The Skeletal System

CHAPTER OBJECTIVES
After studying this chapter, you should be able to:
1. Name the functions of the skeletal system.
2. Name the two types of ossification.
3. Describe why diet can affect bone development in children and bone maintenance in older adults.
4. Describe the histology of compact bone.
5. Define and give examples of bone markings.
6. Name the cranial and facial bones.
7. Name the bones of the axial and appendicular skeleton.
### KEY TERMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetabulum</td>
<td>159</td>
</tr>
<tr>
<td>Acromial process</td>
<td>155</td>
</tr>
<tr>
<td>Alveolus</td>
<td>151</td>
</tr>
<tr>
<td>Atlas</td>
<td>153</td>
</tr>
<tr>
<td>Auditory ossicles</td>
<td>149</td>
</tr>
<tr>
<td>Axis</td>
<td>153</td>
</tr>
<tr>
<td>Calcaneus</td>
<td>161</td>
</tr>
<tr>
<td>Canaliculi</td>
<td>142</td>
</tr>
<tr>
<td>Cancellous or spongy bone</td>
<td>142</td>
</tr>
<tr>
<td>Capitate</td>
<td>157</td>
</tr>
<tr>
<td>Carpalis</td>
<td>157</td>
</tr>
<tr>
<td>Cartilage</td>
<td>138</td>
</tr>
<tr>
<td>Cervical vertebrae</td>
<td>152</td>
</tr>
<tr>
<td>Clavicle</td>
<td>155</td>
</tr>
<tr>
<td>Coccyegeal vertebrae/coccyx</td>
<td>152</td>
</tr>
<tr>
<td>Compact or dense bone</td>
<td>142</td>
</tr>
<tr>
<td>Condyile</td>
<td>145</td>
</tr>
<tr>
<td>Coracoid process</td>
<td>155</td>
</tr>
<tr>
<td>Coronal suture</td>
<td>146</td>
</tr>
<tr>
<td>Costae</td>
<td>155</td>
</tr>
<tr>
<td>Crest</td>
<td>146</td>
</tr>
<tr>
<td>Cuboid</td>
<td>161</td>
</tr>
<tr>
<td>Cuneiforms</td>
<td>161</td>
</tr>
<tr>
<td>Diaphysis</td>
<td>144</td>
</tr>
<tr>
<td>Endochondral ossification</td>
<td>140</td>
</tr>
<tr>
<td>Endosteum</td>
<td>140</td>
</tr>
<tr>
<td>Epiphyseal line</td>
<td>144</td>
</tr>
<tr>
<td>Epiphysis</td>
<td>144</td>
</tr>
<tr>
<td>Ethmoid bone</td>
<td>149</td>
</tr>
<tr>
<td>External occipital crest</td>
<td>146</td>
</tr>
<tr>
<td>External occipital protuberance</td>
<td>146</td>
</tr>
<tr>
<td>Femur</td>
<td>159</td>
</tr>
<tr>
<td>Fibula</td>
<td>160</td>
</tr>
<tr>
<td>Fontanelle</td>
<td>140</td>
</tr>
<tr>
<td>Foramen</td>
<td>146</td>
</tr>
<tr>
<td>Foramen magnum</td>
<td>146</td>
</tr>
<tr>
<td>Fossae</td>
<td>145</td>
</tr>
<tr>
<td>Fracture</td>
<td>144</td>
</tr>
<tr>
<td>Frontal bone</td>
<td>146</td>
</tr>
<tr>
<td>Gladiolus</td>
<td>155</td>
</tr>
<tr>
<td>Glenoid fossa</td>
<td>155</td>
</tr>
<tr>
<td>Hamate</td>
<td>157</td>
</tr>
<tr>
<td>Haversian/central canals</td>
<td>142</td>
</tr>
<tr>
<td>Head</td>
<td>146</td>
</tr>
<tr>
<td>Hematopoiesis</td>
<td>138</td>
</tr>
<tr>
<td>Humerus</td>
<td>155</td>
</tr>
<tr>
<td>Hyoid bone</td>
<td>152</td>
</tr>
<tr>
<td>Ilium</td>
<td>158</td>
</tr>
<tr>
<td>Incus</td>
<td>149</td>
</tr>
<tr>
<td>Intramembranous ossification</td>
<td>140</td>
</tr>
<tr>
<td>Ischium</td>
<td>158</td>
</tr>
<tr>
<td>Kyphosis</td>
<td>154</td>
</tr>
<tr>
<td>Lacrimal bones</td>
<td>151</td>
</tr>
<tr>
<td>Lacunae</td>
<td>142</td>
</tr>
<tr>
<td>Lamella</td>
<td>142</td>
</tr>
<tr>
<td>Lamboid suture</td>
<td>146</td>
</tr>
<tr>
<td>Ligaments</td>
<td>138</td>
</tr>
<tr>
<td>Line</td>
<td>146</td>
</tr>
<tr>
<td>Lordosis</td>
<td>154</td>
</tr>
<tr>
<td>Lumbar vertebrae</td>
<td>152</td>
</tr>
<tr>
<td>Lunate</td>
<td>157</td>
</tr>
<tr>
<td>Malleus</td>
<td>149</td>
</tr>
<tr>
<td>Mandible bone</td>
<td>151</td>
</tr>
<tr>
<td>Manubrium</td>
<td>155</td>
</tr>
<tr>
<td>Mastoid portion of temporal bone</td>
<td>146</td>
</tr>
<tr>
<td>Maxillary bones</td>
<td>150</td>
</tr>
<tr>
<td>Meatus/canal</td>
<td>146</td>
</tr>
<tr>
<td>Medullary cavity</td>
<td>145</td>
</tr>
<tr>
<td>Metacarpal bones</td>
<td>157</td>
</tr>
<tr>
<td>Metaphysis</td>
<td>144</td>
</tr>
<tr>
<td>Metatarsals</td>
<td>161</td>
</tr>
<tr>
<td>Nasal bones</td>
<td>150</td>
</tr>
<tr>
<td>Navicular/scaphoid</td>
<td>157</td>
</tr>
<tr>
<td>Neck</td>
<td>146</td>
</tr>
<tr>
<td>Obturator foramen</td>
<td>159</td>
</tr>
<tr>
<td>Occipital bone</td>
<td>146</td>
</tr>
<tr>
<td>Occipital condyle</td>
<td>146</td>
</tr>
<tr>
<td>Olecranon process</td>
<td>157</td>
</tr>
<tr>
<td>Orbital margin</td>
<td>146</td>
</tr>
<tr>
<td>Ossification</td>
<td>140</td>
</tr>
<tr>
<td>Osteoblasts</td>
<td>140</td>
</tr>
<tr>
<td>Osteoclasts</td>
<td>140</td>
</tr>
<tr>
<td>Osteomalacia</td>
<td>144</td>
</tr>
<tr>
<td>Osteon</td>
<td>142</td>
</tr>
<tr>
<td>Osteoprogenitor cell</td>
<td>140</td>
</tr>
<tr>
<td>Palatine bones</td>
<td>150</td>
</tr>
<tr>
<td>Parietal bones</td>
<td>147</td>
</tr>
<tr>
<td>Patella</td>
<td>159</td>
</tr>
<tr>
<td>Pelvic girdle</td>
<td>158</td>
</tr>
<tr>
<td>Periosteum</td>
<td>140</td>
</tr>
<tr>
<td>Petrous part of temporal bone</td>
<td>146</td>
</tr>
</tbody>
</table>

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INTRODUCTION

The supporting structure of the body is the framework of joined bones that we refer to as the skeleton. It enables us to stand erect, to move in our environment, to accomplish extraordinary feats of artistic grace like ballet moves and athletic endeavors like the high jump as well as normal physical endurance. The skeletal system allows us to move a pen and write and aids us in breathing. It is closely associated with the muscular system. The skeletal system includes all the bones of the body and their associated cartilage, tendons, and ligaments. Despite the appearance of the bones, they are indeed composed of living tissue. The hard, “dead” stonelike appearance of bones is due to mineral salts like calcium phosphate embedded in the inorganic matrix of the bone tissue. Leonardo da Vinci (1452–1519), the famous Italian Renaissance artist and scientist, is credited as the first anatomist to correctly illustrate the skeleton with its 206 bones. See Concept Map 7-1: Skeletal System.

THE FUNCTIONS OF THE SKELETAL SYSTEM

The skeleton has five general functions:

1. It supports and stabilizes surrounding tissues such as muscles, blood and lymphatic vessels, nerves, fat, and skin.

2. It protects vital organs of the body such as the brain, spinal cord, the heart, and lungs, and it protects other soft tissues of the body.

3. It assists in body movement by providing attachments for muscles that pull on the bones that act as levers.

4. It manufactures blood cells. This process is called hematopoiesis (hem-ah-toh-poy-EE-sis) and occurs chiefly in red bone marrow.

5. It is a storage area for mineral salts, especially phosphorus and calcium, and fats.

Associated with the bones are cartilage, tendons, and ligaments. Cartilage, a connective tissue, is the environment in which bone develops in a fetus. It is also found at the ends of certain bones and in joints in adults, providing a smooth surface for adjacent bones to move against each other. Ligaments are tough connective tissue structures that attach bones to bones like the ligament that attaches the head of the femur to the acetabulum of the pelvic bone in the hip joint. Tendons are similar structures that attach muscle to bone.

THE GROWTH AND FORMATION OF BONE

The skeleton of a developing fetus is completely formed by the end of the third month of pregnancy.
However, at this time, the skeleton is predominantly cartilage. During the subsequent months of pregnancy, ossification, the formation of bone, and growth occur. The osteoblasts invade the cartilage and begin the process of ossification. Longitudinal growth of bones continues until approximately 15 years of age in girls and 16 years of age in boys. This takes place at the epiphyseal line or plate. Bone maturation and remodeling continue until the age of 21 in both sexes. It would be incorrect to state that cartilage actually turns into bone. Rather cartilage is the environment in which the bone develops.
The strong protein matrix is responsible for a bone’s resilience or “elasticity” when tension is applied to the bone so that it gives a little under pressure. The mineral salts deposited into this protein matrix are responsible for the strength of the bone so that it does not get crushed when pressure is applied to the bone.

Deposition of Bone

Bone develops from spindle-shaped cells called osteoblasts that develop from undifferentiated bone cells called osteoprogenitor (oss-tee-oh-pro-JEN-th-tohr) cells (Figure 7-1). These osteoblasts are formed beneath the fibrovascular membrane that covers a bone called the periosteum (pair-ee-AHS-tee-um) (Figure 7-2). These osteoblasts are also found in the endosteum (en-DOS-tee-um), which lines the bone marrow or medullary cavity. Deposition of bone is controlled by the amount of strain or pressure on the bone. The more strain, the greater the deposition of bone. The heel bone, or calcaneum, is a large strong bone because it receives the weight of the body when walking. Bones (and muscles) in casts will waste away or atrophy, whereas continued and excessive strain via exercise will cause the bone and muscles to grow thick and strong. This is the reason children are told to run and play to develop strong bones during their formative years. When a cast is removed, the patient participates in physical therapy to build up the bone (and muscles) that became weak while in the cast.

A break in a bone will stimulate injured osteocytes to proliferate. They then secrete large quantities of matrix to form new bone. In addition, other types of bone cells called osteoclasts are present in almost all cavities of bone (see Figure 7-1). They are derived from immune system cells and are responsible for the reabsorption of bone. These are large cells that remove bone from the inner side during remodeling, such as when a bone is broken. These cells are also responsible for the ability of a crooked bone to become straight. If a young child is detected to be bow-legged, the physician will apply braces to the legs. Periodic tightening of the braces puts pressure on the bone so that new bone is deposited by osteocytes (mature osteoblasts), or mature bone cells, while the osteoclasts remove the old bone during this remodeling process. This process can cause a broken bone that was set improperly to heal incorrectly. To correct this, the bone must be broken again and correctly reset to straighten properly.

Types of Ossification

There are two types of ossification (oss-sih-fih-KAY-shun) (the formation of bone by osteoblasts). The first type is intramembranous ossification, in which dense connective tissue membranes are replaced by deposits of inorganic calcium salts, thus forming bone. The membrane itself will eventually become the periosteum of the mature bone. Underneath the periosteum will be compact bone with an inner core of spongy or cancellous bone. Only the bones of the cranium or skull form by this process. Because complete ossification in this way does not occur until a few months after birth, one can feel these membranes on the top of a baby’s skull as the soft spot or fontanelle (fon-tah-NELL). This allows the baby’s skull to give slightly as it moves through the birth canal.

The other bones of the body are formed by the second process called endochondral (en-doh-KON-dral) ossification (Figure 7-3). This is the process in which cartilage is the environment in which the bone cells develop (endo = inside, chondro = cartilage). As the organic matrix becomes synthesized, the osteoblast becomes completely surrounded by the bone matrix and the osteoblast becomes a mature bone cell or osteocyte. Both types of ossification result in compact and cancellous bone.

![FIGURE 7-1. The different types of bone cells.](image)
In order to maintain strong and healthy bones throughout our lives, it is important to maintain a balanced diet with a daily intake of calcium. We can do this by consuming dairy products such as milk, yogurt, and cheeses. In addition to diet, a regular regimen of exercise is also important. As bones are developing in children and adolescents, it is important to increase calcium intake and exercise more rigorously. As we mature we still require calcium; however, we require it in smaller amounts. Daily exercise, as simplistic as walking in older age and running or playing sports in middle age, will help maintain a healthy skeletal system. When playing sports, walking, or running, it is crucial to wear proper foot attire with arch supports and a good fit. This will prevent future problems with bones of the feet. Proper posture during walking and sitting will also maintain healthy and strong bones.
In a healthy body, a balance must exist between the amount of calcium stored in the bones, the calcium in the blood, and the excess calcium excreted by the kidneys and via the digestive system. The proper calcium ion concentration in the blood and bones is controlled by the endocrine system. Two hormones, calcitonin and parathormone, control the calcium concentration in our bodies. Calcitonin causes calcium to be stored in the bones; parathormone causes it to be released into the bloodstream.

The Haversian System of Compact Bone

The haversian (hah-VER-shan) canal, also called an osteon, was named for an English physician, Clopton Havers (1650–1702), who first described it as a prominent feature of compact bone (Figure 7-4). This system allows for the effective metabolism of bone cells surrounded by rings of mineral salts. It has several components. Running parallel to the surface of the bone are many small canals containing blood vessels (capillaries, arterioles, venules) that bring in oxygen and nutrients and remove waste products and carbon dioxide. These canals are called haversian or central canals and are surrounded by concentric rings of bone, each layer of which is called a lamella (lah-MELL-ah). Between two lamellae or rings of bone are several tiny cavities called lacunae (lah-KOO-nee). Each lacuna contains an osteocyte or bone cell suspended in tissue fluid. The lacunae are all connected to each other and ultimately to the larger haversian or central canals by much smaller canals called canaliculi (kan-ah-LIK-you-lye). Canals running horizontally to the haversian (central) canals, also containing blood vessels, are called Volkmann’s or perforating canals. It is tissue fluid that circulates through all these canals and bathes the osteocyte, bringing in oxygen and food and carrying away waste products and carbon dioxide, keeping the osteocytes alive and healthy.

Cancellous Bone

Cancellous or spongy bone is located at the ends of long bones and forms the center of all other bones. It consists of a meshwork of interconnecting sections of bone called trabeculae (trah-BEK-you-lee), creating the spongelike appearance of cancellous bone (Figure 7-2C). The trabeculae give strength to the bone without the added weight of being solid. Each trabecula consists of...
several lamellae with osteocytes between the lamellae just as in compact bone. The spaces between the trabeculae are filled with bone marrow. Nutrients exit blood vessels in the marrow and pass by diffusion through the canaliculi of the lamellae to the osteocytes in the lacunae.

**Bone Marrow**

The many spaces within certain cancellous bone are filled with **red bone marrow**. This marrow is richly supplied with blood and consists of blood cells and their precursors. The function of red bone marrow is hematopoiesis, or the formation of red and white blood cells and blood platelets. Therefore, blood cells in all stages of development will be found in red bone marrow. We shall discuss in more detail the different stages of blood cell development in Chapter 13.

In an adult, the ribs, vertebrae, sternum, and bones of the pelvis all contain red bone marrow in their cancellous tissue. These bones produce blood cells in adults. Red bone marrow within the ends of the humerus or upper arm and the femur or thigh is plentiful at birth but gradually decreases in amount as we age.

**Yellow bone marrow** is connective tissue consisting chiefly of fat cells. It is found primarily in the shafts of long bones within the medullary cavity, the central area of the bone shaft (see Figure 7-2B). Yellow bone marrow extends into the osteons or haversian systems, replacing red bone marrow when it becomes depleted.
The individual bones of the body can be divided by shape into five categories: long, short, flat, irregular, and sesamoid (Figure 7-6).

**Long Bones**

Long bones (see Figure 7-2) are bones whose length exceeds their width and consist of a diaphysis (dye-**AFF**-ih-sis) or shaft composed mainly of compact bone, a metaphysis (meh-**TAFF**-ih-sis) or flared portion at each end of the diaphysis consisting mainly of cancellous or spongy bone, and two extremities, each called an epiphysis (eh-**PIFF**-ih-sis), separated from the metaphysis by the epiphyseal or growth line where longitudinal growth of the bone occurs. The shaft consists mainly of compact bone. It is thickest toward the middle of the bone because strain on the bone is greatest at that point. The strength of a long bone is also ensured by the slight curvature of the shaft, a good
Irregular Bones

*Irregular bones* are bones of a very peculiar and different or irregular shape. They consist of spongy bone enclosed by thin layers of compact bone. Examples of irregular bones are the vertebrae and the ossicles of the ears.

Sesamoid Bones

*Sesamoid (SESS-ah-moyd) bones* are small rounded bones. These bones are enclosed in tendon and fascial tissue and are located adjacent to joints. They assist in the functioning of muscles. The kneecap, or patella, is the largest of the sesamoid bones. Some of the bones of the wrist and ankle could also be classified as sesamoid bones as well as short bones.

**BONE MARKINGS**

The surface of any typical bone will exhibit certain projections called *processes* or certain depressions called *fossae* (*FOSS-ee*), or both. These markings are functional in that they can help join one bone to another, provide a surface for the attachments of muscles, or serve as a passageway into the bone for blood vessels and nerves. The following is a list of some terms and definitions regarding bone markings.

**Processes**

A process is a general term referring to any obvious bony prominence. The following is a list of specific examples of processes.

1. **Spine**: any sharp, slender projection such as the spinous process of a vertebra (see Figure 7-14).
2. **Condyle** (*KON*-dial): a rounded or knuckle-like prominence usually found at the point of articulation with another bone such as the lateral and medial condyles of the femur (see Figure 7-23).
3. **Tubercle** (*TOO*-ber-kl): a small round process like the lesser tubercle of the humerus (see Figure 7-19).
4. **Trochlea** (*TROK*-lee-ah): a process shaped like a pulley as in the trochlea of the humerus (see Figure 7-19).
5. **Trochanter** (tro-*KAN*-ter): a very large projection like the greater and lesser trochanter of the femur (see Figure 7-23).
6. **Crest**: a narrow ridge of bone like the iliac crest of the hip bone (see Figure 7-22).
7. **Line**: a less prominent ridge of bone than a crest.
8. **Head**: a terminal enlargement like the head of the humerus and the head of the femur (see Figures 7-19 and 7-23).
9. **Neck**: that part of a bone that connects the head or terminal enlargement to the rest of the bone, like the neck of the femur (see Figures 7-19 and 7-23).

**Fossae**

A fossa is a general term for any depression or cavity in or on a bone. The following is a list of specific examples of fossae.

1. **Suture**: a narrow junction often found between two bones like the sutures of the skull bones (see Figure 7-9).
2. **Foramen**: an opening through which blood vessels, nerves, and ligaments pass like the foramen magnum of the occipital bone of the skull or the obturator foramen of the pelvic bone (see Figure 7-22).
3. **Meatus or canal**: a long tube-like passage, like the auditory meatus or canal (see Figure 7-9).
4. **Sinus or antrum**: a cavity within a bone like the nasal sinuses or frontal sinus (see Figure 7-8).
5. **Sulcus**: a furrow or groove like the intertubercular sulcus or groove of the humerus (see Figure 7-19).

**DIVISIONS OF THE SKELETON**

The skeleton typically has 206 named bones. The **axial** part consists of the skull (28 bones, including the cranial and facial bones), the hyoid bone, the vertebrae (26 bones), the ribs (24 bones), and the sternum. The **appendicular** part of the skeleton consists of the bones of the upper extremities or arms (64 bones, including the shoulder girdle bones) and the bones of the lower extremities or legs (62 bones, including the bones of the pelvic girdle) (Figure 7-7).

**THE AXIAL SKELETON**

The skull, in the correct use of the term, includes the cranial and the facial bones. We will discuss the cranial bones first.

**The Cranial Bones**

The bones of the cranium have a number of important functions. They protect and enclose the brain and special sense organs like the eyes and ears. Muscles for mastication or chewing and muscles for head movement attach to certain cranial bones. At certain locations, air sinuses or cavities are present that connect with the nasal cavities (Figure 7-8). All of the individual bones of the cranium are united by immovable junction lines called sutures.

The **frontal bone** is a single bone that forms the forehead, the roof of the nasal cavity, and the orbits, which are the bony sockets that contain the eyes (Figure 7-9). Important bone markings are the **orbital margin**, a definite ridge above each orbit located where eyebrows are found, and the **supraorbital ridge**, which overlies the frontal sinus and can be felt in the middle of your forehead. The **coronal suture** is found where the frontal bone joins the two parietal bones.

The two **parietal** (pah-RYE-eh-tal) **bones** form the upper sides and roof of the cranium. They are joined at the **sagittal suture** in the midline.

The **occipital bone** is a single bone that forms the back and base of the cranium (see Figure 7-9) and joins the parietal bones superiorly at the **lambdoid suture**. The inferior portion of this bone has a large opening called the **foramen magnum** through which the spinal cord connects with the brain. On each lower side of the occipital bone is a process called the **occipital condyle**. These processes are significant because they articulate with depressions in the first cervical vertebra (atlas), thus allowing the head to connect with and rest on the vertebrae. Other notable markings are the **external occipital crest** and the **external occipital protuberance**, which can be felt through the scalp at the base of the neck. Several ligaments and muscles attach to these regions.

The two **temporal bones** help form the lower sides and base of the cranium (see Figure 7-9). Each temporal bone encloses an ear and bears a fossa for articulation with the lower jaw or mandible. The temporal bones are irregular in shape and each consists of four parts: the squamous, petrous, mastoid, and tympanic parts. The **squamous portion** is the largest and most superior of the four parts. It is a thin flat plate of bone that forms the temple. Projecting from its lower part is the zygomatic process that forms the lateral part of the zygomatic arch or cheek bone. The **petrous part** is found deep within the base of the skull where it protects and surrounds the inner ear. The **mastoid portion** is located behind and below the auditory meatus or opening of the ear. The mastoid process is a rounded projection of the mastoid portion of the temporal bone easily felt behind the ear. Several muscles of the neck attach...
FIGURE 7-7. The human skeletal system. (A) Anterior view. (B) Posterior view.
FIGURE 7-8. (A) The paranasal sinuses. (B) Cross section of the ear showing the ossicles.
Finally, the **tympanic plate** forms the floor and anterior wall of the external auditory meatus. A long and slender styloid process can be seen extending from the undersurface of this plate. Ligaments that hold the hyoid bone in place (which supports the tongue) attach to this styloid process of the tympanic plate of the temporal bone.

The single **sphenoid bone** forms the anterior portion of the base of the cranium (Figures 7-9 and 7-10). When viewed from below it looks like a butterfly. It acts as an anchor binding all of the cranial bones together.

The single **ethmoid bone** is the principal supporting structure of the nasal cavities and helps form part of the orbits. It is the lightest of the cranial bones (see Figures 7-9 and 7-10).

The six **auditory ossicles** are the three bones found in each ear (see Figure 7-8B): the **malleus** or hammer, the **stapes** (STAY-peez) or stirrup, and the **incus** or anvil. These tiny bones are highly specialized in both structure and function and are involved in exciting the hearing receptors.

The **wormian bones** or **sutural bones** are located within the sutures of the cranial bones. They vary in number, are small and irregular in shape, and are never included in the total number of bones in the body. They form as a result of intramembranous ossification of the cranial bones.

**StudyWARE™ Connection**

Play an interactive game labeling the cranial bones on your StudyWARE™ CD-ROM.
The Facial Bones

Like the bones of the cranium, the facial bones are also united by immovable sutures, with one exception: the lower jawbone or mandible. This bone is capable of movement in a number of directions. It can be elevated and depressed as in talking, and it can protract and retract and move from side to side as in chewing.

The two nasal bones are thin and delicate bones that join in a suture to form the bridge of the nose (see Figure 7-10). The two palatine bones form the posterior part of the roof of your mouth or part of the hard palate. This region is the same as the floor of the nasal cavity. Upward extensions of the palatine bones help form the outer walls of the nasal cavity.

The two maxillary bones make up the upper jaw (see Figure 7-10). Each maxillary bone consists of five parts: a body, a zygomatic process, a frontal process, a palatine process, and an alveolar process. The large body of the maxilla forms part of the floor and outer wall of the nasal cavity, the greater part of the floor of the orbit, and
much of the anterior face below the temple. The body is covered by a number of facial muscles and contains a large maxillary sinus located lateral to the nose. The zygomatic process extends laterally to participate in the formation of the cheek. (Processes are named according to the bone they go to; thus, the zygomatic process of the maxillary bone goes toward and joins the zygomatic or cheekbone.) The frontal process extends upward to the frontal bone or forehead. The palatine process extends posteriorly in a horizontal plane to join or articulate with the palatine bone and actually forms the greater anterior portion of the hard palate or roof of the mouth. The alveolar processes bear the teeth of the upper jaw, and each tooth is embedded in an **alveolus** (al-VEE-oh-lus) or socket. The two maxillary bones join at the intermaxillary suture. This fusion is usually completed just before birth. If the two bones do not unite to form a continuous structure, the resulting defect is called a cleft palate and is usually associated with a cleft lip. With today's surgical techniques, the defect can be repaired early in the development of the child.

The two **zygomatic bones**, also known as the **malar bones**, form the prominence of the cheek and rest on the maxillae (see Figure 7-10). Its maxillary process joins the maxillary bone by connecting with the maxillary bone's zygomatic process. Each zygomatic bone has a frontal process extending upward to articulate with the frontal bone and a smaller temporal process that joins laterally with the temporal bone, thus forming the easily identified zygomatic arch.

The two **lacrimal** (LAK-ram-ill) **bones** make up part of the orbit at the inner angle of the eye (see Figure 7-10). These very small and thin bones lie directly behind the frontal process of the maxilla. Their lateral surface has a depression or fossa that holds the lacrimal sac or tear sac and provides a canal for the lacrimal duct. Tears are directed from this point to the inferior meatus of the nasal cavity after they have cleansed and lubricated the eye.

The two **turbinates** or **nasal conchae bones** are very thin and fragile (see Figure 7-10). There is one in each nostril on the lateral side. They extend to but do not quite reach the bony portion of the nasal septum. They help form a series of shelves in the nasal cavity where air is moistened, warmed, and filtered.

The single **vomer bone** is a flat bone that makes up the lower posterior portion of the nasal septum (see Figure 7-10).

The single **mandible bone** develops in two parts. The intervening cartilage ossifies in early childhood, and the bone becomes fused into a single continuous structure. It is the strongest and longest bone of the face (see Figure 7-10). It consists of a U-shaped body with alveolar processes to bear the teeth of the lower jaw (just like the maxillary bone’s alveolar processes that bear the teeth of the upper jaw). On each side of the body are the rami that extend perpendicularly upward. Each ramus has a condyle for articulation with the mandibular fossa of the temporal bone, thus allowing for the wide range of movement of the lower jawbone (see Figure 7-9).

### The Orbits

The orbits are the two deep cavities in the upper portion of the face that protect the eyes. A number of bones of the skull contribute to their formation. Refer to Figure 7-10 to view these bones. Each orbit consists of the following bones:

**Area of Orbit** | **Participating Bones**
--- | ---
Roof | Frontal, sphenoid
Floor | Maxilla, zygomatic
Lateral wall | Zygomatic, greater wing of sphenoid
Medial wall | Maxilla, lacrimal, ethmoid

### The Nasal Cavities

The framework of the nose surrounding the two nasal fossae is located in the middle of the face between the hard palate inferiorly and the frontal bone superiorly.

The nose is formed by the following bones (see Figure 7-10):

**Area of Nose** | **Participating Bones**
--- | ---
Roof | Ethmoid
Floor | Maxilla, palatine
Lateral wall | Maxilla, palatine
Septum of medial wall | Ethmoid, vomer, nasal
Bridge | Nasal

### The Foramina of the Skull

If one views the skull inferiorly and observes the floor of the cranial cavity, one can observe the largest foramen of the skull, the foramen magnum. One can also observe a number of much smaller foramina or openings that penetrate the individual bones of the skull. They all have names and are passageways for blood vessels and nerves entering and exiting the various organs of the skull.
The Hyoid Bone

The single hyoid bone is a unique component of the axial skeleton because it has no articulations with other bones (Figure 7-11). It is rarely seen as part of an articulated skeleton in a lab. Rather, it is suspended from the styloid process of the temporal bone by two styloid ligaments. Externally, you can detect its position in the neck just above the larynx or voice box a fair distance from the mandible. It is shaped like a horseshoe consisting of a central body with two lateral projections. The larger projections are the greater cornu, and the smaller lateral projections are the lesser cornu. The hyoid bone acts as a support for the tongue and its associated muscles. It also helps elevate the larynx during swallowing and speech.

How to Study the Bones of the Skull

When learning the different bones of the skull, one of the best methods is to first refer to the colored plates in your textbook where each individual bone is portrayed in a different color. Refer to Figure 7-10, the anterior view of the skull, and Figure 7-9, the lateral view of the skull. Once you get a sense of where these bones are located, use a model of a human skull (either real bone or a good plastic reproduction) and search for sutures as a guide. Remember that in a real skull the older the skull, the less obvious the sutures become. As we age, the sutures tend to disappear or become very faint. The colored plates will greatly assist you in learning where the bones of the skull are found.

The Torso or Trunk

The sternum, ribs, and vertebrae make up the trunk or torso of the axial skeleton. The vertebrae are rigid and provide support for the body but the fibrocartilaginous disks between the vertebrae allow for a high degree of flexibility. The disks and vertebrae protect the delicate spinal cord contained within their articulated channels formed from successive foramina.

The spinal column is formed from a series of 26 irregular bones called vertebrae, separated and cushioned by the intervertebral disks of cartilage. A typical vertebra has the following parts or features (Figure 7-12): the body is a thick disk-shaped anterior portion pierced with numerous small holes for nerves and blood vessels that nurture the bone. The neural arch encloses a space, the neural or vertebral foramen, for passage of the spinal cord. The arch has three processes for muscle attachment: the spinous process, quite large on the thoracic vertebrae, directed backward, and two transverse processes, one on each side of the vertebra. The articular processes are used for articulating with the vertebra immediately above by the two superior articular processes and with the vertebra immediately below by the two inferior articular processes. The vertebral arch is composed of two portions on each side, the pedicles notched above and below for passage of nerves to and from the spinal cord, and the laminae, which form the posterior wall of the vertebral column.

Refer to Figure 7-13 for views of the structure of the vertebral column. There are 7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae. These all remain separate throughout life and are referred to as movable. In addition there are five sacral vertebrae that become fused by adult life and form the single sacrum. There are also four coccygeal vertebrae that unite firmly to form the single coccyx or tailbone. These last two, the sacrum and coccyx, are called fixed; hence the vertebrae are referred to in number as 26 rather than 33.
The cervical vertebrae are the smallest vertebrae. The first two have been given special names (Figure 7-14). The first is called the atlas (named after Atlas in Greek mythology who held up the world); it supports the head by articulation with the condyles of the occipital bone. The second vertebra is the axis; it acts as the pivot on which the atlas and head rotate. The thoracic vertebrae have two distinguishing characteristics: the long spinous process pointing downward and six facets, three on each side for articulation with a rib. The lumbar vertebrae are the largest and the strongest. They are modified for the attachment of the powerful back muscles. The sacrum is a triangular and slightly curved bone. The curving coccyx can move slightly to increase the size of the birth canal during delivery in the female.
The normal curvatures of the spine can become exaggerated as a result of injury, poor body posture, or disease (Figure 7-15). When the posterior curvature of the spine is accentuated in the upper thoracic region, the condition is called kyphosis. This results in the commonly referred to condition called hunchback. It is particularly common in older individuals due to osteoporosis. It can also be caused by tuberculosis of the spine, osteomalacia, or rickets. Lordosis, or swayback, is an abnormal accentuated lumbar curvature. It also can result from rickets or spinal tuberculosis. Temporary lordosis is common in men with potbellies and pregnant women who throw back their shoulders to preserve their center of gravity, thus accentuating the lumbar curvature. Scoliosis (skoh-lee-OH-sis), meaning twisted condition, is an abnormal lateral curvature of the spine that occurs most often in the thoracic region. It can be common in late childhood for girls, but the most severe conditions result from abnormal vertebral structure, lower limbs of unequal length, or muscle paralysis on one side of the body. Severe cases can be treated with body braces or surgically before bone growth ceases.

In addition to providing protection for the spinal cord and support for the body, the vertebral column is also built to withstand forces of compression many times the weight of the body. The fibrocartilaginous intervertebral disks act as cushions so that landing on your feet after a jump or a fall will help prevent the vertebrae from fracturing. Epidural anesthetics are commonly injected into the lower lumbar region during labor and birth.
The Thorax

The thorax or the rib cage of the body is made up of the sternum, the costal cartilages, the ribs, and the bodies of the thoracic vertebrae. This bony cage encloses and protects the heart and lungs. It also supports the bones of the shoulder girdle and the bones of the upper extremities.

The Sternum

The sternum is also known as the breastbone (Figure 7-16). It develops in three parts: the manubrium, the gladiolus, and the xiphoid (ZIFFoyd) process. The sternum resembles a sword, with the manubrium resembling the handle of the sword, the gladiolus or body forming the blade, and the xiphoid process forming the tip of the sword. No ribs are attached to the xiphoid, but the manubrium and gladiolus have notches on each side for attachment of the first seven costal (rib) cartilages. The manubrium articulates with the clavicle or collarbone (Figure 7-17). Between these two points of attachment is the suprasternal or jugular notch easily felt through the skin. The diaphragm and the rectus abdominis muscles attach to the xiphoid.

The Ribs

The 12 pairs of ribs are also referred to as the costae (Figure 7-17). They are named according to their anterior attachments. Because the upper seven pairs articulate directly with the sternum, they are called true ribs. The lower five pairs are called false ribs. The costal cartilages of the 8th, 9th, and 10th rib pairs are attached to the cartilage of the 7th rib so they join the sternum only indirectly. Because the 11th and 12th pairs of ribs have no cartilage and do not attach at all anteriorly, these “false” ribs have another name, floating ribs. Of course, all ribs attach posteriorly to the thoracic vertebrae.

THE APPENDICULAR SKELETON

The Bones of the Upper Extremities

The bones of the upper extremities include the bones of the shoulder girdle, the arm, the forearm, the wrist, the hand, and the fingers.

The bones of the shoulder girdle are the clavicle (KLAV-ih-kl) and the scapula (SKAP-you-lah). The clavicle or collarbone is a long slim bone located at the root of the neck just below the skin and anterior to the first rib. The medial end articulates with the manubrium of the sternum and the lateral end with the acromial (ah-KRO-mee-al) process of the scapula. The scapula or shoulder blade is a large, flat, triangular bone located on the dorsal portion of the thorax, covering the area from the second to the seventh rib (Figure 7-18). Two other prominent bony projections on the scapula are the coracoid process, which functions as an attachment for muscles that move the arm, and the glenoid fossa, which receives the head of the humerus and helps form the shoulder joint.

The humerus (HYOO-mehr-us) is the largest and longest bone of the upper arm (Figure 7-19). Its head is rounded and joined to the rest of the bone by its
CHAPTER 7 The Skeletal System

**FIGURE 7-17.** Thoracic cage, anterior view.

**FIGURE 7-18.** Scapula. (A) Anterior view. (B) Posterior view.
anatomic neck. The upper part of the bone has two prominences, the greater and lesser tubercles, which function as insertions for many of the muscles of the upper extremity.

The **ulna** is the longer, medial bone of the forearm (Figure 7-20). Its shaft is triangular, and the distal, or lower, end is called the head. At its proximal end is the **olecranon** (oh-LEK-rahn) **process** or elbow. When banged, nerves are pressed causing the tingling sensation, which gives it the common name of “funny bone.”

The **radius** is the shorter, lateral bone of the forearm. It is joined to the ulna by an interosseus membrane traversing the area between the shafts of the two bones. They move as one. The styloid process of the radius articulates with some of the bones of the wrist.

The bones of the wrist are called **carpals** (Figure 7-21). They are arranged in two rows of four each. In the proximal row from medial to lateral they are the **pisiform** (PYE-zih-form), **triquetral** (try-KWEE-tral), **lunate** (LOO-nate), and **scaphoid** (SKAFF-oyd), also known as the **navicular** (nah-VIK-you-lahr). In the distal row from medial to lateral are the **hamate**, **capitate** (KAP-ih-tate), **trapezoid** (TRAP-eh-zoid), or lesser multiangular, and the **trapezium** (trah-PEE-zee-um), or greater multiangular.

The palm of the hand is made up of the five **metacarpal bones** (see Figure 7-21). These are small, long bones, each with a base, a shaft, and a head. They radiate out from the wrist bones like the spokes of a wheel rather than being parallel. They each articulate with a proximal **phalanx** (FAY-langks) of a finger. Each finger, except the thumb, has three **phalanges** (fah-LAN-jeez): a proximal, a middle, and a terminal, or distal, phalanx. The thumb has only a proximal and distal phalanx.
The Bones of the Lower Extremities

The bones of the lower extremities include the pelvic girdle, which supports the trunk and provides attachment for the legs. It consists of the paired hip bones or coxal bones. Each hipbone consists of three fused parts: the ilium (IL-ee-um), the ischium (ISS-kee-um), and the pubis (PYOO-bis). Other bones of the lower extremity include the thigh, the kneecap, the shin, the calf, the ankle bones, the foot, and the toes.

The pelvic girdle is actually made up of two hip or coxal bones that articulate with one another anteriorly at the pubic symphysis. Posteriorly, they articulate with the sacrum. This ring of bone is known as the pelvis.

The ilium is the uppermost and largest portion of the hipbone. It forms the expanded prominence of the upper hip or iliac crest. It is usually wider and broader in females and smaller and narrower in males. Its crest is projected into the anterior superior iliac spine and the anterior inferior iliac spine (Figure 7-22). The ischium is the strongest portion of a hipbone and is directed slightly posteriorly. Its curved edge is viewed from the front as the lowermost margin of the pelvis. It has the rounded and thick ischial tuberosity, which you sit on, and thus bears the weight of the body in the sitting position. The pubis is superior and slightly anterior to the ischium. Between the pubis and the ischium is the large
obturator (OB-tuh-ray-tohr) foramen. This is the largest foramen in the body and allows for the passage of nerves, blood vessels, and tendons. On the lateral side of the hip just above the obturator foramen is the acetabulum (ass-eh-TAB-you-lum). All three parts of the pelvic bone meet and unite in this socket. It also receives the head of the femur to help form the hip joint.

The femur (FEE-mehr), or thigh, is the largest and heaviest bone of the body (Figure 7-23). This single large bone of the upper leg is not in a vertical line with the axis of the erect body. Rather it has a unique engineering design that allows it to bear and distribute the weight of the body. It is positioned at an angle, slanting downward and inward so that the two femurs appear as a large letter V (Figure 7-6). Its upper extremity bears a large head that fits into the acetabulum of the pelvic bone, with an anatomic neck. Its lower portion is widened into a large lateral condyle and an even larger medial condyle. It articulates distally with the tibia.

The patella (pah-TELL-ah), or kneecap, is the largest of the sesamoid bones. It is somewhat flat and triangular, lying right in front of the knee joint, and is enveloped within the tendon of the quadriceps femoris muscle. Its
only articulation is with the femur. It is a movable bone, and it increases the leverage of the muscles that straighten out the knee.

The tibia (TIB-ee-ah) is the larger of the two bones forming the lower leg (Figure 7-24). It is also known as the shin bone. The rounded condyles of the femur rest on the flat condyle at the proximal end of the tibia.

The fibula (FIB-you-lah) is also known as the calf bone. In proportion to its length, it is the most slender bone of the body. It lies parallel with and on the lateral side of the tibia. It does not articulate with the femur but attaches to the proximal end of the tibia via its head.

The bones of the ankle are known as the tarsal bones (Figure 7-25). The seven short tarsal bones

FIGURE 7-22. (A) Right hipbone, medial view. (B) Anterior view of the pelvis.
resemble the carpal bones of the wrist but are larger. They are arranged in the hindfoot and forefoot. The tarsal bones of the hindfoot are the calcaneus (kal-KAY-nee-us), sometimes called the calcaneum, which is the largest of the tarsal bones and forms the heel, the talus or ankle bone, the navicular (nah-VIK-you-lar), and the cuboid (KYOO-boyd). Because the calcaneus or heel bone receives the weight of the body when walking, it has developed as the largest of the tarsal bones. The tarsal bones of the forefoot are the medial (I), intermediate (II), and lateral (III) cuneiforms (kyoo-NEE-ih-formz).

The rest of the forefoot bones are the metatarsals and phalanges. There are five metatarsal bones in the forefoot. Each is classified as a long bone based on shape and each has a base, shaft, and a head. The heads formed at the distal ends of the metatarsals form what we call the ball of the foot. The bases of the first, second, and third metatarsals articulate with the three cuneiforms; the fourth and fifth metatarsals articulate with the cuboid. The intrinsic muscles of the toes are attached to the shafts of the metatarsals. The first metatarsal is the largest due to its weight-bearing function during walking.

The phalanges of the toes are classified as long bones despite their short length because again they have a base, shaft, and head (see Figure 7-25B). They have the same arrangement as the phalanges of the fingers. There are two phalanges in the great toe, proximal and distal. The proximal one is large due to its weight-bearing function when walking. The other four toes have three each, proximal, middle, and distal phalanges.

THE ARCHES OF THE FOOT

The bones of the foot are arranged in a series of arches that enable the foot to bear weight while standing and to provide leverage while walking. There are two longitudinal arches and one transverse arch. The medial
longitudinal arch is formed by the calcaneus, talus, navicular, the three cuneiforms, and the three medial metatarsals. This is the highest arch of the foot and can easily be noted. The lateral longitudinal arch is much lower and is formed by the calcaneus, the cuboid, and the two lateral metatarsals. The transverse arch is perpendicular to the longitudinal arches and is most pronounced at the base of the metatarsals.

The term pes planus, or flatfoot, indicates a decreased height of the longitudinal arches. It rarely causes any pain and can be inherited or result from muscle weakness in the foot.
FIGURE 7-25. (A) Right ankle and foot, lateral view. (B) Right ankle and foot, superior view.
As we age, less protein matrix is formed in our bone tissue accompanied by a loss of calcium salts. Bones become more fragile and tend to break more easily in older adults. Older adults also develop stiffness and less flexibility of the skeleton due to a decrease in the protein collagen found in the tendon connective tissue that connects bone to muscle, and in ligaments that connect bone to bone. Hence, as we age we should be more conscious of our diet and include more foods that contain calcium. Regular exercise can also help maintain healthy bone tissues. Walking is an excellent way to exercise both bones and muscles.

Do we really “shrink” as we grow older? Shrinking is caused by a thinning of the intervertebral disks in the spinal column. Starting at around age 40, individuals can lose about one-half inch in height every 20 years due to the loss of disk protein.

There are many careers available to individuals who are interested in the skeletal system.

- **Athletic trainers** provide guidance to develop muscles and bones for agility, good looks, and sports training.
- **Chiropractors** or **doctors of chiropractic** complete at least two years of premedical studies, followed by four years of study in an approved chiropractic school, learning mechanical manipulation of the spinal column as a method to maintain a healthy nervous system.
- **Prosthetists** are individuals who create artificial limbs.
- **Orthopedists** are physicians specializing in preventing and correcting disorders of the skeleton, joints, and muscles. There are also careers in orthopedic nursing.
- **Orthotists** are individuals who design, make, and fit braces or other orthopedic devices prescribed by a physician.
- **Paramedics** and **emergency medical technicians** can also further train and specialize in the treatment of skeletal system disorders like broken bones and fractures.
BODY SYSTEMS WORKING TOGETHER TO MAINTAIN HOMEOSTASIS: THE SKELETAL SYSTEM

Integumentary System
- Vitamin D is produced in the skin by UV light.
- It enhances the absorption of calcium in bones for bone and tooth formation.

Muscular System
- Through their tendons, muscles pull on bones, bringing about movement.
- Calcium from bones is necessary for muscle contraction to occur.

Nervous System
- The cranial bones protect the brain, and the vertebrae and intervertebral disks protect the spinal cord.
- Receptors for pain monitor trauma to bones.
- Calcium from bones is necessary for nerve transmission.

Endocrine System
- The hormone calcitonin causes calcium to be stored in bones.
- The hormone parathormone causes calcium to be released from bones.
- Growth hormone from the anterior pituitary gland affects bone development.

Cardiovascular System
- Blood cells transport oxygen and nutrients to bone cells and take away carbon dioxide and waste products.
- Calcium from bones is necessary for blood clotting and normal heart functions.

Lymphatic System
- Red bone marrow produces lymphocytes, which function in our immune response.

Digestive System
- Calcium, necessary for bone matrix development, is absorbed in the intestine from our daily food intake.
- Excess calcium can be eliminated via the bowels.

Respiratory System
- Oxygen is brought into the body via the respiratory system and transported by the blood to bone cells for biochemical respiration.
- The ribs along with the intercostal muscles and diaphragm bring about breathing.

Urinary System
- The kidneys help regulate blood calcium levels.
- Excess calcium can also be eliminated via the kidneys.

Reproductive System
- Bones are a source of calcium during breastfeeding.
- The pelvis aids in supporting the uterus and developing fetus during pregnancy in the female.

COMMON DISEASE, DISORDER, OR CONDITION

OSTEOPOROSIS

Osteoporosis (oss-tee-oh-poh-ROH-sis) is a disorder of the skeletal system characterized by a decrease in bone mass with accompanying increased susceptibility to bone fractures. This results from decreased levels of estrogens that occur after menopause in women and in both men and women in old age. Estrogens help maintain bone tissue by stimulating osteoblasts to form new bone.

Osteoporosis occurs more often in middle-aged and elderly women, but it can also affect teenagers who do not eat a proper balanced diet, people allergic to dairy products, and anyone with eating disorders. The bone mass becomes depleted in such a way that the skeleton cannot withstand everyday mechanical stress. Bone fractures are common, even from normal daily activities. This disease is responsible for height loss, hunched backs, and pain in older individuals. Adequate diet and exercise can prevent osteoporosis.

(continues)
PAGET’S DISEASE
Paget’s disease is a common nonmetabolic disease of bone whose cause is unknown. It usually affects middle-aged and elderly individuals. Symptoms include an irregular thickening and softening of the bones. There is excessive bone destruction and unorganized bone repair. Areas of the body affected are the skull, pelvis, and limbs. Treatment includes a high-protein and high-calcium diet with mild but regular exercise.

GIGANTISM
Gigantism (JYE-gan-tizm) is the result of excessive endochondral ossification at the epiphyseal plates of long bones. This results in abnormally large limbs, giving the affected individual the appearance of a very tall “giant.”

DWARFISM
Dwarfism is the opposite condition of gigantism and results from inadequate ossification occurring at the epiphyseal plates of long bones. This results in an individual being abnormally small. This condition is not to be confused with a genetic dwarf.

SPINA BIFIDA
Spina bifida (SPY-nah BIFF-ih-dah) is a congenital defect in the development of the posterior vertebral arch in which the laminae do not unite at the midline. It is a relatively common disorder. It may occur with only a small deformed lamina, or it may be associated with the complete absence of laminae, causing the contents of the spinal canal to protrude posteriorly. If the condition does not involve herniation of the meninges or contents of the spinal canal, treatment is not required.

HERNIATED DISK
A herniated disk is a rupture of the fibrocartilage surrounding an intervertebral disk that cushions the vertebrae above and below. This produces pressure on spinal nerve roots, causing severe pain and nerve damage. The condition occurs most often in the lumbar region and is also known as a slipped disk. Treatment can include prolonged bed rest to promote healing or surgery to remove the damaged disk.

CLEFT PALATE AND CLEFT LIP
A cleft palate, more common in females, occurs when the palatine processes of the maxillary bones do not fuse properly, resulting in an opening between the oral and nasal cavities (Figure 7-26). A person with this condition cannot speak clearly and has difficulty eating or drinking. A child born with this condition can have it surgically repaired and corrected; hence, we rarely see this condition in developed countries. A cleft lip, more common in males, occurs when the maxillary bones do not form normally, producing a cleft in the upper lip. Treatment is by surgical repair in infancy. A child could be born with both a cleft palate and a cleft lip.

BLACK EYE
A black eye is caused by a blow to the supraorbital ridge, which overlies the frontal sinus. This results in a skin laceration with bleeding. Tissue fluid and blood accumulate in the connective tissue around the eyelid. This swelling, bruising, and discoloration produces a black eye, also called a periorbital ecchymosis or bruise.

DEViated SEPTUM
A deviated septum develops when the nasal septum shifts to the left (usually) during normal growth. It can be aggravated by a severe blow to the nasal area. Serious deflections can interfere with nasal flow, can cause frequent nose bleeding, or may result in headaches or shortness of breath. Severe deviation can be corrected through surgical procedures.
SINUSITIS
Sinusitis is an inflammation of any one or more of the paranasal sinuses: the frontal, ethmoidal, sphenoidal, and/or the maxillary sinus. This inflammation and swelling of the mucous membrane blocks drainage from the sinuses to the nose resulting in accumulation of drainage materials causing pressure, pain, and headache. It is caused by a number of factors including infections, allergic reactions, and changes in atmospheric pressure as when flying in a plane or underwater swimming. Treatment includes antibiotics, decongestants, analgesics, and surgery to aid drainage in individuals with chronic sinusitis.

WHIPLASH
A whiplash injury affects the cervical vertebrae and their associated muscles and ligaments. It is caused by a violent back-and-forth movement of the neck and head as experienced in a rear-end car collision or by athletic injuries. It results in severe pain and stiffness to the neck region and can produce fractures to the spinous process of the cervical vertebrae and/or torn ligaments, tendons, and muscles in this area.

ACROMEGALY
Acromegaly is a chronic condition caused by overactivity of the anterior pituitary gland, resulting in excessive secretions of growth hormone (Figure 7-27). It produces widening and thickening of the bones of the hands, face, jaws, and feet with accompanying tissue enlargement. Developing complications over time include heart disease, hypertension, excess blood sugar, and atherosclerosis (cholesterol containing plaque in the arteries). Treatment can include radiation or surgical removal of part of the pituitary gland.

FRACTURED CLAVICLE
A fractured clavicle is the most commonly broken bone in the body. It can occur from falling when you use your outstretched arm to soften the fall or from excessive force on the anterior thorax as during an automobile accident when using a shoulder seat belt harness. The most common treatment for a fractured clavicle is the use of a shoulder/arm sling to keep the arm stationary and not allowing it to move outward. This allows the osteoclasts to reabsorb the damaged bone and the osteoblasts to lay down new bone for repair.
SUMMARY OUTLINE

INTRODUCTION
1. The skeleton is the supporting structure of the body; it allows muscles to bring about movement and breathing.
2. The solid appearance of bone is due to mineral salts that form the inorganic matrix surrounding the living bone cells.
3. Leonardo da Vinci was the first to correctly illustrate the 206 bones of the body.

THE FUNCTIONS OF THE SKELETAL SYSTEM
The skeleton has five functions:
1. Support surrounding tissues
2. Protect vital organs and soft tissues
3. Provide levers for muscles to pull on
4. Manufacture blood cells in red bone marrow by hematopoiesis
5. Act as a storage area for mineral salts, especially calcium and phosphorus, and fat in yellow marrow

THE GROWTH AND FORMATION OF BONE
1. After 3 months, the fetal skeleton is completely formed and made primarily of hyaline cartilage. Ossification and growth then develop.
2. Longitudinal growth of bone continues until approximately 15 years of age in girls and 16 in boys.
3. Bone maturation continues until 21 years of age in both sexes.

Deposition of the Bone
1. Bone develops from spindle-shaped embryonic bone cells called osteoblasts.
2. Osteoblasts develop into mature bone cells called osteocytes. They form under the fibrovascular membrane covering bone, called the periosteum, and under the membrane lining of the medullary cavity, called the endosteum.
3. The more strain or pressure on a bone, the more the bone will develop.
4. Osteoclasts are large cells that are responsible for the reabsorption of injured bone. They also reabsorb bone during remodeling.

Types of Ossification
The two types of ossification are:
1. Intramembranous ossification: a process in which dense connective membranes are replaced by deposits of inorganic calcium salts. The bones of the cranium form in this way.
2. Endochondral ossification: the process whereby cartilage is the environment in which the bone cells develop. All other bones of the body develop in this way.

Maintaining the Bone
1. The correct amount of calcium stored in the bones, the proper amount of calcium in the blood, and the excretion of excess calcium are controlled by the endocrine system.
2. The parathyroid glands secrete parathormone, which causes calcium to be released into the bloodstream. Another hormone, calcitonin, causes calcium to be stored in the bones.

THE HISTOLOGY OF BONE
There are two types of bone tissue:
1. Compact or dense bone is strong and solid.
2. Cancellous or spongy bone has many open spaces filled with bone marrow.

The Haversian System of Compact Bone
1. An English physician, Clopton Havers (1650–1702), first described the histologic features of compact bone.
2. Haversian canals or osteons are small canals containing blood vessels running parallel to the surface of compact bone and are surrounded by concentric rings of solid bone called lamellae.
3. In these rings of bone are cavities called lacunae; each lacuna contains an osteocyte bathed in fluid.
4. Lacunae are connected to one another and eventually to the osteons by smaller canals called canaliculi.
5. The tissue fluid that circulates in these canals carries nutrients and oxygen to and waste away from the bone cells.

Cancellous Bone
1. Cancellous bone consists of a meshwork of bone called trabeculae.
2. Trabeculae create the spongy appearance of cancellous bone.
3. The spaces between the trabeculae are filled with bone marrow.
Bone Marrow

There are two types of bone marrow:

1. Red bone marrow’s function is hematopoiesis, the formation of blood cells.
2. In an adult the ribs, vertebrae, sternum, and pelvis contain red bone marrow in their cancellous tissue.
3. Yellow bone marrow is found in the shafts of long bones within their cancellous tissue.
4. Yellow bone marrow stores fat cells.

The Classification of Bones

The bones of the body can be classified, based on shape, into five categories.

1. Long bones consist of a shaft or diaphysis, a flared portion at the end of the diaphysis called a metaphysis, and two extremities called epiphyses. Examples are the clavicle, humerus, radius, ulna, femur, tibia, and fibula as well as the phalanges, metacarpals, and metatarsals.
2. Short bones have a somewhat irregular shape. Examples are the tarsal bones of the foot and the carpal bones of the hand.
3. Flat bones are flat and serve to protect or provide extensive muscle attachment. Examples are some bones of the cranium, the ribs, scapula, and part of the hipbone.
4. Irregular bones have a very peculiar or irregular shape. Examples are the vertebrae and the ossicles of the ear.
5. Sesamoid bones are small rounded bones enclosed in tendon and fascial tissue near joints. One example is the largest sesamoid bone, the patella.

Bone Markings

1. Bones exhibit certain projections called processes. Examples of processes are the spine, condyle, tubercle, trochlea, trochanter, crest, line, head, and neck.
2. Bones also exhibit certain depressions called fossae. Examples of fossae are suture, foramen, meatus or canal, sinus or antrum and sulcus.
3. These markings are functional to help join bones to one another, to provide a surface for muscle attachment, or to serve as a passageway for blood vessels and nerves into and out of the bone.

Divisions of the Skeleton

1. The human skeleton has 206 bones.
2. The skeleton can be divided into the axial skeleton (skull, hyoid, vertebrae, ribs, and sternum) and the appendicular skeleton (bones of the upper and lower extremities).

The Axial Skeleton

1. The cranial bones consist of the frontal bone, the two parietal bones, the occipital bone, the two temporal bones, the sphenoid bone, the ethmoid bone, the six auditory ossicles (malleus, incus, stapes in each ear), and the varying wormian or sutural bones.
2. The facial bones consist of the two nasal bones, the two palatine bones, the two maxillary bones (upper jaw), the two zygomatic or malar bones (cheekbones), the two lacrimal bones, the two turbinates or nasal conchae, the single vomer bone, and the single lower jawbone, the mandible.

The Orbits, Nasal Cavities, and Foramina

1. The orbits are the two deep cavities that enclose and protect the eyes. A number of bones of the skull contribute to their formation.
2. The framework of the nose surrounds the two nasal cavities made by a number of bones of the skull.
3. Foramina are passageways for blood vessels and nerves. The largest foramen of the skull is the foramen magnum for passage of the spinal cord.

The Hyoid Bone

1. The hyoid bone does not articulate with any other bones. It is suspended by ligaments from the styloid process of the temporal bone.
2. Its function is to support the tongue.

The Torso or Trunk

1. The sternum, ribs, and vertebrae make up the torso or trunk.
2. A typical vertebra has a number of characteristics: a disk-shaped body, an arch that encloses the spinal foramen, a spinous process and two transverse processes for muscle attachment, and two superior articular processes and two inferior articular processes for articulation with the vertebrae immediately above and below.
3. There are seven cervical vertebrae: the first is called the atlas and the second the axis.
4. There are 12 thoracic vertebrae that articulate with the ribs.
5. There are five lumbar vertebrae, the strongest.
6. The single sacrum is made of five fused sacral vertebrae.
7. The single coccyx or tailbone is made up of four fused coccygeal vertebrae.
8. The sternum or breastbone develops in three parts; it looks like a sword: the manubrium or handle, the gladiolus or body that looks like the blade, and the xiphoid process that resembles the tip of the sword.
9. There are 12 pairs of ribs: the upper seven pairs articulate directly with the sternum through their costal cartilages and are called true ribs; the lower five pairs are called false ribs; because the 11th and 12th pairs have no costal cartilage to articulate indirectly with the sternum like the 8th, 9th, and 10th pairs, they are called floating ribs.

THE APPENDICULAR SKELETON

The Bones of the Upper Extremities
1. The bones of the shoulder girdle are the clavicle or collarbone and the scapula or shoulder blade.
2. The humerus is the bone of the upper arm.
3. The forearm bones are the ulna, the longer of the two bones, with its proximal olecranon process or funny bone of the elbow, and the radius, the shorter bone that articulates with some of the wrist or carpal bones.
4. The carpal bones of the wrist are the pisiform, triquetral, lunate, and scaphoid (in the proximal row); the hamate, capitate, trapezoid or lesser multiangular; and the trapezium (type) or greater multiangular (in the distal row).
5. The bones of the palm of the hand are the five metacarpals.
6. The bones of the fingers are the 14 phalanges in each hand.

The Bones of the Lower Extremities
1. Each hip or pelvic bone consists of three fused bones: the ischium, ilium, and pubis. They form the pelvic girdle. The female ilium is wider than the male’s, and we all sit on our ischial tuberosity.
2. The femur or thighbone is the largest bone in the body.
3. The patella or kneecap is the largest of the sesamoid bones; it is wrapped in the tendon of the quadriceps femoris muscle.

4. The tibia or shinbone is the largest bone of the lower leg.
5. The fibula of the lower leg is the most slender bone in the body. It is also known as the calfbone.
6. The tarsal bones of the foot are the calcaneus or heel, the talus or ankle, the navicular, and the three cuneiforms.
7. The metatarsals make up the rest of the foot bones along with the 14 phalanges of the toes.

THE ARCHES OF THE FOOT
1. The foot has three arches: the medial longitudinal arch is the highest, the lateral longitudinal arch, and the transverse arch.
2. Pes planus or flatfoot results from decreased height in the longitudinal arches.

REVIEW QUESTIONS
1. Name five functions of the skeleton.
2. Why should parents make sure that their young child drinks milk, exercises, and plays in the sunlight on a daily basis?
3. Name the cranial bones.
4. Name the facial bones.
5. Name the carpal bones of the wrist.
6. Name the tarsal bones of the foot.

Critical Thinking Question

FILL IN THE BLANK
Fill in the blank with the most appropriate term.

1. The two common types of bone tissue are __________________ and __________________.
2. Bone develops from spindle-shaped cells called __________________ found beneath the periosteum.
3. __________________ are large cells, present in the cavities of bone, which function in the reabsorption of bone.
4. __________________ ossification is a process in which dense connective tissue or membranes are replaced by deposits of inorganic calcium.
5. The “replacement” of cartilaginous structures with bone is called __________________ ossification.
6. A disease of bone in children caused by a deficiency of vitamin D and sunlight is
7. Haversian canals are surrounded by concentric rings of bone, each layer of which is called a ___________________; between these are tiny cavities called ____________________, each containing an osteocyte.

8. __________________ bone marrow’s function is hematopoiesis.

9. __________________ bone marrow consists chiefly of fat cells.

10. The bridge of the nose is made up of the paired __________________ bones.

11. The hard palate of the roof of the mouth is made up of the two __________________ bones.

12. The ________________ bone, found in the axial skeleton, has no articulations with other bones and functions as a support for the tongue.

13. The first cervical vertebra is called the ________________ and supports the head; the second cervical vertebra is called the ________________.

14. The sternum or breastbone develops in three parts: the ________________, the body or ________________, and the ________________.

15. There are 12 pairs of ribs. The upper seven pairs articulate directly with the sternum and are called ________________ ribs; the lower five pairs do not directly join the sternum and are called ________________ ribs.

**MATCHING**

Place the most appropriate number in the blank provided.

__ Periosteum  
__ Osteomalacia  
__ Epiphysis  
__ Process  
__ Condyle  
__ Fossa  
__ Fissure/suture  
__ Foramen  
__ Meatus  
__ Sinus  
__ Sulcus  
__ Forehead  
1. Rounded or knuckle-like prominence  
2. Depression in or on a bone  
3. Canal, tubelike passage  
4. Orifice through which vessels and nerves pass  
5. Fibrovascular membrane covering bone  
6. Zygomatic bone  
7. Any marked, bony prominence  
8. Frontal bone  
9. Cavity within a bone  
10. Two extremities of a long bone  
11. Furrow or groove  
12. Alveolus  
13. Narrow ridge of bone  
14. Narrow slit between two bones  
15. Rickets in adults  
16. Temporal bone  
17. Parietal bone

**TRUE OR FALSE**

T F 1. Cartilage actually turns into bone during ossification.
T F 2. The protein matrix of bone is responsible for its elasticity and the salts deposited in the matrix prevent crushing.
T F 3. The more strain on a bone, the less the bone will develop.
T F 4. It is possible for crooked bones in children to become straight due to the continued process of reabsorption.
T F 5. The proper calcium ion concentration of the blood is controlled and maintained by the parathyroid glands.
T F 6. The foramen magnum is the largest orifice in the skeleton and is found at the base of the parietal bone.
T F 7. Like the bones of the cranium, all the facial bones are united by immovable sutures.
T F 8. If the thoracic vertebrae become excessively curved, a condition known as kyphosis develops.
T F 9. The 11th and 12th ribs have another name, floating ribs, because they do not articulate at all with other parts of the skeleton.
T F 10. The scapula is the bone whose common name is the collarbone.

**Search and Explore**

Search the Internet for any one of the following famous people: Andre the Giant, Richard Kiel, or Carel Struycken. Give an oral presentation on the individual you chose and describe their disease.
Lorette, a 70-year-old woman, is being evaluated by an orthopedist at a local clinic following a recent wrist fracture. A year ago, Lorette fell and experienced a vertebral fracture, which is still creating serious back pain. The health care provider notes that Lorette has a stooped posture and a hunched back. Her medical record reveals a history of small fractures, as well as an abnormal yearly loss of height.

Questions

1. What condition might be responsible for Lorette’s medical history and current problems?
2. Which individuals are most likely to develop this condition?
3. What hormone protects women from developing this problem prior to menopause?
4. What is the medical term for hunchback, and what causes it to develop?
5. Why might Lorette have lost height over the years?
6. What measures can individuals take to prevent this skeletal disorder?
LABORATORY EXERCISE:

THE SKELETAL SYSTEM

Materials needed: An articulated human skeleton, either real bone, if possible, or a good plastic reproduction; a number of skulls (one skull per 4–5 learners); disarticulated examples of human bones, an articulated foot, and an articulated hand; a microscope slide of compact bone

1. Break into groups of 4 to 5 learners. Use the colored plates from your textbook and identify the cranial and facial bones with their major sutures by working with the skulls provided by your instructor.

2. Move to the articulated skeleton and identify the other bones of the body.

3. Look at an articulated hand and a foot and identify the carpal bones of the wrist and the tarsal bones of the foot.

4. Examine a hyoid bone and identify its parts.

5. Try to identify various bone markings mentioned in your text.

6. Examine a long bone that has been split open to view compact and cancellous tissue.

7. Review the histology of compact bone by viewing a microscope slide of compact bone. Identify all the parts of the haversian system or osteon.