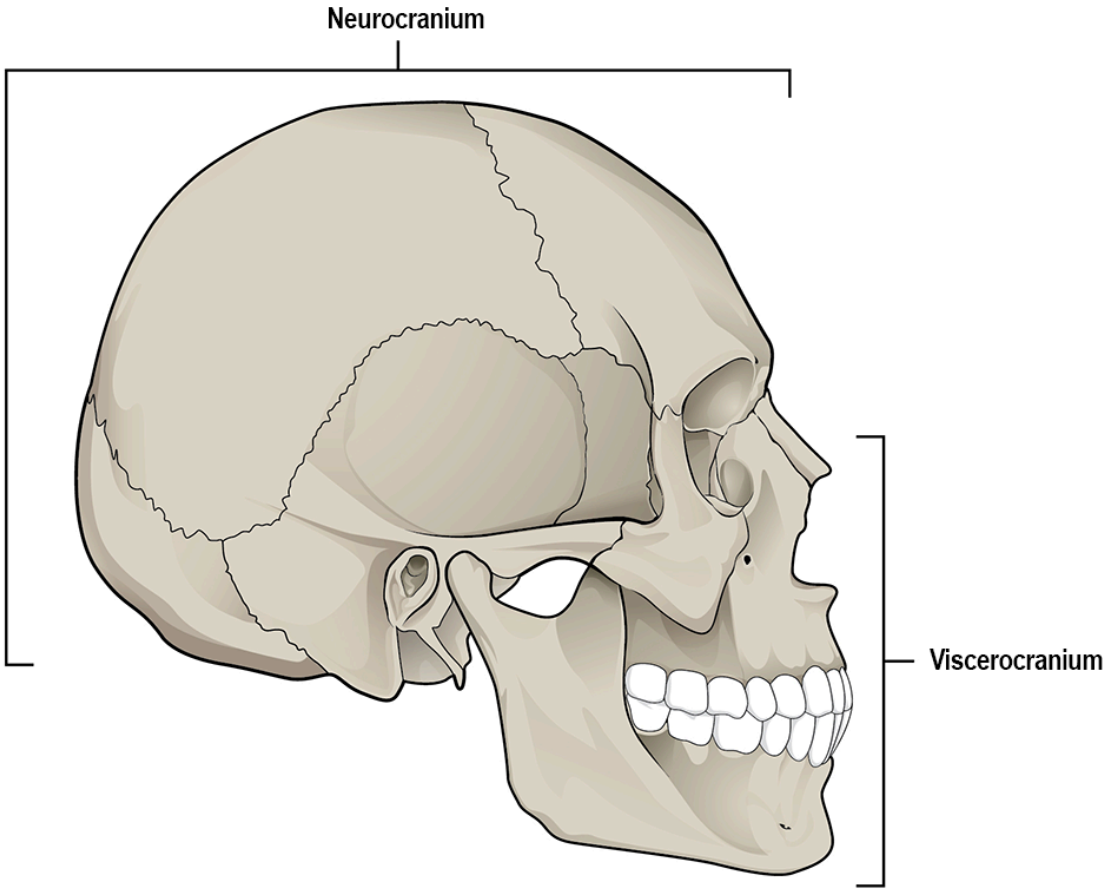

Figure A.11: The skull consists of the cranium and the mandible (jawbone). The cranium is further divided into the neurocranium and viscerocranium. A full text description of this image is available. Credit: Parts of the Skull (Anatomy & Physiology, Figure 7.3) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Bones and Some Features of the Neurocranium

Frontal bone: an unpaired bone consisting of two parts: a superior, vertically oriented portion called the squama and an inferior, horizontally oriented portion that forms the roof of the **orbit** (eye socket; Figures A.12 and A.13).

The **coronal suture** is the articulation between the frontal bone and the two parietal bones posterior and lateral to the frontal.

The frontal bone develops initially as two separate bones that fuse together during growth. Occasionally this fusion is incomplete, resulting in a **metopic suture** that persists between the two halves (left and right) of the frontal bone (Cunningham, Scheuer, and Black 2017).

The **glabella** is a bony projection between the brow ridges. The glabella in females tends to be flat while it is more rounded and protruding in males (Walker 2008).

The **supraorbital margin** is the upper edge of the orbit. The thickness of the edge may be used as an indicator of sex. The border tends to be thin and sharp in females and blunt and thick in males.

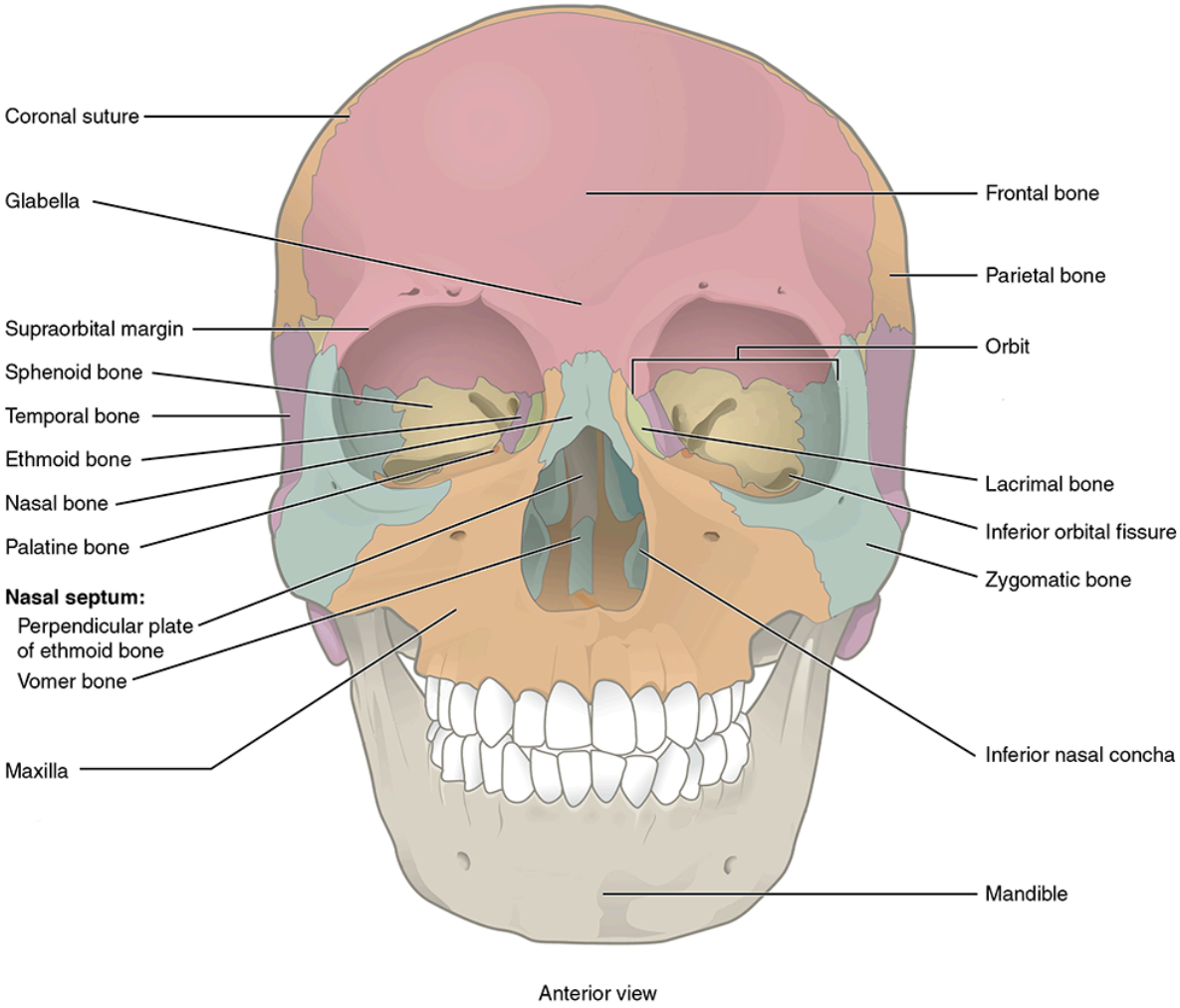

Figure A.12: Anterior view of the skull. A full text description of this image is available. Credit: Anterior View of Skull (Anatomy & Physiology, Figure 7.4) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

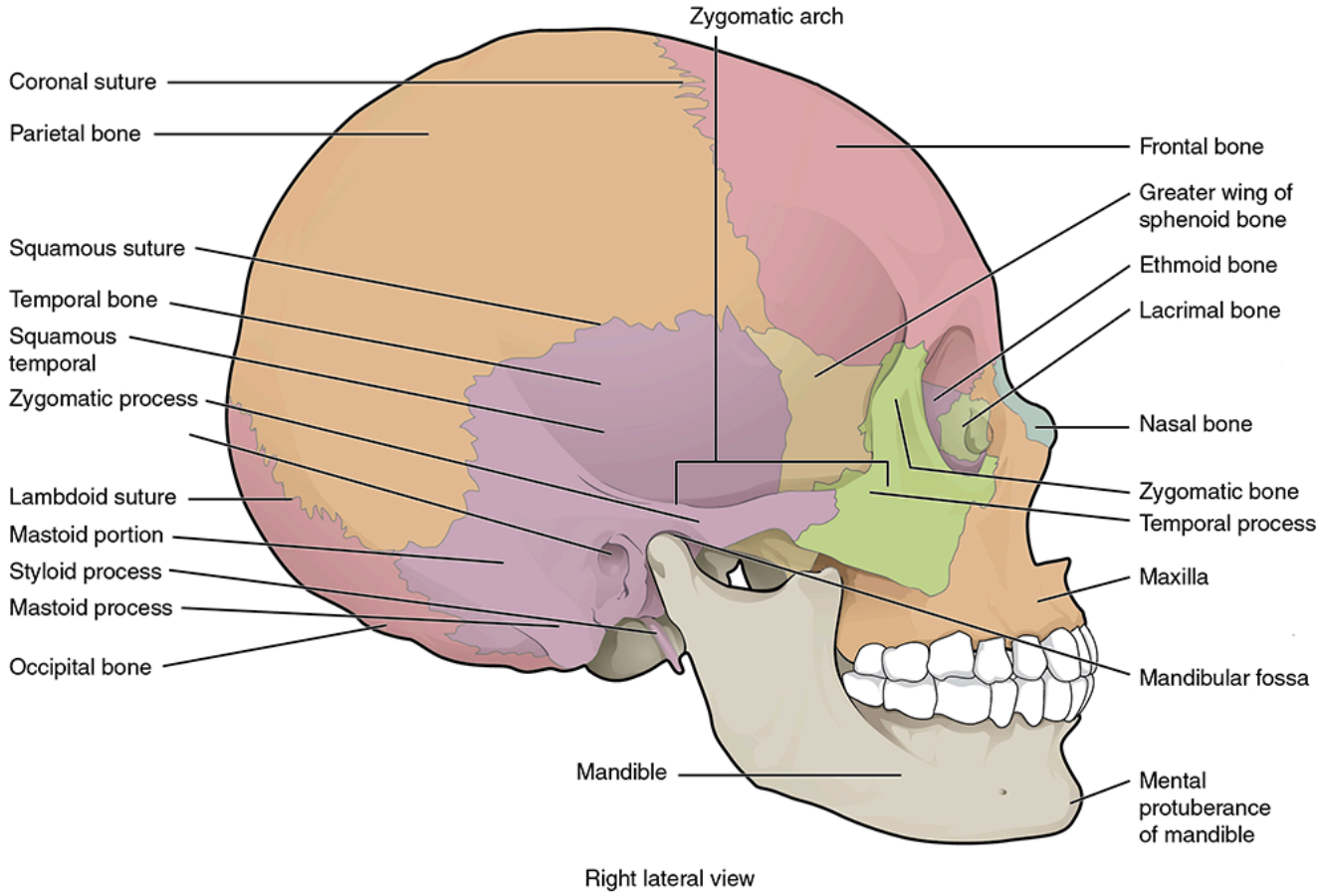

Figure A.13: The lateral view of the skull. Credit: Lateral View of Skull (Anatomy & Physiology, Figure 7.5) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Parietal bone: Paired bones that form the majority of the roof and sides of the neurocranium (Figures A.12 and A.13).

The **sagittal suture** is the articulation between the right and left parietal bones. It extends from the coronal suture to the lambdoidal suture, which separates the parietal bones from the occipital bone posteriorly.

Each parietal bone is marked by two **temporal lines** (superior and inferior), which are anterior-posterior arching lines that serve as attachment sites for a major chewing muscle (temporalis) and its associated connective tissue.

Temporal bone: Paired bones on the lateral side of the neurocranium that are divided into two portions: squamous (or flat) portion that forms the lateral side of the neurocranium and the petrous (or rock-like) portion that houses the special sense organs of the ear for hearing and balance as well as the three tiny bones of the middle ear: incus, malleus, and stapes (Figures A.13, A.14, and A.15).

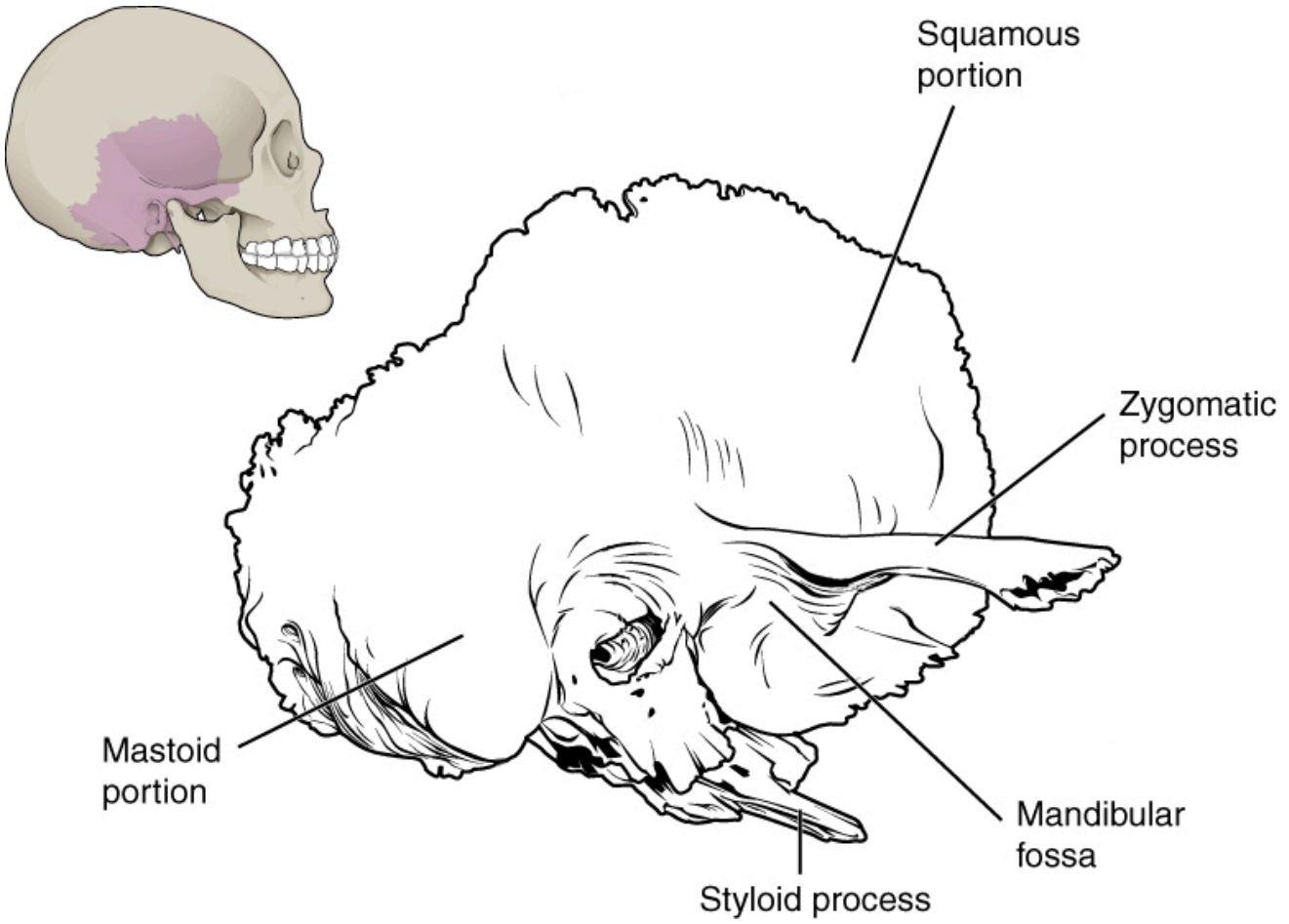

Figure A.14: A lateral view of the isolated temporal bone shows the squamous portion. A full text description of this image is available. Credit: Temporal Bone (Anatomy & Physiology, Figure 7.7) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

The **squamosal suture** is the articulation between the squamous portion of the temporal bone and the inferior border of the parietal bone.

The **mastoid process** is a prominent muscle attachment site for several muscles including the large sternocleidomastoid muscle. Males tend to have longer and wider mastoid processes compared to females (Walker 2008).

The **styloid process** is a thin, pointed, inferior projection of the temporal bone that serves as an attachment site for several muscles and a ligament of the throat.

The **zygomatic process of the temporal bone** is a long thin, arch-like process that originates from the squamous portion of the temporal bone. The zygomatic process articulates with the temporal process of the zygomatic bone to form the **zygomatic arch** (or cheekbone).

The **mandibular fossa** is the depression in the temporal bone where the mandibular condyle (see below, under mandible) articulates to form the temporomandibular (or jaw) joint.

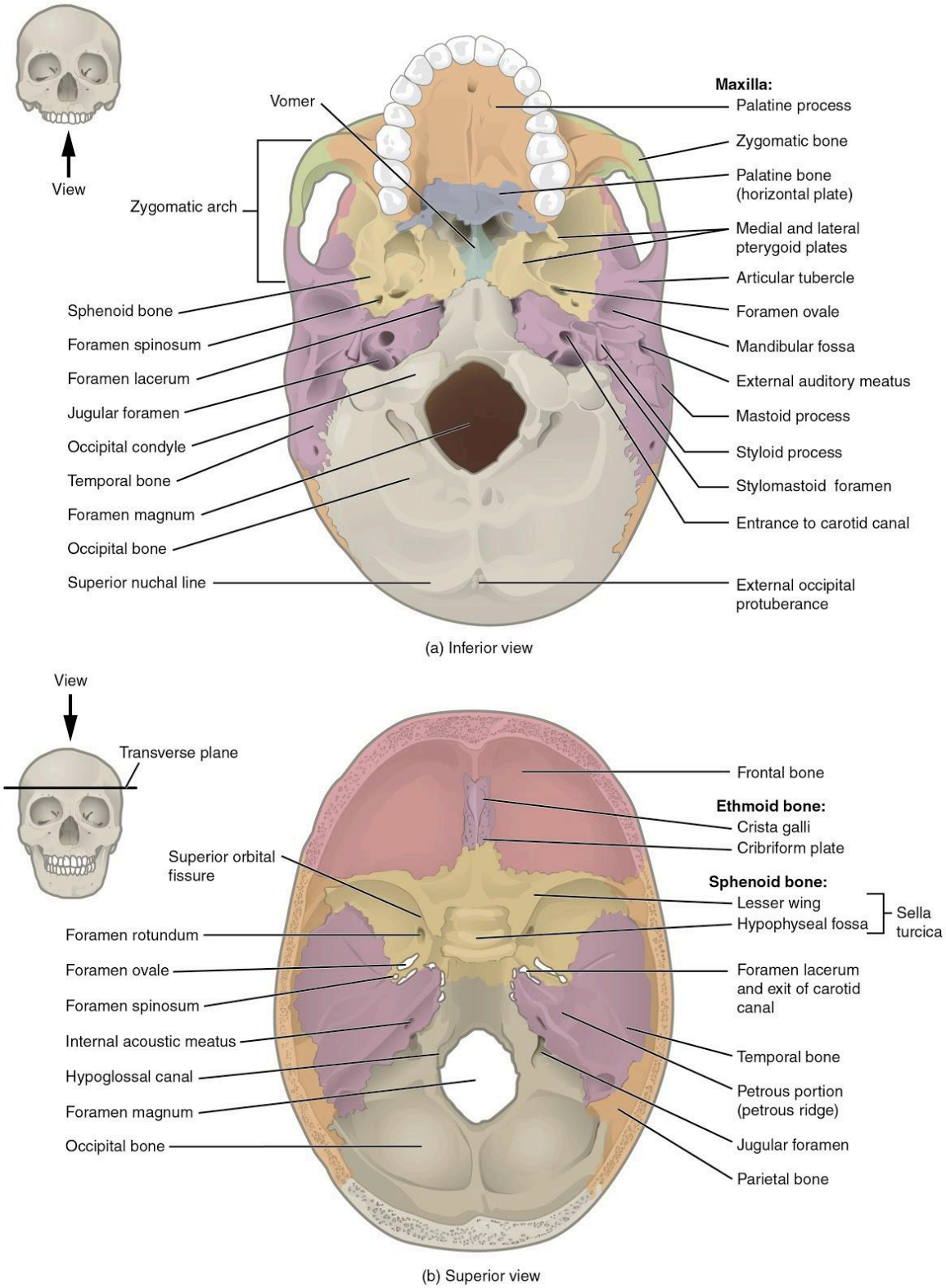

Figure A.15a–b: a. The base of the cranium. b. The floor of the cranial cavity. A full text description of this image is available. Credit: External and Internal Views of Base of Skull (Anatomy & Physiology, Figure 7.8) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Occipital bone: Unpaired bone that forms the posterior and inferior portions of the neurocranium (see Figures A.13 and A.15).

The **lambdoidal suture** is the articulation between the occipital bone and the two parietal bones. It resembles the shape of the Greek letter lambda.

The **external occipital protuberance** (EOP) is a bump along the posterior margin of the occipital bone where the nuchal ligament attaches.

The **nuchal lines** are parallel ridges that meet on the midline at the EOP and serve as attachment sites for neck muscles. Nuchal lines are usually more pronounced in males.

The occipital bone contains a large circular opening called the **foramen magnum**, which provides a space for passage of the brainstem/spinal cord from the neurocranium into the vertebral canal of the spine.

Sphenoid bone: Unpaired, butterfly-shaped bone that forms the central portion of the bottom of the neurocranium. The sphenoid is divided into several regions, including the body, greater wings, lesser wings, and pterygoid processes (with pterygoid plates; see Figures A.15 and A.16). This bone is critical to supporting the brain and several nerves and blood vessels supplying this region.

Pterygoid plates are flat projections of the pterygoid processes that serve as attachment sites for chewing muscles and muscles of the throat.

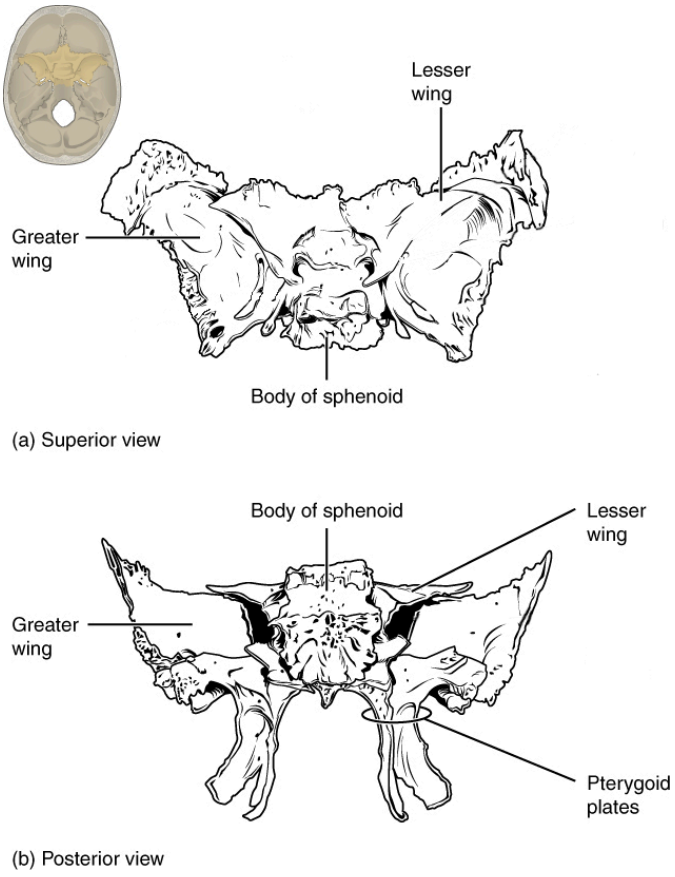

Figure A.16: Shown in isolation in (a) superior and (b) posterior views, the sphenoid forms the central portion of the neurocranium. The sphenoid has multiple openings for the passage of nerves and blood vessels. A full text description of this image is available. Credit: Sphenoid Bone (Anatomy & Physiology, Figure 7.10) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Ethmoid bone: Unpaired bone consisting of a median vertical plate that forms part of the bony nasal septum and a horizontal plate (cribriform plate) with many small **cribriform foramina** (holes) that transmit olfactory nerves (special sense of smell; Figure A.17).

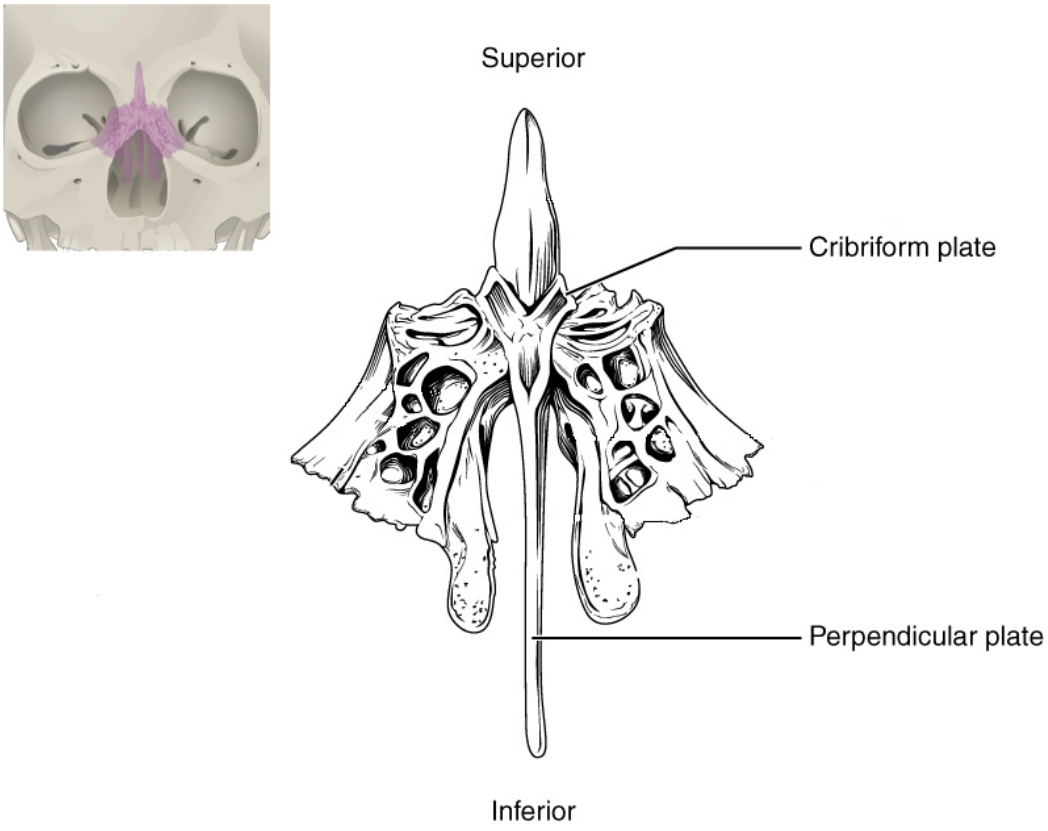

Figure A.17: The unpaired ethmoid bone is located at the midline within the central skull. It forms the upper nasal septum and contains foramina to convey olfactory nerves. A full text description of this image is available. Credit: Ethmoid Bone (Anatomy & Physiology, Figure 7.12) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Bones of the Viscerocranium

Maxilla bone: Paired bones that form the upper jaw, support the upper teeth, and form the inferior margin of the cheek (Figures A.12, A.15, and A.18).

The **nasal spine** is a thin projection on the midline at the inferior border of the nasal aperture.

The **zygomatic process of the maxilla** is the portion of the bone that articulates with the zygomatic bone to form the anterior portion of the zygomatic arch.

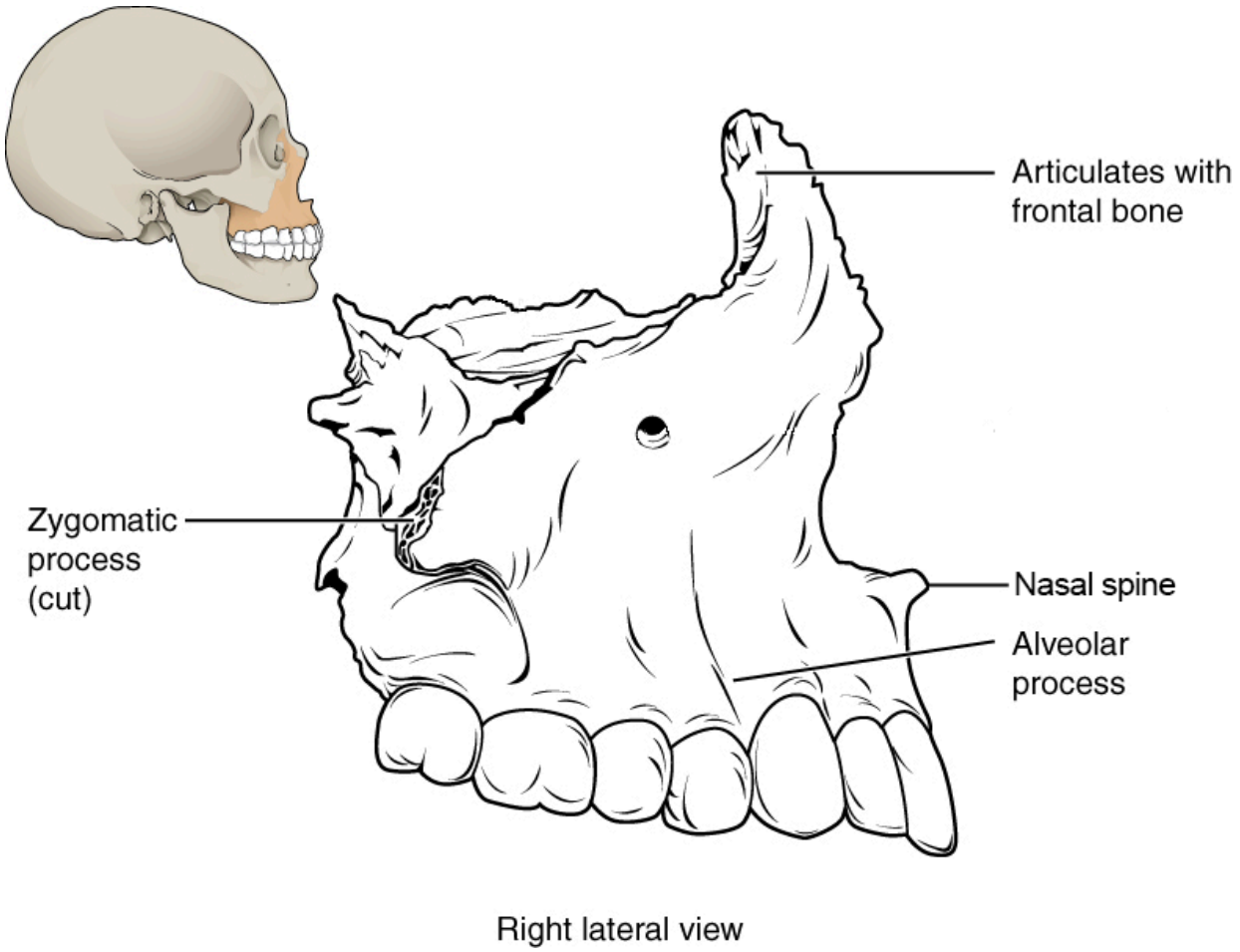

Figure A.18: The maxilla forms the upper jaw and supports the upper teeth. A full text description of this image is available. Credit: Maxillary Bone (Anatomy & Physiology, Figure 7.14) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Nasal bone: Small, paired, flat, rectangular bones that form the bridge of the nose (Figure A.19).

Nasal aperture is the anterior opening into the nasal cavity.

Zygomatic bone: Paired bones that form the anterolateral portion of the cheekbone and contribute to the lateral and inferior wall of the orbit (Figure A.19).

The **temporal process of the zygomatic bone** is the portion of the bone that articulates with the temporal bone to form the anterior portion of the zygomatic arch.

Palatine bone: Paired L-shaped bones that form the posterior portion of the roof of the mouth, floor of the orbit, and the floor and lateral walls of the nasal cavity (Figures A.15 and A.19).

Lacrimal bone: Small, flat, paired bones that form the anterior portion of the medial wall of the orbit (Figure A.19).

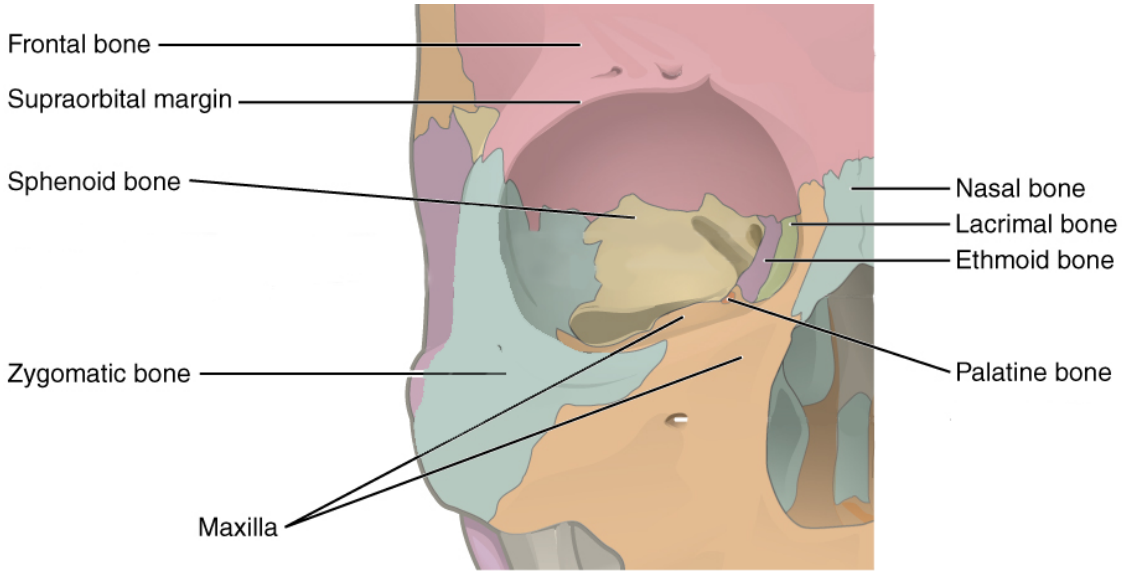

Figure A.19: Seven skull bones contribute to the walls of the orbit: frontal, zygomatic, maxilla, lacrimal, ethmoid, palatine, and sphenoid. A full text description of this image is available. Credit: Bones of the Orbit (Anatomy & Physiology, Figure 7.16) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Vomer bone: Unpaired thin bone that forms the inferior portion of the bony nasal septum. It articulates with the ethmoid superiorly (Figure A.20).

Inferior nasal concha bone: Paired bones that project and curl like a scroll from the lateral wall of the nasal cavity (Figure A.21).

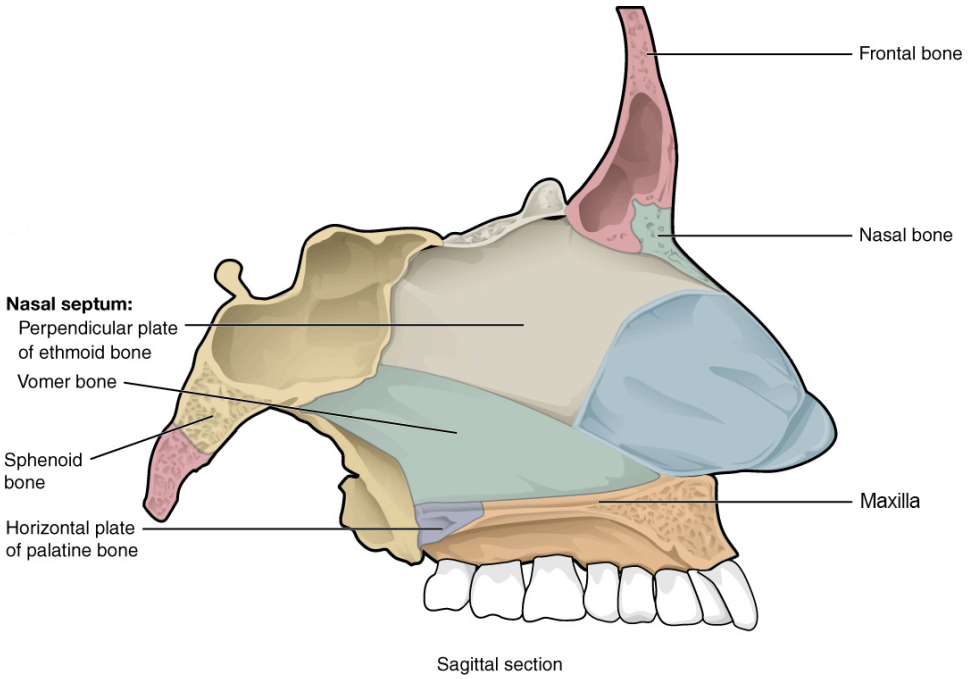

Figure A.20: The nasal septum is formed by the perpendicular plate of the ethmoid bone and the vomer bone. A full text description of this image is available. Credit: Nasal Septum (Anatomy & Physiology, Figure 7.17) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

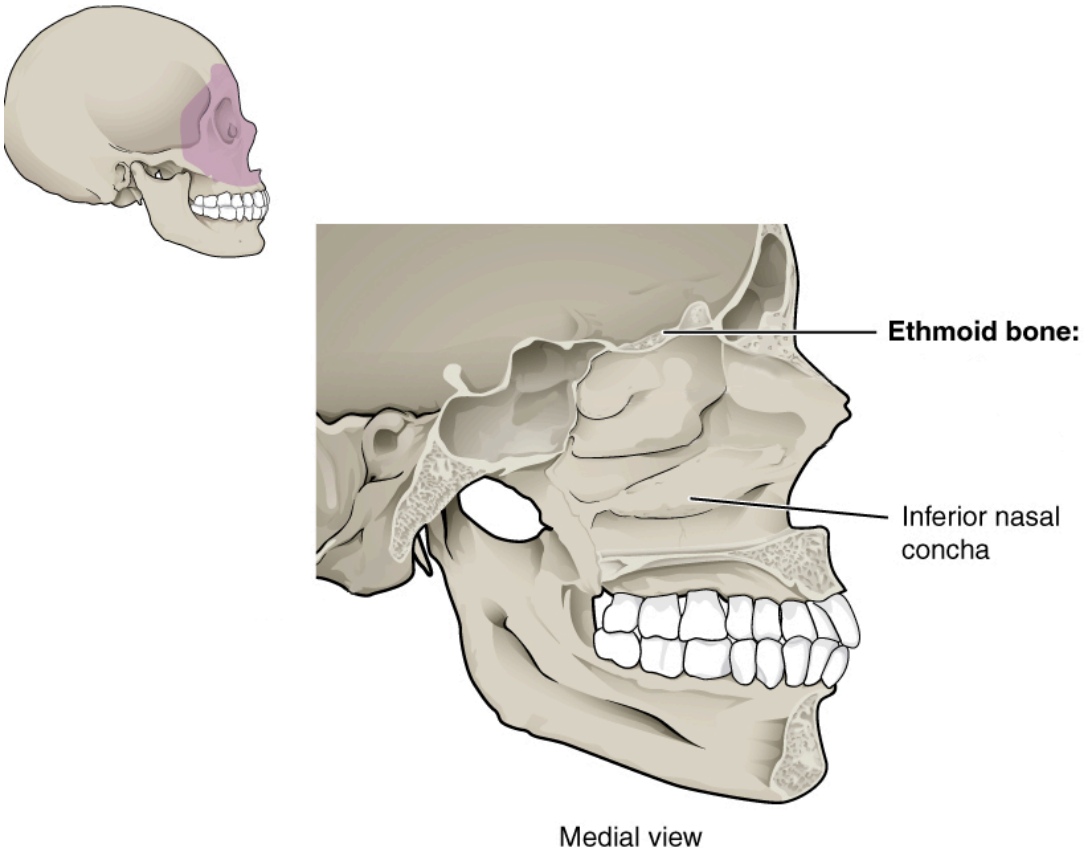

Figure A.21: Inferior nasal concha scroll from the lateral wall of the nasal cavity. A full text description of this image is available. Credit: Lateral Wall of Nasal Cavity (Anatomy & Physiology, Figure 7.13) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Hyoid bone: Unpaired U-shaped bone that sits in the neck inferior to the mandible. The hyoid is the only bone of the skeleton that does not articulate with another bone. Instead, it is encased in a sling of muscles that move the larynx (voice box), pharynx, and tongue (Figure A.22).

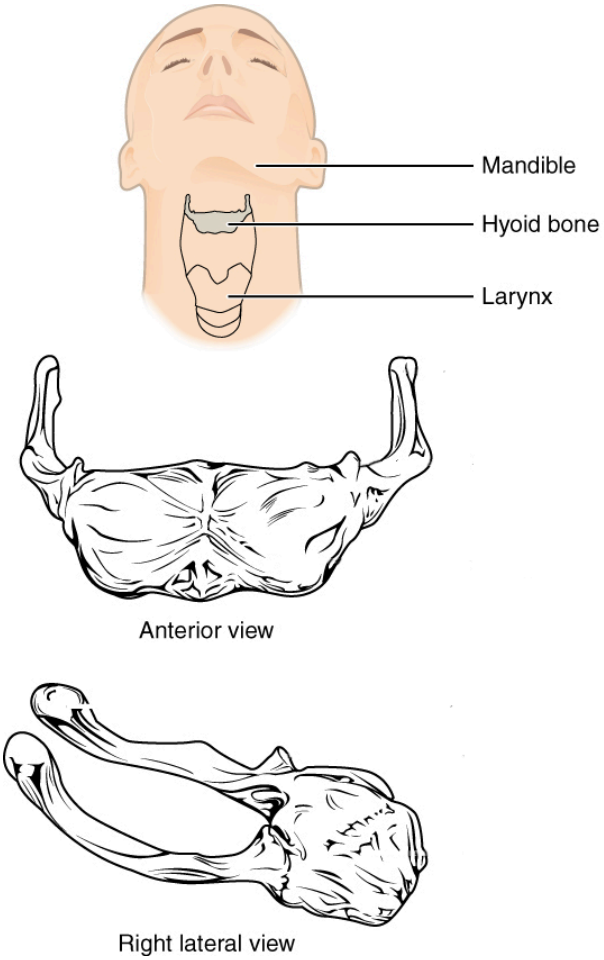

Figure A.22: The hyoid bone is located in the upper neck and does not join with any other bone. It provides attachments for muscles that move the tongue, larynx, and pharynx. A full text description of this image is available. Credit: Hyoid Bone (Anatomy & Physiology, Figure 7.19) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Mandible: Unpaired bone with a horizontal (and anteriorly arched) body and a vertical ramus that articulates with the mandibular fossa to form the temporomandibular (jaw) joint. The body of the mandible houses the lower teeth (Figure A.13 and A.23).

The **mental protuberance (eminence)** is the most anteriorly projecting point on the mandible—the so-called "chin." Males tend to have a more prominent mental protuberance than females (Walker 2008).

The **ramus of the mandible** projects superiorly from the body of the mandible and ascends to one of two features on the superior aspect: coronoid process or mandibular condyle.

The **coronoid process** is a bony projection off the anterior and superior aspect of the mandibular ramus. The inferior attachment of the temporalis muscle (a chewing muscle) attaches here.

The **mandibular condyle**, a rounded projection off the posterior and superior aspect of the mandibular ramus. It articulates with the temporal (mandibular) fossa of the temporal bone at the temporomandibular (TMJ) joint.

The **gonial (or mandibular) angle** is the rounded posteroinferior border of the mandible. It tends to be smooth in females with a more obtuse angle but is laterally flared in males and closer to a right angle in shape (Christensen, Passalacqua, and Bartelink 2019).

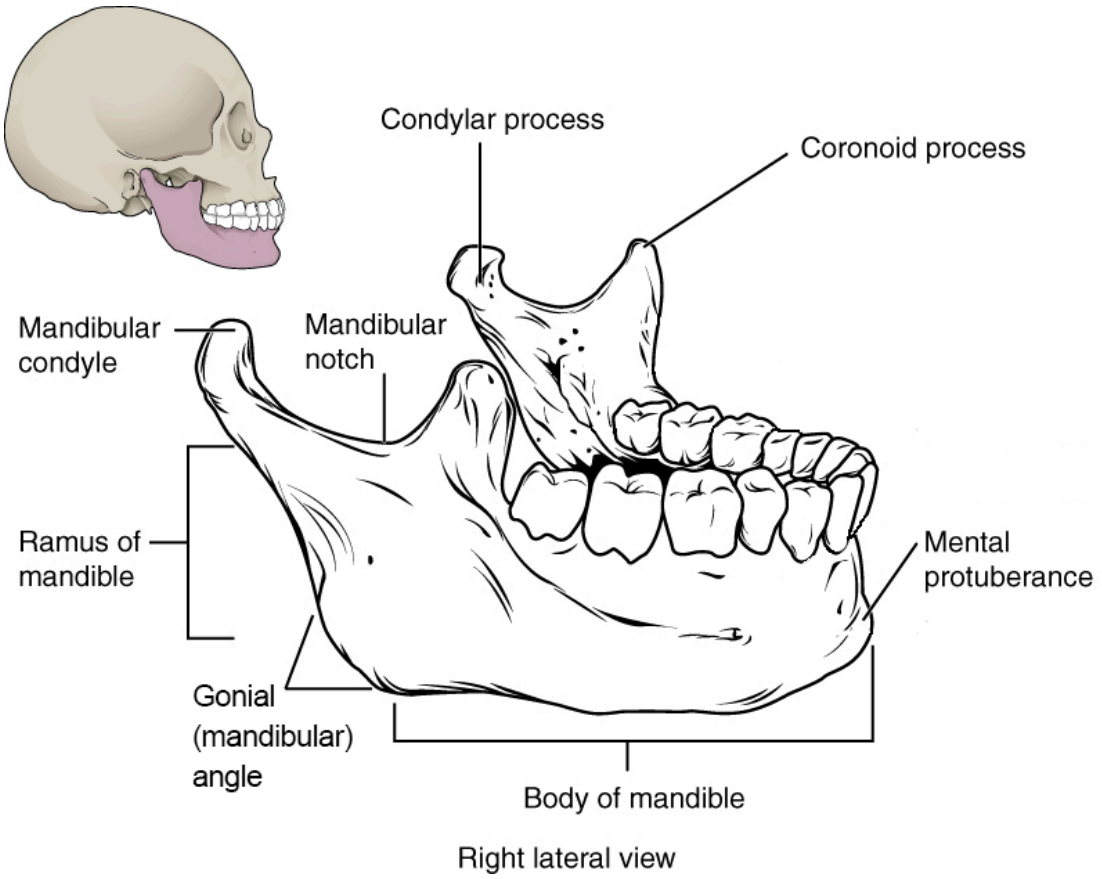

Figure A.23: Isolated view of the mandible, the only moveable bone of the skull. A full text description of this image is available. Credit: Isolated Mandible (Anatomy & Physiology, Figure 7.15) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Teeth: Adults normally have 32 teeth, distributed among four quadrants of the mouth (upper left, upper right, lower left, lower right). In each quadrant, there are eight teeth: two incisors (central and lateral), one canine, two premolars, and three molars. Each of these types of teeth has a different shape that reflects its function during chewing:

Incisors are flat and shovel shaped and are used to bite into a food item.

Canines are conical, with a single pointed cusp used to puncture a food item.

Premolars have two rounded cusps and are used to grind and mash a food item.

Molars have four (upper molars) or five (lower molars) flatter cusps and are used to grind food prior to swallowing.

The teeth have their own set of directional terms that help differentiate the different parts of the tooth. For example, the anterior portion of the tooth is called **mesial**, while the posterior portion of the tooth is called distal. In the case of teeth in the front of the mouth, mesial refers to the aspect toward the midline of the body; distal refers to the aspect away from the midline. Similarly, the side of the tooth facing the lips is called the **buccal** surface and the side facing the tongue is called the **lingual** surface. Finally, we can talk about the **occlusal surface** of the tooth, which is the surface that comes in contact with food or the teeth from the other jaw when the jaw is closed. Sometimes the occlusal surface of the incisors is called the **incisal surface**.

Vertebral Column

The adult vertebral column consists of 32–33 individual vertebrae, divided into five regions: cervical, thoracic, lumbar, sacral, and coccygeal.

General Structure of a Vertebra

A typical vertebra consists of an anteriorly situated **centrum** (body)—the main weight-bearing element of the vertebra—and a posteriorly projecting **vertebral arch** (Figure A.24). The vertebral arch consists of the paired pedicles and paired laminae. The **pedicle** connects the **transverse process**—a laterally projecting process that serves as an attachment site for muscles and ligaments—to the vertebral body; the **lamina** connects the **spinous process**—a posteriorly projecting process that serves as an attachment site for muscles and ligaments—to the transverse process. Projecting inferiorly off the vertebral arch is the **inferior articular process,** and projecting superiorly off the vertebral arch is the **superior articular process**. Between the vertebral body anteriorly and the vertebral arch posteriorly is an open space called the **vertebral foramen**.

Vertebrae articulate with one another through two major types of joints: **intervertebral disc joints** between adjacent vertebral bodies and **zygapophyseal (facet) joints** between the inferior articular process of one vertebra and the superior articular process of the vertebra immediately inferior to it. When all vertebrae are articulated into a column, the adjacent vertebral foramina form the **vertebral canal**, through which the spinal cord travels from the foramen magnum of the occipital bone to approximately the level of the second lumbar vertebra. At the level of each vertebra, the spinal cord gives off a pair (left and right) of spinal nerves that exit between vertebrae through the intervertebral foramen formed by adjacent vertebral arches. Even though the spinal cord ends in the lumbar region, the spinal nerves emanating from the spinal cord continue all the way to the sacral (and sometimes coccygeal) region, culminating in a total of 30–31 pairs of spinal nerves.

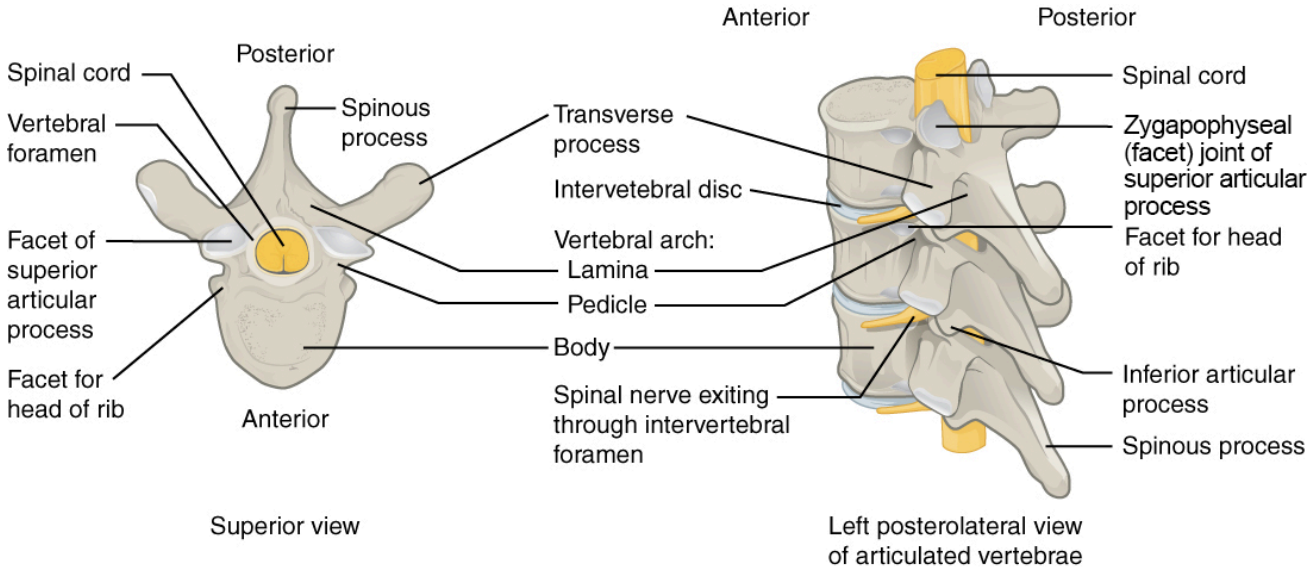

Figure A.24: A typical vertebra consists of a body and a vertebral arch. The arch is formed by the paired pedicles and paired laminae. Arising from the vertebral arch are the transverse, spinous, superior articular, and inferior articular processes. The vertebral foramen provides for passage of the spinal cord. Each spinal nerve exits through an intervertebral foramen, located between adjacent vertebrae. A full text description of this image is available. Credit: Parts of a Typical Vertebra (Anatomy & Physiology, Figure 7.23) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Regional Differences in Vertebral Shape

In the **cervical region** of the vertebral column, there are seven vertebrae (named C1–C7 from superior to inferior; Figure A.25). The first two cervical vertebrae are unique from each other and all other cervical vertebrae, and they get special names: atlas (C1) and axis (C2). The atlas lacks a vertebral body (having only two large articular facets for articulation with the occipital bone of the skull: the **atlanto-occipital joint** for nodding the head) and does not have a spinous process. The axis is notable for the superiorly projecting **dens** (or **odontoid process**), which articulates with the atlas to create the **atlanto-axial joint** for head rotation. Otherwise, a typical cervical vertebra has a small vertebral body, a bifid (split) spinous process, a transverse process with a transverse foramen on it for passage of the vertebral artery and vein, and a triangular-shaped vertebral foramen.

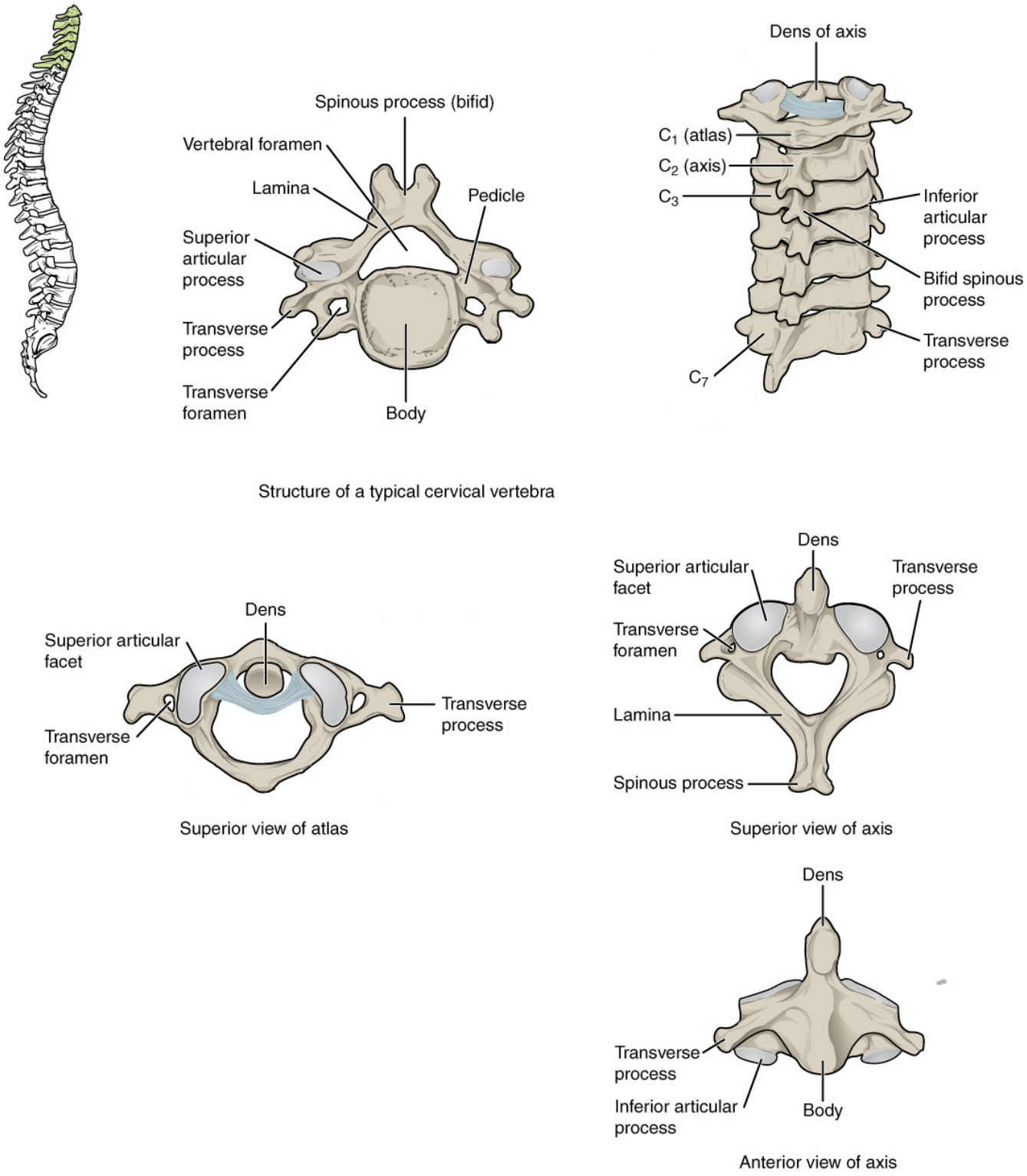

Figure A.25: A typical cervical vertebra has a small body, a bifid spinous process, transverse processes that have a transverse foramen, and a triangular vertebral foramen. The atlas (C1 vertebra) does not have a body or spinous process. The axis (C2 vertebra) has the upward projecting dens, which articulates with the atlas. A full text description of this image is available. Credit: Cervical Vertebra (Anatomy & Physiology, Figure 7.25) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

The vertebrae in the other regions of the spinal column are less variable in shape than the cervical region vertebrae. There are 12 **thoracic region** vertebrae (T1–T12), and they can be easily distinguished from the vertebrae in other regions because they have articular facets on their vertebral

bodies for articulation with the head of a rib, as well as articular facets on the transverse process for articulation with the rib tubercle (Figure A.26). In particular, the vertebral bodies of T2–T9 have two pairs of articular facets called **demifacets** (superior and inferior), for articulation with multiple ribs; T1 and T10–T12 have single facets for articulation with a single rib. All five **lumbar region** vertebrae (L1–L5) are distinguished by their large vertebral body and rounded spinous process (Figure A.27). Finally, there is the **sacrum**, which is a bone of the pelvis that forms from the fusion of all five sacral region vertebrae (S1–S5), and there is the **coccyx,** which comprises three to four fused coccygeal region vertebrae that form the tailbone (Figure A.28).

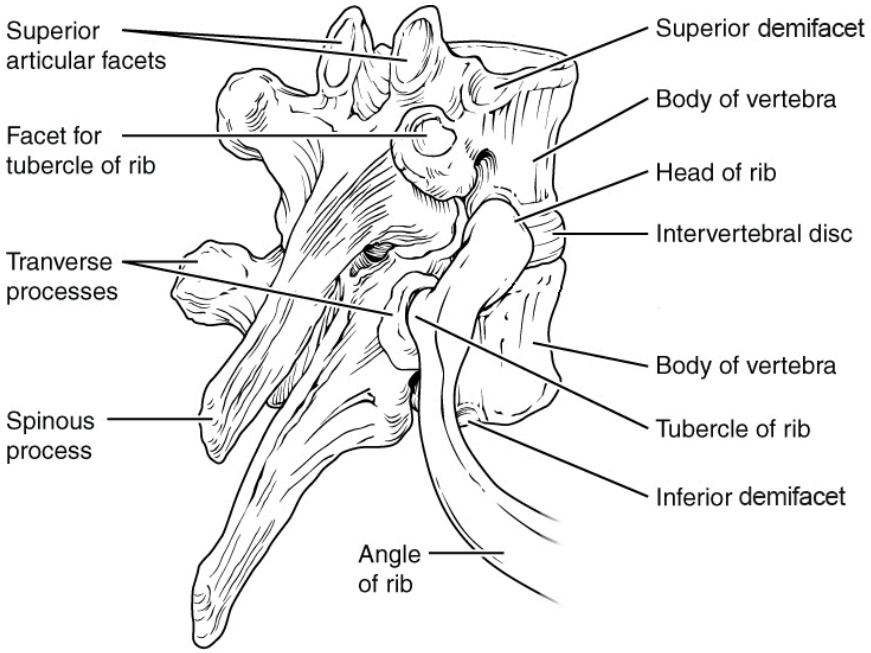

Figure A.26: Thoracic vertebrae have superior and inferior articular facets on the vertebral body for articulation with the head of a rib, as well as a transverse process facet for articulation with the rib tubercle. A full text description of this image is available. Credit: Rib Articulation in Thoracic Vertebrae (Anatomy & Physiology, Figure 7.27) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

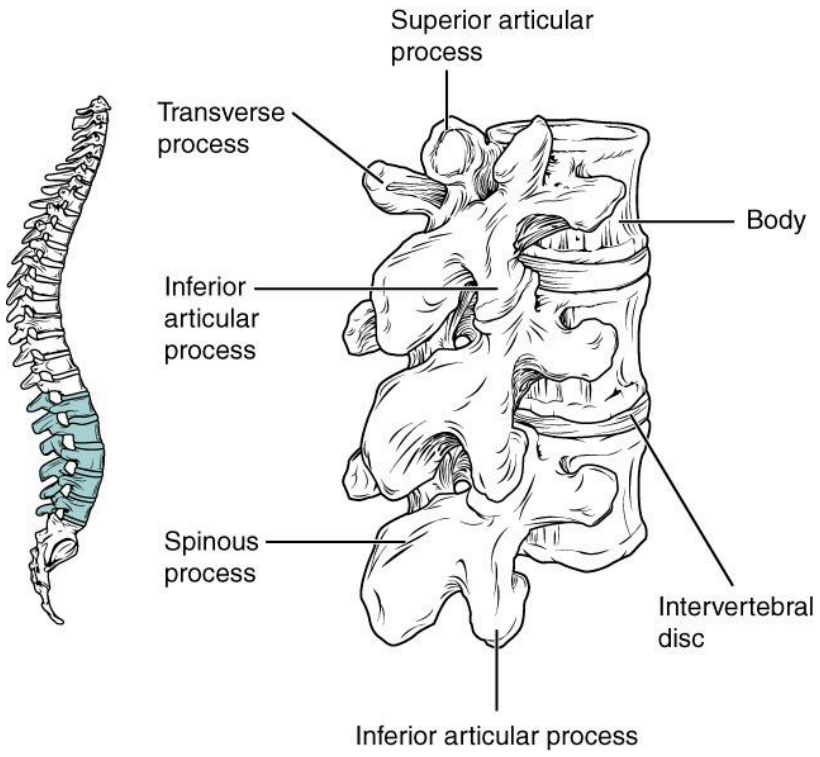

Figure A.27: Lumbar vertebrae are characterized by having a large, thick body and a short, rounded spinous process. A full text description of this image is available. Credit: Lumbar Vertebrae (Anatomy & Physiology, Figure 7.28) by OpenStax is under a CC BY 4.0 License.

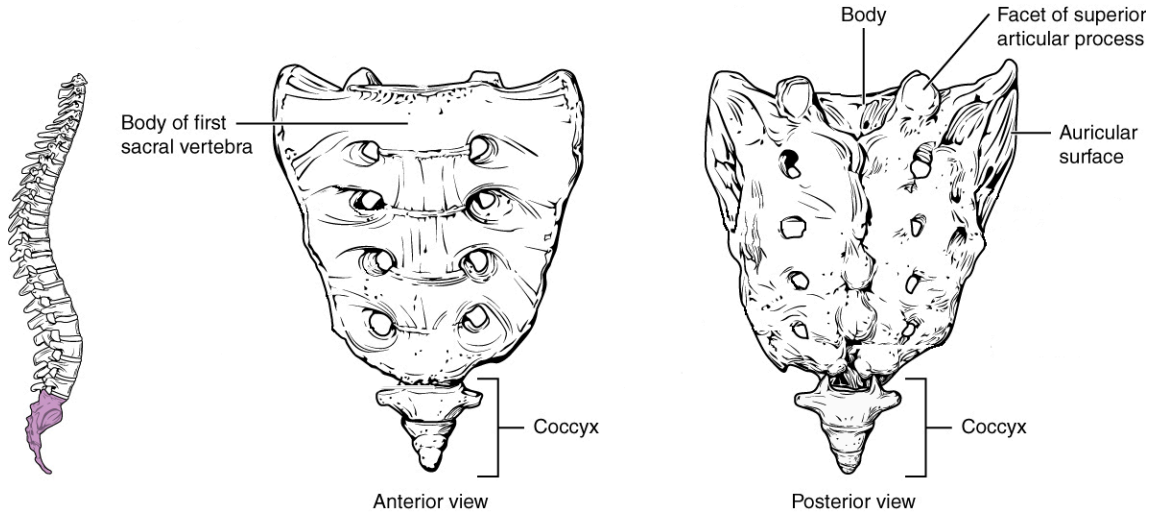

Figure A.28: The sacrum is formed from the fusion of five sacral vertebrae, whose lines of fusion are indicated by the transverse ridges. The coccyx is formed by the fusion of three to four coccygeal vertebrae. A full text description of this image is available. Credit: Sacrum and Coccyx (Anatomy & Physiology, Figure 7.29) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Curvatures of the Vertebral Column

The adult spine is curved in the midsagittal plane in four regions of the vertebral column (cervical, thoracic, lumbar, and sacral; Figure A.29). During the fetal period of development, the vertebral column forms an anteriorly concave curvature called a **kyphosis**. But during the postnatal period, when an infant learns to hold its head up and then again when it learns to walk, it develops secondary curvatures called lordoses (singular:

lordosis) that are posteriorly concave in the cervical and lumbar vertebral regions, while the kyphoses remain in the thoracic and sacral regions. The end result is an S-shaped curvature to our spine that enables us to keep our head and torso above our center of mass (near our pelvis) while walking around on two legs.

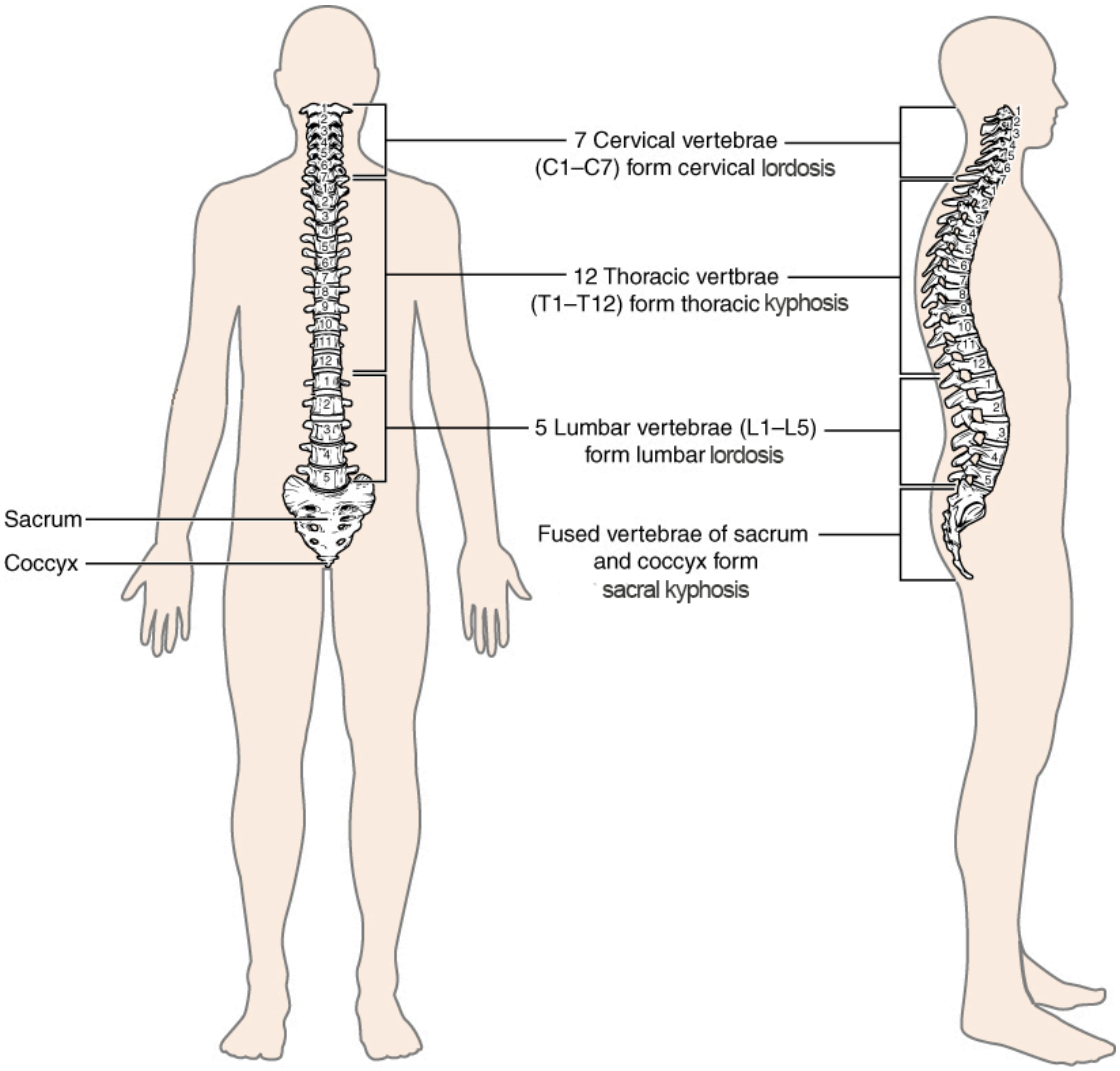

Figure A.29: The adult vertebral column is curved in the midsagittal plane, with two primary curvatures (thoracic and sacral kyphoses) and two secondary curvatures (cervical and lumbar lordoses). A full text description of this image is available. Credit: Vertebral Column (Anatomy & Physiology, Figure 7.20) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Thoracic Cage

The thoracic cage is formed from the sternum, the 12 ribs and their cartilages (costal cartilages), and the 12 thoracic vertebrae with which the ribs articulate (Figure A.30). The **sternum** comprises the **manubrium** (superior portion), the **body of the sternum,** and the **xiphoid process**

. Each rib has a head and neck (with rib tubercle) at the vertebral end of the rib as well as a flattened shaft that extends to articulate with the sternum. All ribs articulate with the vertebral column at two points: the transverse process facet (**rib tubercle**) and vertebral body articular facet (**head of rib**). But articulations between the ribs and the sternum vary, where some ribs (1–7, the "true ribs") attach directly to the sternum via their costal cartilages, other ribs (8–10, the "false ribs") attach indirectly to the sternum via the costal cartilage of the rib above, and some ribs (11–12, the "floating ribs") do not attach to the sternum at all. With increasing age, the **sternal end of the rib** becomes thinner and irregularly shaped compared to the smooth, rounded shape seen in young adults (Hartnett 2010).

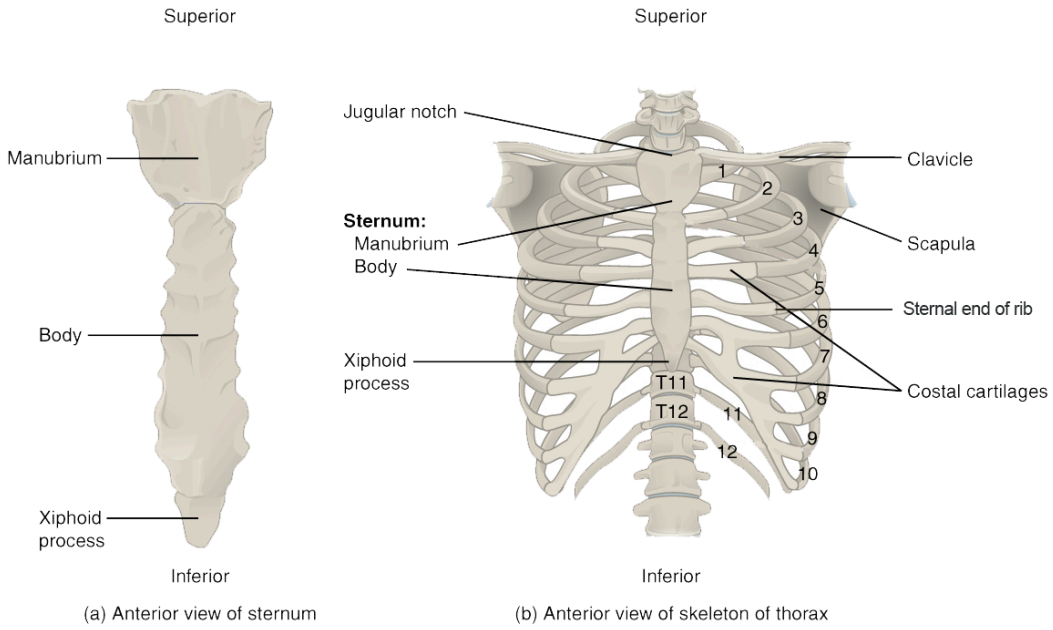

Figure A.30: The thoracic cage is formed by the (a) sternum and (b) 12 pairs of ribs with their costal cartilages. The ribs are anchored posteriorly to the 12 thoracic vertebrae. The sternum consists of the manubrium, body, and xiphoid process. The ribs are classified as true ribs (1–7) and false ribs (8–12). The last two pairs of false ribs are also known as floating ribs (11–12). A full text description of this image is available. Credit: Thoracic Cage (Anatomy & Physiology, Figure 7.32) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Appendicular Skeleton

Pectoral Girdle

The pectoral girdle consists of the **clavicle** and the **scapula**, and it serves as the proximal base of the upper limb as well as the anchor for the upper limb to the axial skeleton. The clavicle is an S-shaped bone, and it forms the strut that connects the scapula to the sternum (Figure A.31). The scapula is a large, flat bone with three angles (superior, inferior, and lateral) and three borders (medial, lateral, and superior). The lateral angle is noteworthy because it serves as the articulation for the head of the humerus of the upper limb at the **glenoid cavity (or fossa) (**Figure A.32). The borders and the anterior and posterior surfaces of the scapula are sites of muscle attachment. The scapula also has three important projections for muscle and ligament attachments: the **coracoid process** anteriorly and superiorly; the **acromion**, which articulates with the lateral end of the clavicle; and the **spine** on the posterior aspect of the scapula.

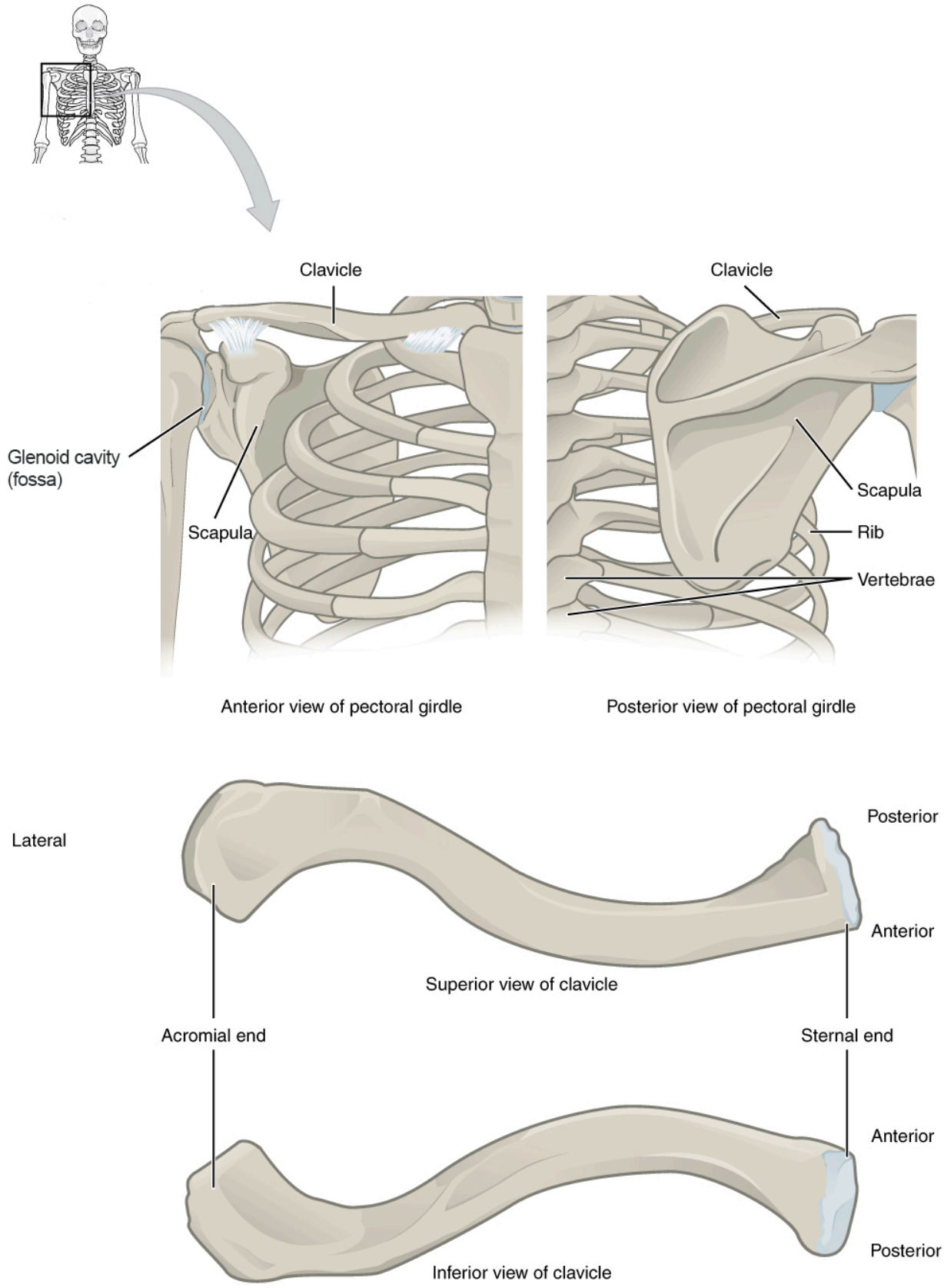

Figure A.31: The pectoral girdle consists of the clavicle and the scapula, which serve to attach the upper limb to the axial skeleton at the sternum. A full text description of this image is available. Credit: Pectoral Girdle (Anatomy & Physiology, Figure 8.3) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

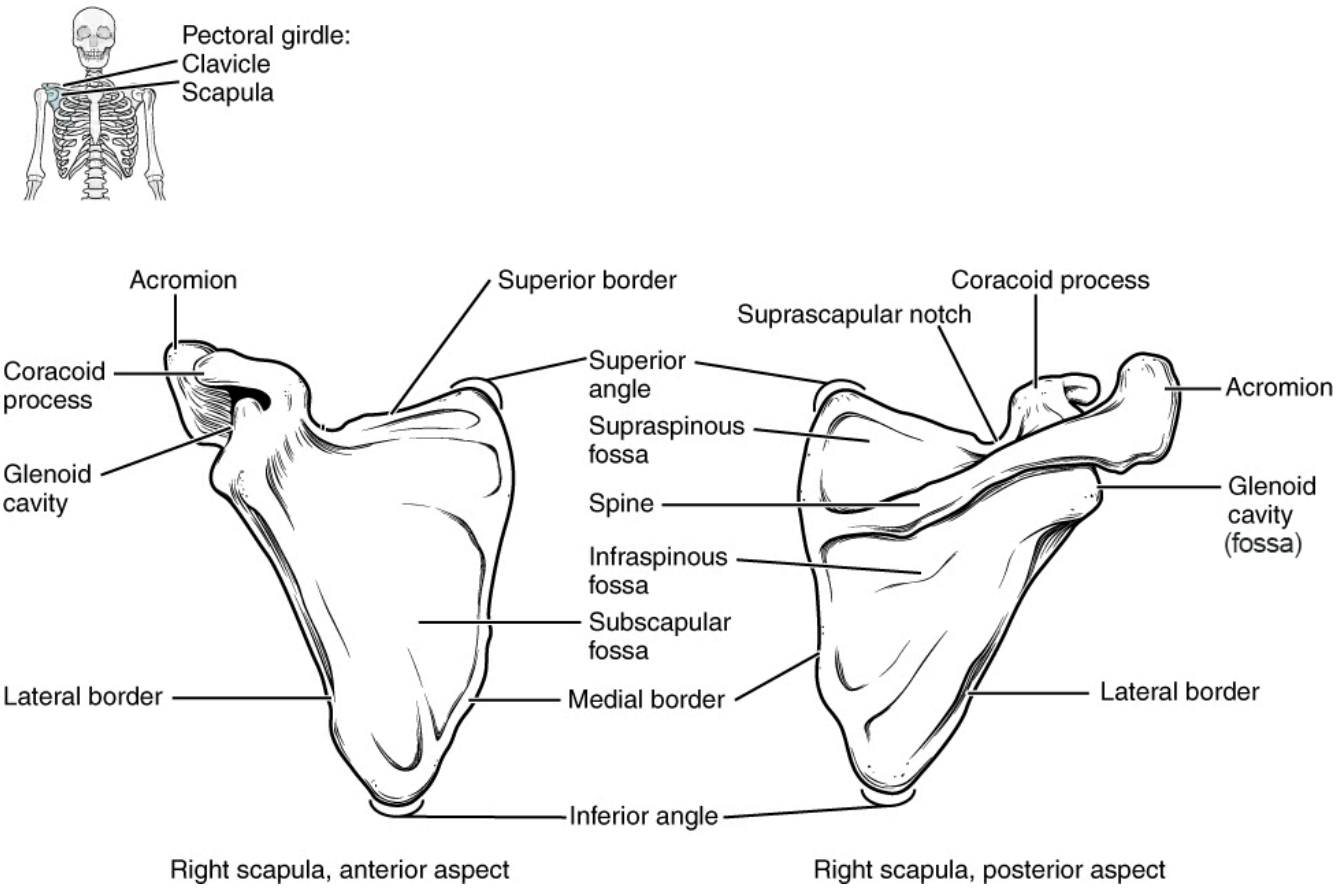

Figure A.32: The scapula is shown from its anterior (deep) side and its posterior (superficial) side. A full text description of this image is available. Credit: Scapula (Anatomy & Physiology, Figure 8.4) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Upper Limb

The bones of the upper limb skeleton include the humerus, radius, ulna, eight carpal (wrist) bones, five metacarpal (hand) bones, and 14 phalanges (finger bones). Each of these bones is described below along with several of the prominent features.

The **humerus** is the bone of the arm. On the proximal epiphysis of the humerus are attachment sites for muscles of the rotator cuff (**greater tubercle and lesser tubercle**). A major shoulder muscle (deltoid muscle) attaches to the humerus along the lateral aspect of the diaphysis at the **deltoid tuberosity**. On the distal epiphysis of the humerus, the medial epicondyle is an attachment site for muscles that flex the forearm, and the lateral epicondyle is an attachment site for muscles that extend the forearm (Figure A.33).

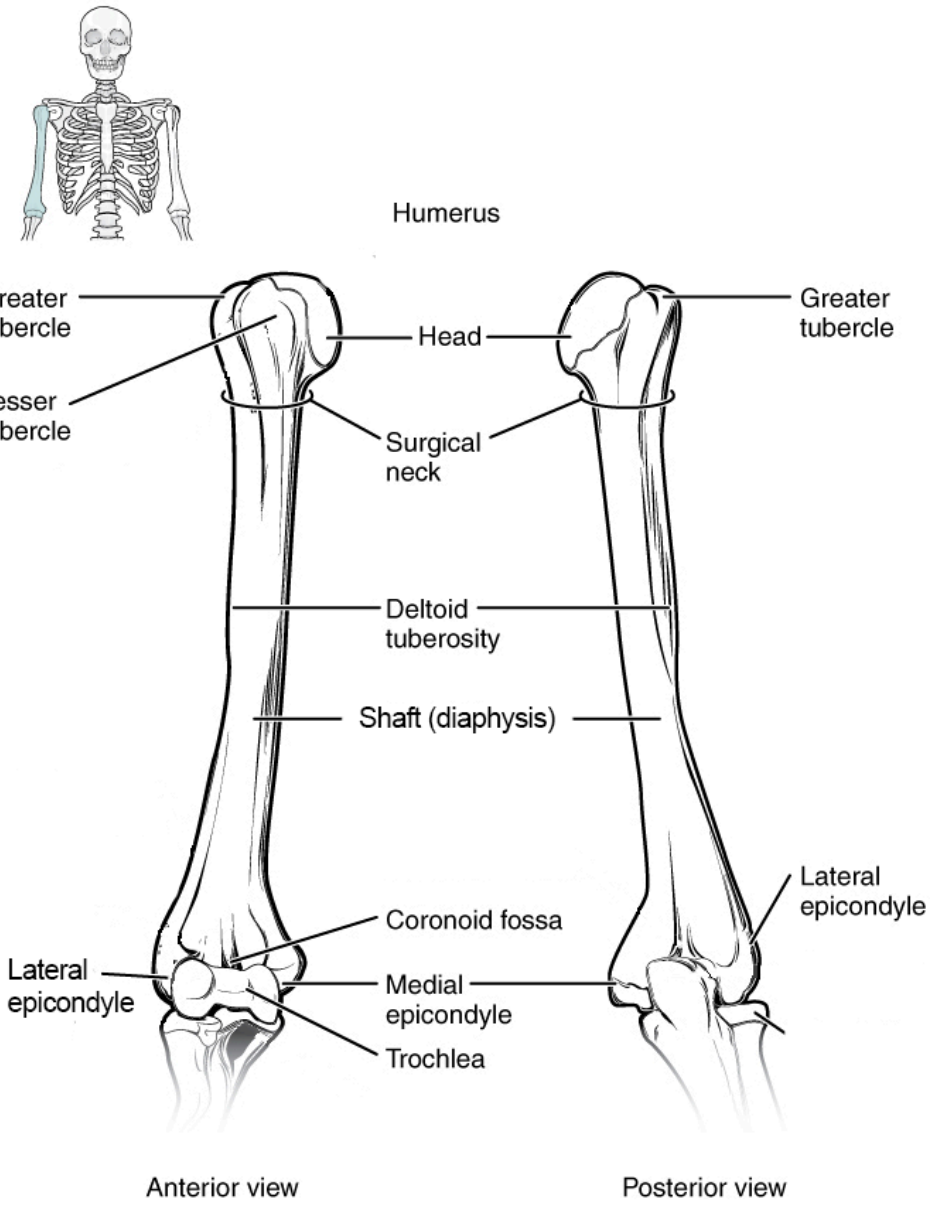

Figure A.33: The humerus is the single bone of the upper arm region. It articulates with the radius and ulna bones of the forearm to form the elbow joint. A full text description of this image is available. Credit: Humerus and Elbow Joint (Anatomy & Physiology, Figure 8.5) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

There are two bones of the forearm, attached to each other by a thick connective tissue interosseous membrane: the radius and the ulna (Figure A.34). The **radius** is lateral to the ulna in anatomical position (this is called supination of the forearm), but it crosses over the ulna when the wrist is rotated so that the thumb points medially (this is called pronation of the forearm). On the proximal end of the radius is the **radial tuberosity**, an attachment site for the biceps brachii muscle that will help supinate and flex the forearm; on the distal end of the radius is the **styloid process of radius**, an attachment site for ligaments of the wrist. The **ulna** also has a styloid process (**styloid process of ulna**), but unlike the one on the radius it does not have a relevant function. Instead, the important processes on the ulna are located proximally, and they include the **olecranon process** for the attachment of the triceps brachii muscle (a muscle that extends the forearm and arm) and the coronoid process for the attachment of the brachialis muscle (a muscle that flexes the forearm).

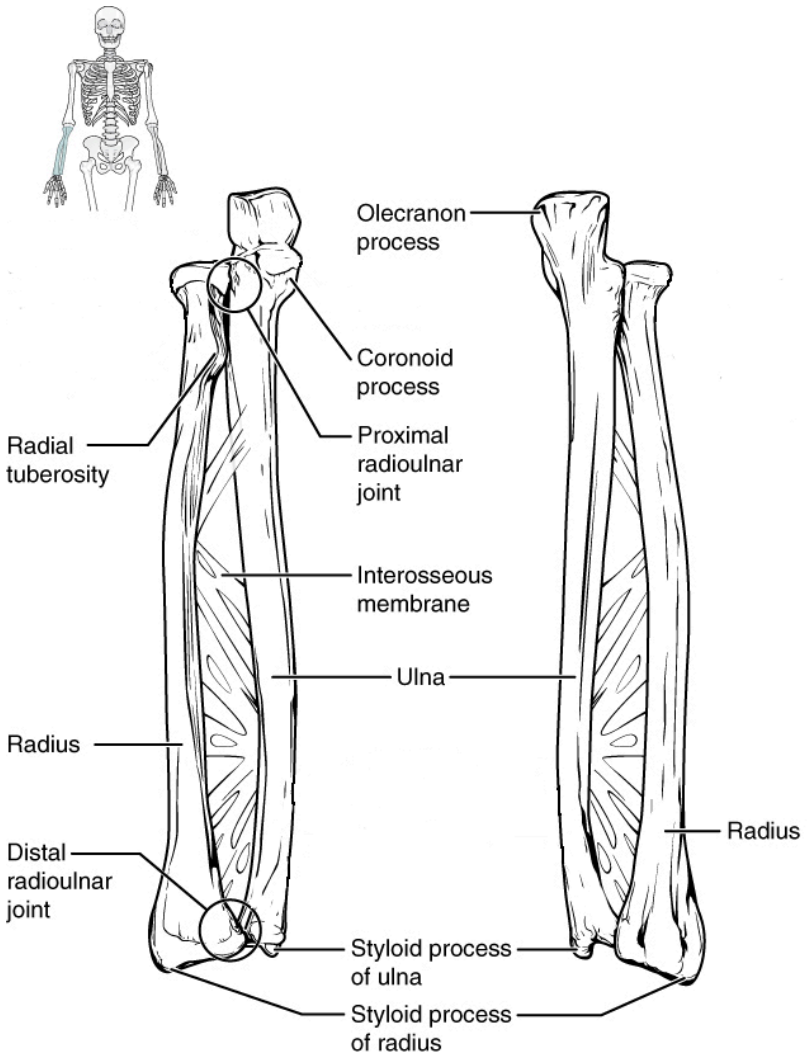

Figure A.34: The ulna is located on the medial side of the forearm, and the radius is on the lateral side. These bones are attached to each other by an interosseous membrane. A full text description of this image is available. Credit: Ulna and Radius (Anatomy & Physiology, Figure 8.6) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

There are eight **carpal bones** that comprise the wrist, and they are organized into two rows: proximal and distal (Figure A.35). The proximal row of carpals (from lateral to medial) includes the scaphoid, lunate, triquetrum, and pisiform. The distal row (from lateral to medial) includes the trapezium, trapezoid, capitate, and hamate with its distinctive hamulus (hook) for muscle and ligament attachments. Distal to the carpal bones are the digital rays, each of which contains a **metacarpal** (hand) bone and three **phalanges** (proximal, middle, and distal) or finger bones. The exception to this rule is the thumb, which has fewer phalanges (proximal and distal, but no middle) than the other digits.

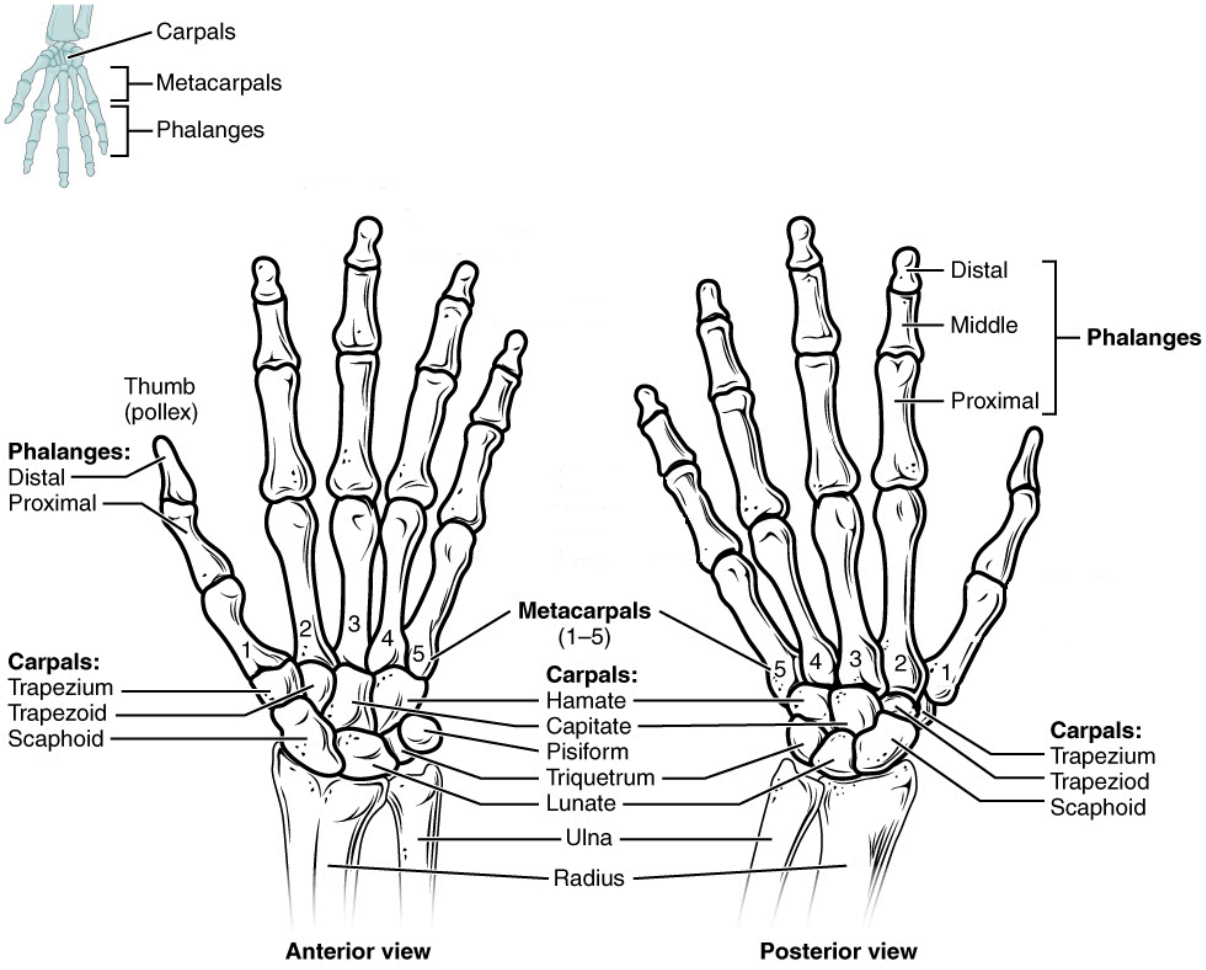

Figure A.35: The eight carpal bones form the base of the hand. These are arranged into proximal and distal rows of four bones each. The five metacarpal bones form the palm of the hand. The thumb and fingers contain a total of 14 phalanges. A full text description of this image is available. Credit: Bones of the Wrist and Hand (Anatomy & Physiology, Figure 8.7) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Pelvic Girdle

The pelvic girdle consists of the two **os coxae** and the sacrum that articulates with both, and it serves as the proximal base and anchor of the lower limb to the axial skeleton. Each os coxa comprises three bones that fuse together during growth: ilium, ischium, and pubis. These three bones fuse in a region called the **acetabulum**, which is the socket for the ball-and-socket hip joint (Figure A.36). The **ilium**, the flared superior portion of the pelvis, is the largest bone of the os coxa and serves as a major site of attachments for muscles from the abdomen, back, and lower limb. The ilium has several important features including the **auricular surface**, the surface where the ilium articulates with the sacrum. The auricular surface is used to estimate age at death as the surface progressively deteriorates with increasing age to appear coarse and porous. The **greater sciatic notch** is a large notch in the ilium that allows for several structures to leave the pelvis and enter the lower extremity, including the sciatic nerve. In females, the notch tends to be symmetrical whereas in males it tends to curve posteriorly (Nawrocki et al. 2018).

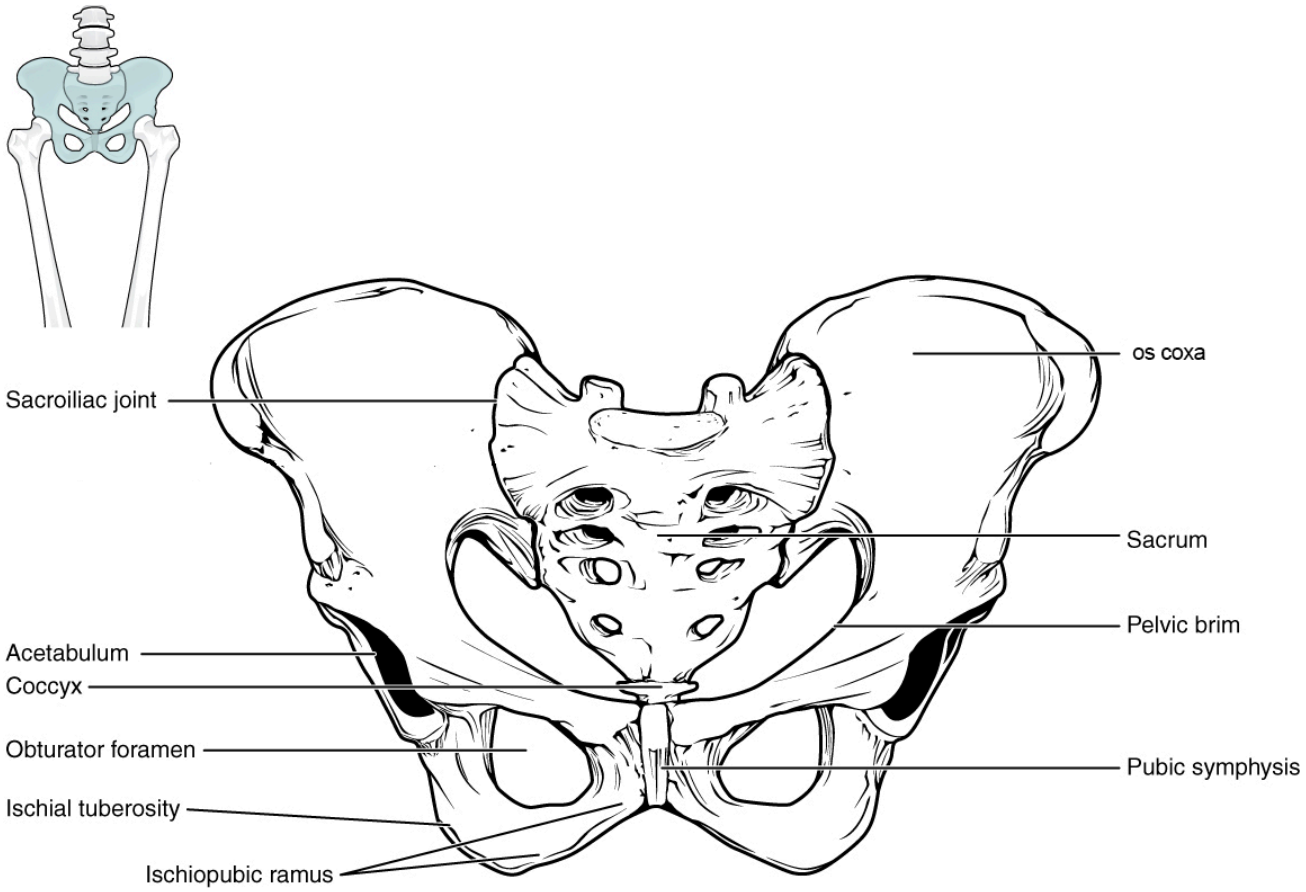

Figure A.36: The pelvic girdle consists of two os coxae and the sacrum. It serves to anchor the axial skeleton to the lower limb. A full text description of this image is available. Credit: Pelvis (Anatomy & Physiology, Figure 8.12) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

The **ischium** forms the posterior and inferior portion of the os coxa. There are two significant projections of note on the ischium: the ischial spine and tuberosity. The **ischial spine** is the attachment point for a major pelvic ligament and is located inferior to the greater sciatic notch of the ilium. The **ischial tuberosity** is the proximal attachment site for the hamstring muscles of the lower limb.

The anterior and medial portions of the os coxa are formed by the **pubis**. The pubis is a useful bone with which to sex a skeleton in a forensic context (Bass 2005; Buikstra and Ubelaker 1994). The **body of pubis** is the superior and medial portion (Figure A.37). The body tends to be rectangular in cross-section in females and triangular in males. The bony projection that unites the ischium and pubis anteriorly is called the **ischiopubic ramus**. Females tend to display a thin and sharp ramus on the medial surface while the surface in males tends to be broad and blunt. The joint that unites the two pubic bones in the front of the pelvis is called the **pubic symphysis**, which is a structure commonly used in age estimation. In young adults, the surface is billowed, but it transitions to being smooth and porous with increasing age (Hartnett 2010). The **subpubic concavity** is a depression inferior to the ischiopubic ramus. Female pelves tend to exhibit this concavity while male pelves tend not to. Finally, the large opening encircled by the pubis and ischium is called the **obturator foramen**. The shape of the foramen in females has been described as triangular while it is more likely to appear oval in males (Bass 2005).

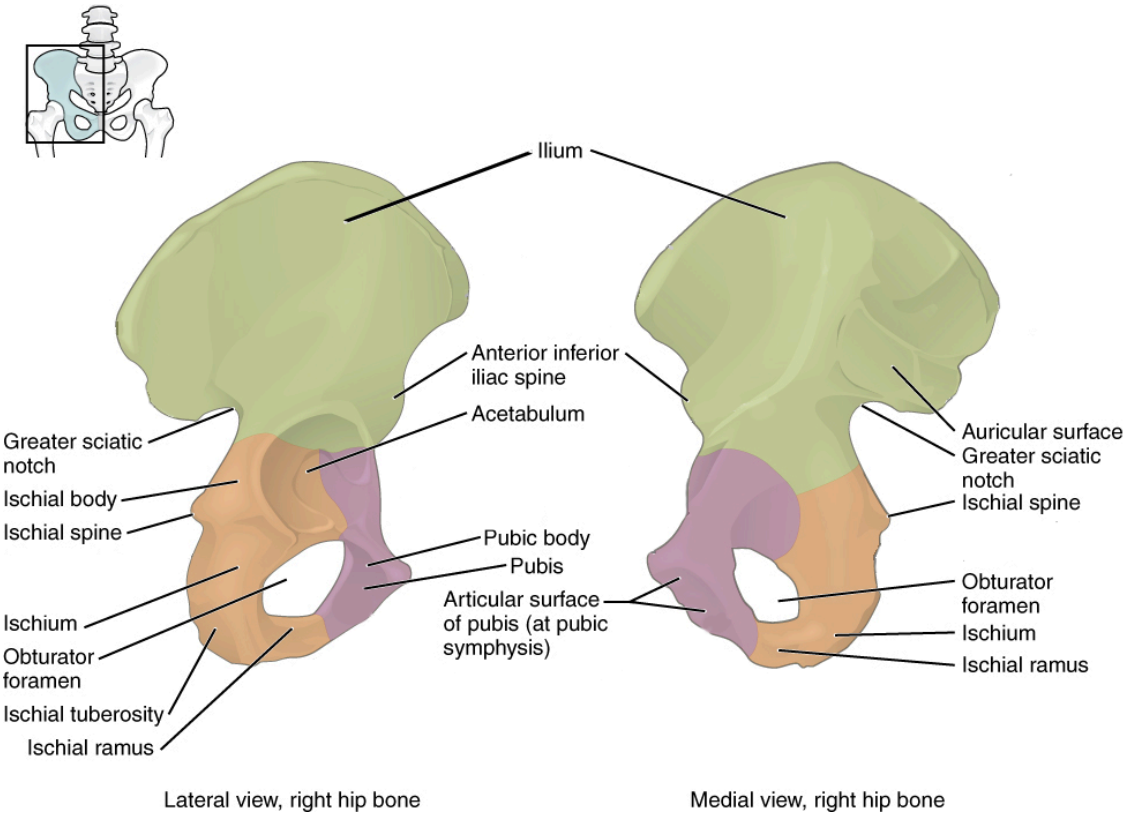

Figure A.37: The os coxae consist of three bones that fuse during development. The ilium forms the large, fan-shaped superior portion, the ischium forms the posteroinferior portion, and the pubis forms the anteromedial portion. A full text description of this image is available. Credit: The Hip Bone (Anatomy & Physiology, Figure 8.13) by OpenStax has been modified (some labels removed) and is under a CC BY 4.0 License.

Lower Limb

The bones of the lower limb skeleton include the femur, patella, tibia, fibula, seven tarsal (ankle) bones, five **metatarsal** (foot) bones, and 14 phalanges (toe bones). Each of these bones is described below along with several of the prominent features.

The **femur** is the bone of the thigh. On the proximal epiphysis of the femur are attachment sites for major hip and thigh muscles on the **greater trochanter**, **lesser trochanter**, and **gluteal tuberosity** (Figure A.38). The raised ridge on the posterior aspect of the femoral diaphysis is called the **linea aspera**, and it is a major attachment site for the quadriceps femoris muscles and other muscles, and it terminates distally by splitting into medial and lateral epicondyles, additional sites of muscle attachment. The distal epiphysis of the femur is marked by two rounded condyles that articulate with the proximal part of the tibia. The anterior surface of the distal femur articulates with the **patella** (kneecap), a bone that develops within the tendon of the quadriceps femoris muscle to enhance the function of the muscle. The patella does not articulate with the tibia.

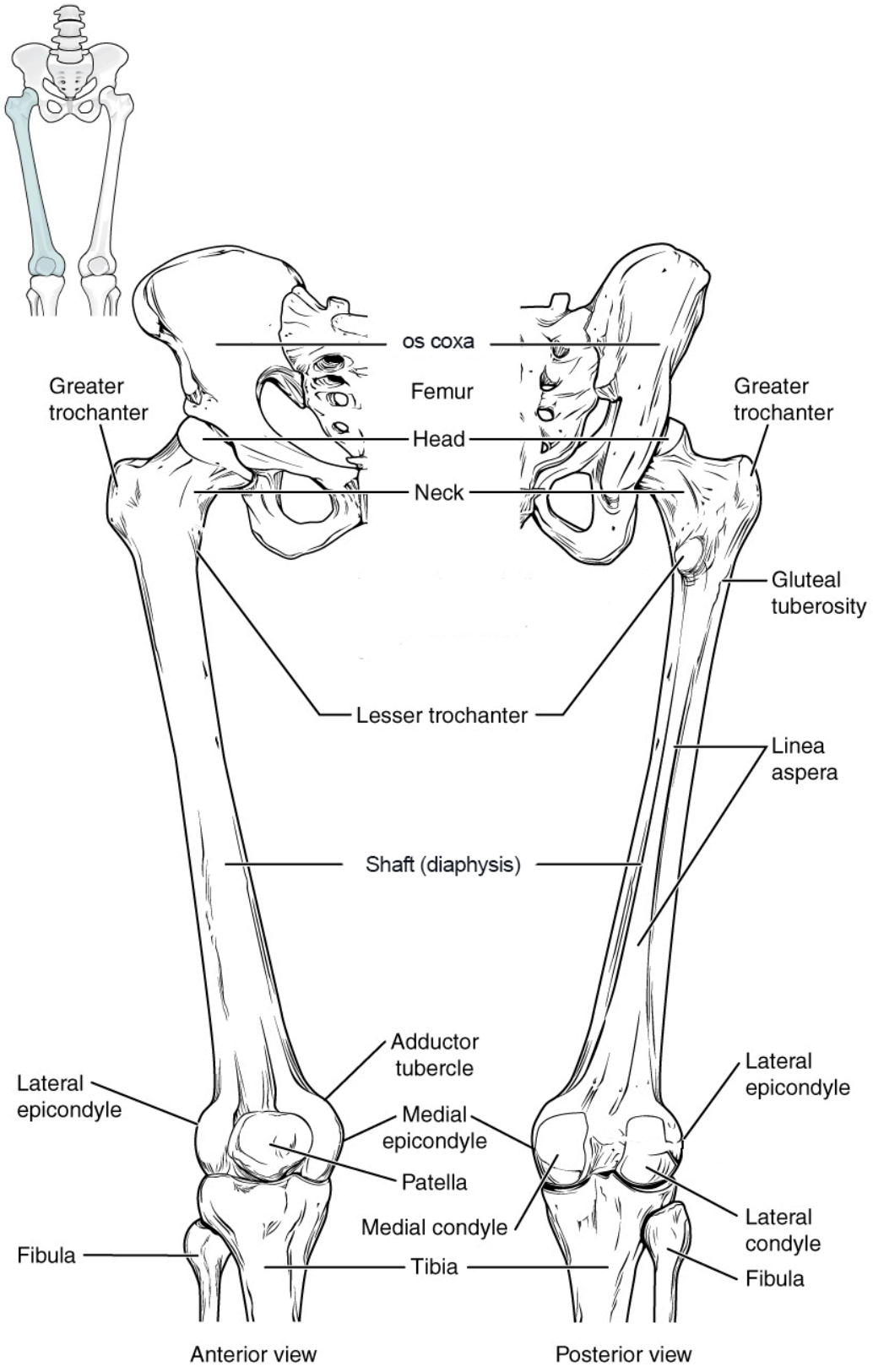

Figure A.38: The femur is the bone of the thigh that articulates superiorly with the os coxa at the hip joint and inferiorly with the tibia at the knee joint. The patella only articulates with the distal end of the femur. A full text description of this image is available. Credit: Femur and Patella (Anatomy & Physiology, Figure 8.16) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

There are two bones of the leg: **tibia** and **fibula**. The tibia is the robust, medial bone of the leg, and it is connected to the laterally positioned fibula by an interosseous membrane like in the forearm (Figure A.39). The proximal epiphysis of the tibia has two articular facets called tibial condyles that articulate with the femoral condyles. On the anterior surface of the proximal tibia is a raised projection called the **tibial tuberosity**, where the quadriceps muscle tendon attaches distally after containing the patella. On the distal epiphysis of the tibia is the **medial malleolus**, which articulates with the talus in the ankle joint. The **lateral malleolus** is a feature of the distal end of the fibula; the proximal end of the fibula articulates with the lateral portion of the proximal tibia.

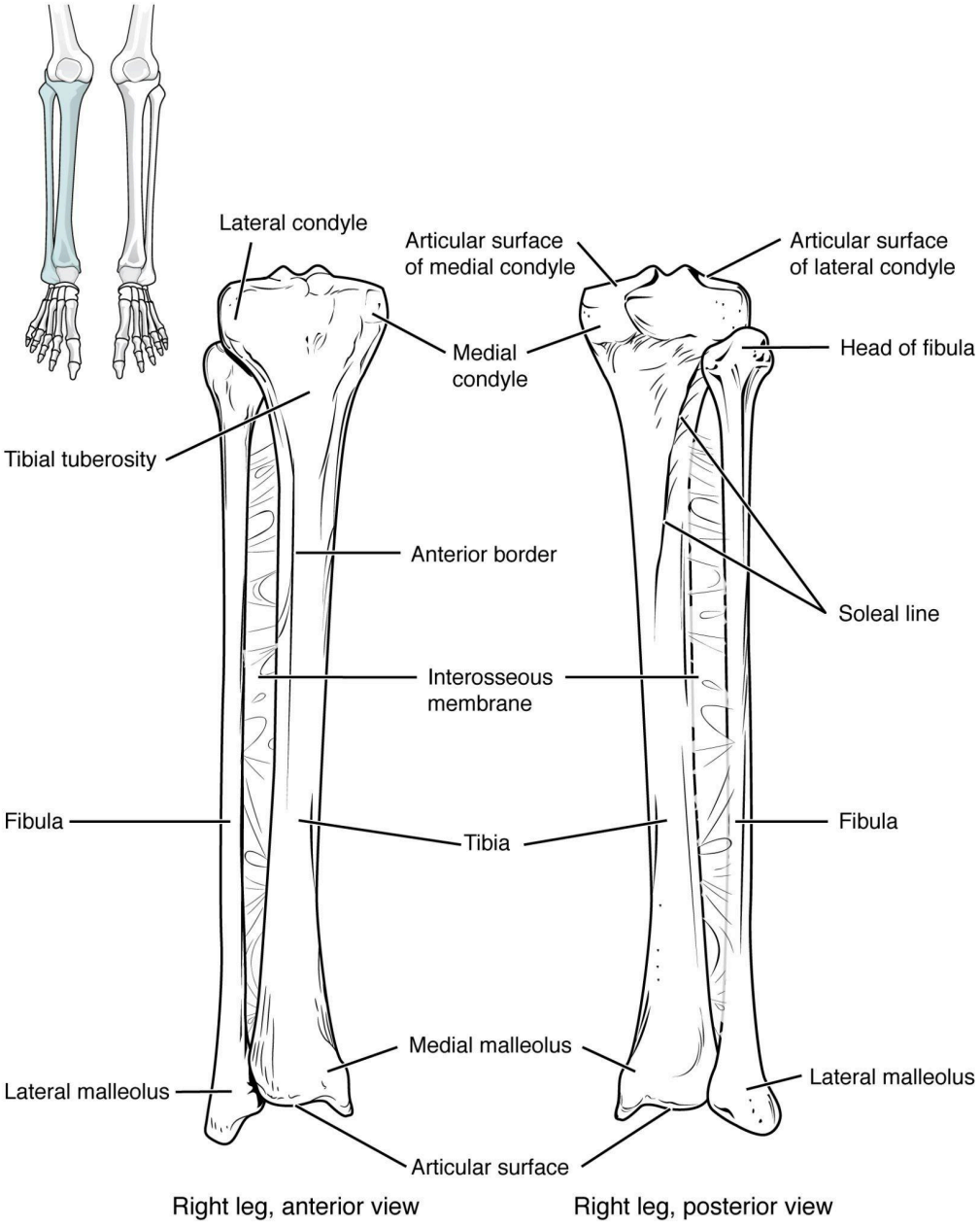

Figure A.39: The tibia is the larger, weight-bearing bone located on the medial side of the leg. It is connected to the laterally positioned fibula by an interosseous membrane. A full text description of this image is available. Credit: Tibia and Fibula (Anatomy & Physiology, Figure 8.18) by OpenStax has been modified (label removed) and is under a CC BY 4.0 License.

There are seven **tarsal bones** that comprise the ankle (Figure A.40). The **talus** is the most superior of the tarsals, and it articulates with the distal tibia and distal fibula superiorly and with the calcaneus inferiorly. The **calcaneus** is the heel of the foot; it is the largest of the tarsals. On the posterior-most aspect of the calcaneus is the **calcaneal tuberosity**, which is the attachment site for the Achilles tendon of the posterior leg. Distal

to the talus is the medially positioned navicular, the three cuneiform bones (medial, intermediate, and lateral), and the laterally positioned cuboid. Distal to the tarsals are the digital rays, each of which contains a metatarsal (foot) bone and three phalanges (proximal, middle, and distal) or toe bones. The exception to this rule is the big toe, which has fewer phalanges (proximal and distal, but no middle) than the other digits.

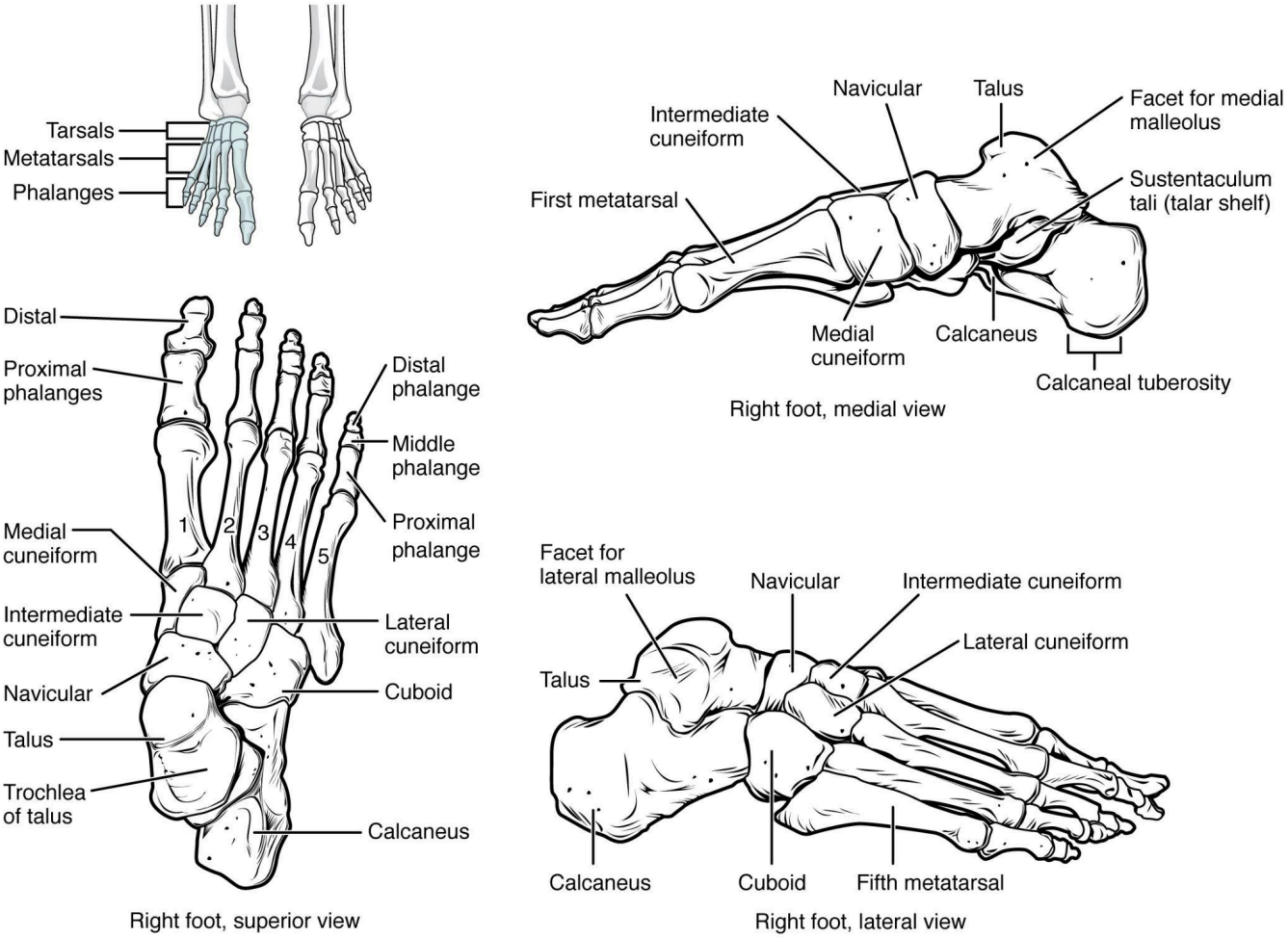

Figure A.40: The bones of the foot are divided into three groups. The posterior foot is formed by the seven tarsal bones. The mid-foot has the five metatarsal bones. The toes contain 14 phalanges. A full text description of this image is available. Credit: Bones of the Foot (Anatomy & Physiology, Figure 8.19) by OpenStax has been modified (some labels modified or removed) and is under a CC BY 4.0 License.

Review Questions

- Which bony features of the pelvic girdle are relevant to estimating age and/or sex in forensic and bioarchaeological contexts? Give specific examples of how these features differ among sexes.
- What is the mechanistic difference between endochondral and intramembranous bone formation?
- Which bones articulate with the calcaneus? Which bones articulate with the humerus?
- Which elements of the skeleton belong to the axial skeleton versus the appendicular skeleton?

Key Terms

Acetabulum: Shallow cavity of the coxa for articulation of the head of the femur.

Acromion: Lateral projection of the spine of scapula.

Anatomical position: Standing upright, facing forward with arms at the side and palms facing forward.

Anterior (ventral): Toward the front.

Appendicular skeleton: Part of the skeleton that consists of the bones of the pectoral and pelvic girdls, arms, and legs.

Atlanto-axial joint: Joint between the atlas (C1 vertebrae) and the axis (C2 vertebrae), used for turning the head side to side.

Atlanto-occipital joint: Joint between the atlas (C1 vertebrae) and occipital bone, used for nodding the head.

Auricular surface: Roughened joint surface for articulation of the sacrum.

Axial skeleton: Part of the skeleton that consists of the bones of the head and trunk.

Body of pubis: Superior bar of the pubis.

Body of the sternum: Central portion of the sternum where ribs articulate.

Buccal: Toward the cheek.

Calcaneal tuberosity: Roughened attachment site at the posterior calcaneus.

Calcaneus: Large bone that forms the heel.

Cancellous (or trabecular) bone: Porous bone found at the ends of long bones and within flat and irregular bones.

Canines: Conical teeth with a single pointed cusp used to puncture a food item.

Carpal bones: The 8 bones of the wrist: scaphoid, lunate, triquetrum, pisiform, trapezium, trapezoid, capitate, and hamate.

Centrum: Anterior body of vertebra; the main weight-bearing element of the vertebra.

Cervical region: Neck region that contains 7 vertebrae.

Clavicle: The collarbone, which connects the sternum to the scapula to form the pectoral girdle.

Coccyx: Small triangular bone that projects from the inferior part of sacrum.

Coracoid process: Hook-shaped projection from the anterior surface of the scapula.

Coronal (frontal) plane: An imaginary line that divides the body into anterior and posterior halves.

Coronal suture: Joint that connects the frontal bone to the paired parietal bones.

Coronoid process: Triangular eminence from the superior part of the mandibular ramus.

Coronoid process of ulna: Triangular projection from the anterior surface of proximal ulna.

Cortical (or compact) bone: Dense, outer surface of bone.

Cranial sutures: Fibrous joints that connect bones of the skull and face.

Cranium: Bones of the head that support the brain and face.

Cribriform foramina: Small openings in the superior plate of the ethmoid that transmit olfactory nerves.

Deltoid tuberosity: Lateral projection for attachment of deltoid muscle.

Demifacets: Partial joint surfaces on the lateral surface of the centrum of thoracic vertebrae.

Dens (or odontoid process): Projection from superior surface of centrum of C2.

Diaphysis: Shaft or central part of a long bone.

Distal: Further away from the center of the body or point of attachment.

Endochondral bone formation: Process of bone formation that occurs from a cartilage model.

Epiphysis: End of long bones.

Ethmoid bone: Unpaired bone of the skull that separates the nasal cavity from the brain.

External occipital protuberance (EOP): Projection from the occipital superior to nuchal lines.

Femur: Long bone of the thigh.

Fibula: Lateral bone of the leg.

Flat bone: Bones that are flat with thin layers of cortical bone surrounding cancellous bone.

Foramen magnum: Large opening in the occipital where the spinal cord passes.

Frontal bone: An unpaired bone that forms the anterior and superior part of the cranium.

Glabella: Part of the forehead between the eyebrows.

Glenoid cavity (or fossa): Shallow depression for the articulation of the head of the humerus.

Gluteal tuberosity: Roughened attachment site for the gluteus maximus muscle.

Gonial (or mandibular) angle: Posterior border of the mandible at the junction of the ramus and body.

Greater sciatic notch: Large indentation of the ilium.

Greater trochanter: Large projection from the lateral surface of the proximal femur.

Greater tubercle: Large projection on the superior and lateral surface of the humerus.

Head of rib: Posterior part of the rib that articulates with the centrum.

Humerus: Long bone of the arm.

Hyoid bone: U-shaped bone in the neck that does not articulate with another bone.

Ilium: Large flat bone of the superior part of the coxa.

Incisal surface: Toward the cutting edge.

Incisors: Flat and shovel shaped teeth that are used to bite into a food item.

Inferior (caudal): Away from the head or downward.

Inferior articular process: Inferior projections from the vertebral arch that connect to superior articular processes of the inferior vertebra.

Inferior nasal concha: Scroll-like paired bones that attach to the lateral part of the nasal cavity.

Intervertebral disc joints: Fibrocartilaginous joints that connect adjacent centra of vertebrae.

Intramembranous bone formation: Process of bone formation that occurs in mesenchyme and gives rise to flat bones of the skull.

Irregular bone: Bones that have a complex appearance.

Ischial spine: Thin, square projection from the ischium.

Ischial tuberosity: Large, round protrusion of the posterior and inferior ischium.

Ischiopubic ramus: Thin bar of bone that unites the pubis and ischium.

Ischium: The posterior and inferior portion of the os coxae.

Kyphosis: Anterior curvature of the spine.

Lacrimal bone: Paired bones that form the anterior and medial part of the orbit.

Lambdoidal suture: Joint that connects the parietal and occipital bones.

Lamina: Flattened portion of the vertebral arch.

Lateral: Further away from the midline.

Lateral malleolus: Prominence of the distal fibula that forms the outer part of the ankle.

Lesser trochanter: Projection from the medial surface of the proximal femur.

Lesser tubercle: Projection on the anterior and superior surface of the humerus.

Linea aspera: Elongated projection of the posterior surface of the femur.

Lingual: Toward the tongue.

Long bone: Bones that are longer than they are wide.

Lordosis: Posterior curvature of the spine.

Lumbar region: Lower back region that consists of 5 vertebrae.

Mandible: Lower jaw bone.

Mandibular condyle: Rounded projection of the mandibular ramus.

Mandibular fossa: Depression at the base of the temporal bone where the mandibular condyle articulates to form the temporomandibular (or jaw) joint.

Manubrium: Upper part of the sternum.

Mastoid process: Bony projection from the back of the temporal bone.

Maxilla bone: Upper jaw bone.

Medial: Toward the midline.

Medial malleolus: Prominence of the distal tibia that forms the inner part of the ankle.

Medullary cavity: Central cavity in the diaphysis of long bones that contains bone marrow.

Mental protuberance (eminence): Triangular projection at the front of the mandible.

Mesial: Toward the middle.

Metacarpal: The 5 bones of the palm of the hand.

Metaphysis: Junction between diaphysis and epiphysis where bone growth occurs.

Metatarsal: The 5 bones at the distal part of the foot.

Metopic suture: Joint that connects paired frontal bones and usually fuses early in childhood.

Midsagittal plane: Plane that divides the body vertically into equal left and right halves. It is also called the medial plane, because it occurs on the midline of the body.

Molars: Teeth with flatter cusps that are used to grind food prior to swallowing.

Nasal aperture: Anterior opening of the nasal cavity.

Nasal bone: Paired bones that form the bridge of the nose and the roof of the nasal cavity.

Nasal spine: Bony projection from the inferior part of the nasal aperture.

Neurocranium: Bones of the cranium that protects the brain.

Nuchal lines: Ridges on occipital from attachment of neck and back muscles.

Obturator foramen: Irregularly shaped opening within the pubis and ischium.

Occipital bone: Unpaired bone at the posterior and base of the skull.

Occlusal: Toward the chewing surface.

Olecranon process: Posterior projection of the proximal ulna.

Orbit: Bony cavity that houses the eye and associated structures.

Os coxa: Hip bone, forms from the fusion of the ilium, ischium, and pubis.

Osteoblast: Cell that secretes the matrix for bone formation.

Osteoclast: A multinucleated bone cell that resorbs bone tissue during growth and repair.

Osteocyte: Mature bone cell that lies within the bone matrix.

Osteogenic cells: Stem cells that differentiate into osteoblasts.

Osteology: The study of bones.

Palatine bone: Paired bones that form the posterior part of the hard palate.

Parasagittal plane: A vertical imaginary line adjacent to the sagittal plane that divides the body into unequal halves.

Parietal bone: Paired bones forming the lateral walls of the cranium.

Patella: Knee cap; a bone that forms in the tendon of the quadriceps femoris muscle.

Pedicle: Projection that connects the lamina to the centrum.

Phalanges: The 14 bones of the digits.

Posterior (or dorsal): Toward the back.

Premolars: Teeth with two rounded cusps that are used to grind and mash a food item.

Proximal: Closer to the center of the body or point of attachment.

Pterygoid plates: Flat projections of the sphenoid that serve as attachment sites for chewing muscles and muscles of the throat.

Pubic symphysis: Joint surface that unites the two pubic bones anteriorly.

Pubis: Anterior and inferior portion of the coxa.

Radial tuberosity: Rough projection for attachment of biceps brachii muscle.

Radius: Lateral bone of the forearm.

Ramus of the mandible: Bar-like portion of the posterior mandible.

Rib tubercle: Posterior part of the rib that articulates with the transverse process.

Sacrum: Triangular bone at the base of the spine that consists of 5 fused vertebrae.

Sagittal plane: An imaginary line that divides the body into left and right halves.

Sagittal suture: Joint that connects the parietal bones.

Scapula: Flat, triangular bone that connects the upper limb to the pectoral girdle.

Sesamoid bone: Bones that form within a tendon.

Short bone: Bones that are as wide as they are long.

Sphenoid bone: Unpaired bone that forms the anterior part of the base of the skull.

Spine: Elongated ridge on posterior surface.

Spinous process: Posterior projection of vertebral arch at the junction of the lamina.

Squamosal suture: Joint that connects the parietal and temporal bones.

Sternal end of the rib: Anterior part of rib that connects to the sternal body through costal cartilage.

Sternum: Breastbone; flat bone of the anterior chest wall.

Styloid process: Thin projection from the base of the temporal bone.

Styloid process of radius: Projection from the distal radius.

Styloid process of ulna: Projection from the distal ulna.

Subpubic concavity: Depression below the pubic symphysis to the ischiopubic rami.

Superior (or cranial): Toward the head.

Superior articular process: Superior projections from the vertebral arch that connect to inferior articular processes of the superior vertebra.

Supraorbital margin: External ridge at the superior part of the orbit.

Talus: Ankle bone that articulates with the tibia.

Tarsal bones: The 7 bones at the proximal end of foot; talus, calcaneus, navicular, cuneiforms (medial, intermediate, lateral), and cuboid.

Temporal bone: Paired bones at the lateral and base of the skull that contain the middle and inner ear.

Temporal lines: Ridges on the parietal bone from attachments of temporalis muscle and fascia.

Temporal process of zygomatic bone: Long process that forms the anterior half of the zygomatic arch.

Thoracic region: Trunk region that consists of 12 vertebrae that attach to ribs.

Tibia: Medial bone of the leg.

Tibial tuberosity: Roughened attachment site on the anterior surface of the proximal tibia.

Transverse plane: An imaginary line that divides the body into superior and inferior halves.

Transverse process: Lateral projection at the junction of the pedicle and lamina.

Ulna: Medial bone of the forearm.

Vertebral arch: Circular ring of bone at the posterior vertebra.

Vertebral canal: Cavity that contains the spinal cord.

Vertebral foramen: Opening formed by the vertebral arch.

Viscerocranium: Bones of the cranium that make up the face skeleton.

Vomer: Unpaired bone that forms the inferior part of the bony nasal septum.

Xiphoid process: Lower part of the sternum.

Zygapophyseal (facet) joints: Synovial joints between the superior and inferior articular processes.

Zygomatic arch: Bridge of bone at the cheek.

Zygomatic bone: Paired bones that form the anterior and lateral parts of the mid-face.

Zygomatic process of temporal bone: Long process that forms the posterior half of the zygomatic arch.

Zygomatic process of the maxilla: Portion of the bone that articulates with the zygomatic bone to form the anterior portion of the zygomatic arch.

About the Authors

Jason M. Organ, Ph.D.

Indiana University School of Medicine, jorgan@iu.edu

Jason M. Organ is an associate professor of anatomy, cell biology, and physiology at the Indiana University School of Medicine (IUSM) and Editor-in-Chief of *Anatomical Sciences Education*, the premier peer-reviewed journal for anatomy education research. Jason earned an M.A. in anthropology from the University of Missouri and a PhD in functional anatomy and evolution from Johns Hopkins University School of Medicine, and he completed a postdoctoral research fellowship in physical medicine and rehabilitation at the Johns Hopkins Kennedy Krieger Institute. He is the director of the IUSM clinical anatomy and physiology M.S. program and was the 2018 recipient of the prestigious Basmajian Award from the American Association for Anatomy for excellence in teaching gross anatomy and outstanding accomplishments in biomedical research and scholarship in education. Follow him on Twitter: @OrganJM.

Jessica N. Byram, Ph.D.

Indiana University School of Medicine, jbyram@iu.edu

Jessica N. Byram is an assistant professor of anatomy, cell biology, and physiology at the Indiana University School of Medicine (IUSM). Jessica earned her M.S. in human biology with a focus in forensic anthropology from the University of Indianapolis and her Ph.D. in anatomy education at IUSM. Jessica is the director of the anatomy education track Ph.D. program at IUSM. Her research interests include medical professionalism, investigating professional identity formation in medical students and residents, and exploring how to improve the learning environments at medical institutions.

References

Bass, William M. 2005. *Human Osteology: A Laboratory and Field Manual, 5th edition.* Columbia, MO: Missouri Archaeological Society.

Boldsen, Jesper L., George R. Milner, Lyle W. Konigsberg, and James W. Wood. 2002. "Transition Analysis: A New Method for Estimating Age from Skeletons." In *Paleodemography: Age Distributions from Skeletal Samples*, edited by Robert D. Hoppa and James W. Vaupel, 73–106. Cambridge UK: Cambridge University Press.

Buikstra, Jane E., and Douglas H. Ubelaker. 1994. *Standards for Data Collection From Human Skeletal Remains*. Arkansas Archaeological Survey Research Series, 44. Fayetteville, AR: Arkansas Archeological Survey.

Burr, David B., and Jason M. Organ. 2017. "Postcranial Skeletal Development and Its Evolutionary Implications." In *Building Bones: Bone Formation and Development in Anthropology*, edited by Christopher J. Percival and Joan T. Richtsmeier, 148–174. Cambridge, UK: Cambridge University Press.

Christensen, Angi M., Nicholas V. Passalacqua, and Eric J. Bartelink. 2019. *Forensic Anthropology: Current Methods and Practice*. London: Academic Press.

Cunningham, Craig, Louise Scheuer, and Sue Black. 2017. *Developmental Juvenile Osteology, 2nd Edition*. London: Elsevier.

Hartnett, Kristen M. 2010 "Analysis of Age-at-Death Estimation Using Data from a New, Modern Autopsy Sample—Part II: Sternal End of the Fourth Rib. *Journal of Forensic Sciences* 55 (5): 1152–1156.

Meindl, Richard S., and C. Owen Lovejoy. 1985. "Ectocranial Suture Closure: A Revised Method for the Determination of Skeletal Age at Death Based on the Lateral-Anterior Sutures." *American Journal of Physical Anthropology* 68 (1): 57–66.

Nawrocki, Stephen P., Krista E. Latham, Thomas Gore, Rachel M. Hoffman, Jessica N. Byram, and Justin Maiers. 2018. "Using Elliptical Fourier Analysis to Interpret Complex Morphological Features in Global Populations." In *New Perspectives in Forensic Human Skeletal Identification*, edited by Krista E. Latham, Eric J. Bartelink, and Michael Finnegan, 301–312. London: Elsevier/Academic Press.

Walker, Phillip L. 2008. "Sexing Skulls Using Discriminant Function Analysis of Visually Assessed Traits." *American Journal of Physical Anthropology* 136 (1): 39–50.