Student Objectives

When you have completed the exercises in this chapter, you will have accomplished the following objectives:

Skeletal Cartilages
1. Describe the functional properties of the three types of cartilage tissue.
2. Locate the major cartilages of the adult skeleton.
3. Explain how cartilage grows.

Classification of Bones
4. Name the major regions of the skeleton and describe their relative functions.
5. Compare and contrast the structure of the four bone classes and provide examples of each class.

Functions of Bones
6. List and describe five important functions of bones.

Bone Structure
7. Indicate the functional importance of bone markings.
8. Describe the gross anatomy of a typical long bone and flat bone. Indicate the locations and functions of red and yellow marrow, articular cartilage, periosteum, and endosteum.

9. Describe the histology of compact and spongy bone.
10. Discuss the chemical composition of bone and the advantages conferred by the organic and inorganic components.

Bone Development
11. Compare and contrast intramembranous ossification and endochondral ossification.
12. Describe the process of long bone growth that occurs at the epiphyseal plates.

Bone Homeostasis: Remodeling and Repair
13. Compare the locations and remodeling functions of the osteoblasts, osteocytes, and osteoclasts.
14. Explain how hormones and physical stress regulate bone remodeling.
15. Describe the steps of fracture repair.

Homeostatic Imbalances of Bone

Developmental Aspects of Bones: Timing of Events
17. Describe the timing and cause of changes in bone architecture and bone mass throughout life.
2. Using the key choices, characterize the following statements relating to the structure of a long bone. Enter the appropriate answers in the answer blanks.

**Key Choices**

A. Diaphysis  
B. Epiphyseal plate  
C. Epiphysis  
D. Red marrow  
E. Yellow marrow cavity  
F. Periosteum

1. Location of spongy bone in an adult’s bone
2. Location of compact bone in an adult’s bone
3. Site of hematopoiesis in an adult’s bone
4. Scientific name for bone shaft
5. Site of fat storage
6. Region of longitudinal growth in a child
7. Composed of hyaline cartilage until the end of adolescence
8. Inner layer consists primarily of osteoblasts and osteogenic cells

3. Figure 6.2 is a sectional diagram showing the five-layered structure of a typical flat bone. Select different colors for the layers below. Add labels and leaders to identify Sharpey’s fibers and trabeculae. Then answer the questions that follow, referring to Figure 6.2 and inserting your answers in the answer blanks.

- Spongy bone
- Compact bone
- Periosteum

![Figure 6.2](image)
1. Which layer is called the diploe? 

2. Name the membrane that lines internal bone cavities. 

4. Five descriptions of bone structure are provided in Column A. 

First, identify the structure by choosing the appropriate term from Column B and placing the corresponding answer in the answer blank. 

Second, consider Figure 6.3A, a diagrammatic view of a cross section of bone, and Figure 6.3B, a higher-magnification view of compact bone tissue. Select different colors for the structures and bone areas in Column B and use them to color the coding circles and corresponding structures on the diagrams. As concentric lamellae would be difficult to color without confusing other elements, identify one lamella by using a bracket and label. 

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
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</thead>
<tbody>
<tr>
<td>1. Layers of calcified matrix</td>
<td>A. Central (Haversian) canal</td>
</tr>
<tr>
<td>2. &quot;Residences&quot; of osteocytes</td>
<td>B. Concentric lamellae</td>
</tr>
<tr>
<td>3. Longitudinal canal, carrying blood vessels and nerves</td>
<td>C. Lacunae</td>
</tr>
<tr>
<td>4. Nonliving, structural part of bone</td>
<td>D. Canaliculi</td>
</tr>
<tr>
<td>5. Tiny canals connecting lacunae</td>
<td>E. Bone matrix</td>
</tr>
<tr>
<td></td>
<td>F. Osteocyte</td>
</tr>
</tbody>
</table>

Figure 6.3
5. Classify each of the following terms as a projection (P), a depression (D), or an opening (O). Enter the appropriate letter in the answer blanks.


6. Circle the term that does not belong in each of the following groupings.

   1. Rigi(l)     Calcium salts     Hydroxyapatites     Collagen     Hardness
   2. Hematopoiesis Red marrow      Yellow marrow       Spongy bone    Diploë
   3. Lamellae     Cellular extensions Canaliculi       Circulation    Osteoclasts
   4. Osteon       Marrow cavity    Volkmann's canals Haversian canal Canaliculi
   5. Epiphysis    Articular cartilage Periosteum       Hyaline cartilage
   6. Perichondrium Periosteum       Appositional growth Osteoblasts
   7. Spongy       Cancellous       Woven       Lamellar     Trabecular

Bone Development

1. The following events apply to the endochondral ossification process as it occurs in the primary ossification center. Put these events in their proper order by assigning each a number (1–6).

   ___ 1. Cavity formation occurs within the hyaline cartilage.
   ___ 2. Collar of bone is laid down around the hyaline cartilage model just beneath the periosteum.
   ___ 3. Periosteal bud invades the marrow cavity.
   ___ 4. Perichondrium becomes vascularized to a greater degree and becomes a periosteum.
   ___ 5. Osteoblasts lay down bone around the cartilage spicules in the bone's interior.
   ___ 6. Osteoclasts remove the cancellous bone from the shaft interior, leaving a marrow cavity that then houses fat.

2. For each statement that is true, insert T in the answer blank. For false statements, correct the underlined words by inserting the correct words in the answer blanks.

   ______________________ 1. When a bone forms from a fibrous membrane, the process is called endochondral ossification.
2. **Membrane** bones develop from hyaline cartilage structures.

3. The organic bone matrix is called the **osteoid**.

4. The enzyme alkaline phosphatase encourages the deposit of **collagen fibers** within the matrix of developing bone.

5. When trapped in lacunae, osteoblasts change into **osteocytes**.

6. Large numbers of **osteocytes** are found in the inner periosteum layer.

7. During endochondral ossification, the **periosteal bud** invades the deteriorating hyaline cartilage shaft.

8. **Primary** ossification centers appear in the epiphyses.

9. Epiphyseal plates are made of **spongy bone**.

10. In appositional growth, bone reabsorption occurs on the **periosteal** surface.

11. “Maturation” of newly formed (noncalcified) bone matrix takes about **10 days**.

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### Follow the events of intramembranous ossification by writing the missing words in the answer blanks.

1. The initial supporting structure for this type of ossification is a fibrous membrane formed by **fibrous tissue**. The first recognizable event is a clustering of the **fibrous membrane** cells to form a(n) **stroma** in the fibrous membrane. These cells then differentiate into **osteoblasts** which begin secreting **osteoid** around the fibers of the membrane. Within a few days, calcium salt deposit or **mineralization** occurs, producing true **bone**. The first network of trabeculae formed are arranged irregularly. This early membrane bone is referred to as **membrane bone**. As it forms, a layer of vascular **connective tissue** condenses on the external face of the bone structure, forming a **periosteal**. Eventually lamellar bone replaces **membrane bone**, and the vascular tissue within the **periosteal** differentiates into red marrow. The final result is a flat bone.

2.

3.

4.

5.

6.

7.

8.

9.

10.
4. Figure 6.4 is a diagram representing the histological changes in the epiphyseal plate of a growing long bone.

First, select different colors for the types of cells named below. Color the coding circles and the corresponding cells in the diagram.

- Cells depositing osteoid
- Dividing cartilage cells
- Older, enlarging, vesiculating cells
- Cells cutting themselves off from nutrients

Second, identify bracketed zones A–D on the diagram as: growth, ossification, hypertrophic, or calcification.

Third, complete the statements on page 129, referring to Figure 6.4 and the labeled regions on the diagram. Insert the correct words in the spaces provided.
1. The cell type in region A is [1].

2. The type of cell in region B is [2].

3. Calcification of the cartilage matrix begins in region [3].

4. The cartilaginous matrix begins to deteriorate in region [4].


**Bone Homeostasis: Remodeling and Repair**

1. Using the key choices, insert the correct answers in the answer blanks below.

   **Key Choices**
   
   A. Atrophy  
   B. Calcitonin  
   C. Gravity  
   D. Osteoblasts  
   E. Osteoclasts  
   F. Osteocytes  
   G. Parathyroid hormone  
   H. Stress and/or tension

   1. When blood calcium levels begin to drop below homeostatic levels, [1] is released, causing calcium to be released from bones.

   2. Mature bone cells, called [2], maintain bone in a viable state.

   3. Disuse such as that caused by paralysis or severe lack of exercise results in muscle and bone [3].

   4. Large tubercles and/or increased deposit of bony matrix occur at sites of [4].

   5. Immature, or matrix-depositing, bone cells are referred to as [5].

   6. [6] causes blood calcium to be deposited in bones as calcium salts.

   7. Bone cells that liquefy bone matrix and release calcium to the blood are called [7].

   8. Astronauts must perform isometric exercises when in outer space because bones atrophy under conditions of weightlessness or lack of [8].

2. Circle the term that does not belong in each of the following groupings.
6. For each of the following statements about bone breakage and the repair process that is true, insert T in the answer blank. For false statements, correct the underlined words by inserting the correct words in the answer blanks.

1. A **hematoma** usually forms at a fracture site.
2. Deprived of nutrition, **osteocytes** at the fracture site die.
3. Nonbony debris at the fracture site is removed by **fibroblasts**.
4. **Osteocytes** produce collagen fibers that span the break.
5. **Osteoblasts** from the medullary cavity migrate to the fracture site.
6. The **fibrocartilaginous callus** is the first repair mass to splint the broken bone.
7. The bony callus is composed of **compact** bone.
Covering All Your Bases

Multiple Choice

Select the best answer or answers from the choices given.

1. Important bone functions include:
   A. support of the pelvic organs
   B. protection of the brain
   C. providing levers for movement of the limbs
   D. protection of the skin and limb musculature
   E. storage of water

2. Which of the following are correctly matched?
   A. Short bone—wrist
   B. Long bone—leg
   C. Irregular bone—sternum
   D. Flat bone—cranium

3. Terms that can be associated with any type of bone include:
   A. periosteum
   B. diaphysis
   C. diploe
   D. cancellous bone
   E. medullary cavity

4. Which would be common locations of osteoblasts?
   A. Osteogenic layer of periosteum
   B. Lining of red marrow spaces
   C. Covering articular cartilage
   D. Lining central canals
   E. Aligned with Sharpey’s fibers

5. Which of the listed bone markings are sites of muscle or ligament attachment?
   A. Trochanter
   B. Meatus
   C. Facet
   D. Spine
   E. Condyle

6. Which of the following are openings or depressions?
   A. Fissure
   B. Tuberosity
   C. Meatus
   D. Fossa
   E. Tubercle

7. A passageway connecting neighboring osteocytes in an osteon is a:
   A. central canal
   B. lamella
   C. lacuna
   D. canaliculus
   E. perforating canal

8. Between complete osteons are remnants of older, remodeled osteons known as:
   A. circumferential lamellae
   B. concentric lamellae
   C. interstitial lamellae
   D. lamellar bone
   E. woven bone

9. Which of these could be found in cancellous bone?
   A. Osteoid
   B. Trabeculae
   C. Central canals
   D. Osteoclasts
   E. Canaliculi

10. Elements prominent in osteoblasts include:
    A. rough ER
    B. secretory vesicles
    C. lysosomes
    D. smooth ER
    E. heterochromatin

11. Which of the following are prominent in osteoclasts?
    A. Golgi apparatus
    B. Lysosomes
    C. Microfilaments
    D. Exocytosis
12. Endosteum is in all these places, except:
   A. around the exterior of the femur
   B. on the trabeculae of spongy bone
   C. lining the central canal of an osteon
   D. often directly touching bone marrow

13. Which precede(s) intramembranous ossification?
   A. Chondroblast activity
   B. Mesenchymal cells
   C. Woven bone
   D. Collagen formation
   E. Osteoid formation

14. Which of the following is (are) part of the process of endochondral ossification and growth?
   A. Vascularization of the fibrous membrane surrounding the cartilage template
   B. Formation of diploë
   C. Destruction of cartilage matrix
   D. Appositional growth
   E. Mitosis of chondroblasts

15. What is the earliest event (of those listed) in endochondral ossification?
   A. Ossification of proximal epiphysis
   B. Appearance of the epiphyseal plate
   C. Invasion of the shaft by the periosteal bud
   D. Cavitation of the cartilage shaft
   E. Formation of secondary ossification centers

16. Which zone of the epiphyseal plate is most influenced by sex hormones?
   A. Zone of resting cartilage
   B. Zone of hypertrophic cartilage
   C. Zone of proliferating cartilage
   D. Zone of calcification

17. The region active in appositional growth is:
   A. osteogenic layer of periosteum
   B. within central canals
   C. endosteum of red marrow spaces
   D. internal callus
   E. epiphyseal plate

18. Deficiency of which of the following hormones will cause dwarfism?
   A. Growth hormone
   B. Sex hormones
   C. Thyroid hormones
   D. Calcitonin
   E. Parathyroid hormone

19. A remodeling unit consists of:
   A. osteoblasts
   B. osteoid
   C. osteocytes
   D. osteoclasts
   E. chondroblasts

20. The calcification front marks the location of:
   A. newly formed osteoid
   B. newly deposited hydroxyapatite
   C. actively mitotic osteoblasts
   D. active osteoclasts
   E. the activity of alkaline phosphatase

21. A deficiency of calcium in the diet would lead to:
   A. an increase of parathyroid hormone in the blood
   B. an increase in calcitonin secretion
   C. an increase in somatomedin levels in the blood
   D. increased secretion of growth hormone

22. Ionic calcium plays a role in:
   A. the transmission of nerve impulses
   B. blood clotting
   C. muscle contraction
   D. cytokinesis
   E. the activity of sudoriferous glands

23. Which of the following is not associated with Wolff's law?
   A. Compression
   B. Gravity
   C. Growth hormone
   D. Orientation of trabeculae
   E. Bone atrophy following paralysis
24. The initial event following a bone fracture is:
   A. formation of granulation tissue
   B. ossification of internal callus
   C. hemorrhage and hematoma formation
   D. remodeling
   E. endochondral ossification

25. Women suffering from osteoporosis are frequent victims of ________ fractures of the vertebrae.
   A. compound D. compression
   B. spiral E. depression
   C. comminuted

26. Which of the listed bone disorders is (are) caused by hormonal imbalances?
   A. Osteomalacia D. Achondroplasia
   B. Osteoporosis E. Paget's disease
   C. Gigantism

27. At birth, ossification has progressed to the point where:
   A. only intramembranous ossification has begun
   B. endochondral ossification is complete
   C. some secondary ossification centers have appeared
   D. only major long bones have primary centers of ossification
   E. appositional growth has yet to begin

28. The growth spurt of puberty is triggered by:
   A. high levels of sex hormones
   B. the initial, low levels of sex hormones
   C. growth hormone
   D. parathyroid hormone
   E. calcitonin

Word Dissection

For each of the following word roots, fill in the literal meaning and give an example, using a word found in this chapter.

<table>
<thead>
<tr>
<th>Word root</th>
<th>Translation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. call</td>
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</tr>
<tr>
<td>2. cancel</td>
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<tr>
<td>3. clast</td>
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<td>4. fract</td>
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<td>10. soma</td>
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<td>11. trab</td>
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