Chapter 6 - Bones and Skeletal Tissues

Objectives

Skeletal Cartilages

1. Describe the structure of cartilage.
2. List the three types of skeletal cartilage, their functions, and locations.

Classification of Bones

3. Name the axial and appendicular groups of bones of the skeleton.
4. Describe the shape classes of bones, and give examples of each.

Functions of Bones

5. List the functions of bones.

Bone Structure

6. Name the various types of bone markings.
7. Describe the anatomical structure of typical long, short, flat, and irregular bones.
8. List the locations of red bone marrow in the bones of infants, children, and adults.
9. Describe the anatomy of compact and spongy bone. List all structural elements.
10. Explain the organic and inorganic composition of bone, and the function of each.

Bone Development

11. Describe the processes of intramembranous and endochondral ossification, and list the bones that are formed by each process.
12. Describe the processes of lengthwise bone growth and growth in width during postnatal development.
13. Discuss the effects of growth hormone, thyroxine, and sex hormones testosterone and estrogen on bone growth.

Bone Homeostasis: Remodeling and Repair

14. Discuss the uses and mechanisms of bone remodeling, bone depositions, and bone resorption in the body.
15. Explain the hormonal mechanism controlling bone remodeling.
16. Discuss the role of mechanical stress on bone remodeling.
17. List the types and characteristics of bone fractures.
18. Describe the events of bone repair.

Homeostatic Imbalances of Bone

19. Identify the causes and effects of bone disorders: osteomalacia, rickets, osteoporosis, and Paget’s disease.
20. Discuss the role of hormones in the development of osteoporosis.

Developmental Aspects of Bone: Timing of Events

21. Explain the timing of primary and secondary ossification of the skeleton, and the role of epiphyseal plates in bone growth.
22. Describe the changes in bone deposition and bone resorption that occur during different stages of life.

Lecture Outline

I. Skeletal Cartilages (p. 176; Fig. 6.1)

A. Basic Structure, Types, and Locations (p. 176; Fig. 6.1)

1. Skeletal cartilages are made from cartilage, surrounded by a layer of dense irregular connective tissue called the perichondrium.

2. Hyaline cartilage is the most abundant skeletal cartilage, and includes the articular, costal, respiratory, and nasal cartilages.

3. Elastic cartilages are more flexible than hyaline, and are located only in the external ear and the epiglottis of the larynx.

4. Fibrocartilage is located in areas that must withstand a great deal of pressure or stretch, such as the cartilages of the knee and the intervertebral discs.

B. Growth of Cartilage (p. 176)

1. Appositional growth results in outward expansion due to the production of cartilage matrix on the outside of the tissue.

2. Interstitial growth results in expansion from within the cartilage matrix due to division of lacunae-bound chondrocytes and secretion of matrix.

II. Classification of Bones (pp. 176-178; Figs. 6.1-6.2)

A. There are two main divisions of the bones of the skeleton: the axial skeleton, consisting of the skull, vertebral column, and rib cage; and the appendicular skeleton, consisting of the bones of the upper and lower

limbs, and the girdles that attach them to the axial skeleton (pp. 176-177; Fig. 6.1).

B. Shape (pp. 177-178; Fig. 6.2)

1. Long bones are longer than they are wide, have a definite shaft and two ends, and consist of all limb bones except patellas, carpals, and tarsals.

2. Short bones are somewhat cube-shaped and include the carpals and tarsals.

3. Flat bones are thin, flattened, often curved bones that include most skull bones, the sternum, scapulae, and ribs.

4. Irregular bones have complicated shapes that do not fit in any other class, such as the vertebrae and coxae.

III. Functions of Bones (pp. 178-179)

A. Bones support the body and cradle the soft organs, protect vital organs, allow movement, store minerals such as calcium and phosphate, and house hematopoietic tissue in specific marrow cavities.

IV. Bone Structure (pp. 179-184; Figs. 6.3-6.6; Table 6.1)

A. Gross Anatomy (pp. 179-181; Fig. 6.3, 6.4; Table 6.1)

1. Bone markings are projections, depressions, and openings found on the surface of bones that function as sites of muscle, ligament, and tendon attachment, as joint surfaces, and as openings for the passage of blood vessels and nerves.

2. Bone Textures: Compact and Spongy Bone

a) All bone has a dense outer layer consisting of compact bone that appears smooth and solid.

b) Internal to compact bone is spongy bone, which consists of honeycomb, needle-like, or flat pieces, called trabeculae.

3. **Structure of a Typical Long Bone**

a) Long bones have a tubular bone shaft, consisting of a bone collar surrounding a hollow medullary cavity, which is filled with yellow bone marrow in adults.

b) Epiphyses are at the ends of the bone, and consist of internal spongy bone covered by an outer layer of compact bone.

c) The epiphyseal line is located between the epiphyses and diaphysis, and is a remnant of the epiphyseal plate.

d) The external surface of the bone is covered by the periosteum.

e) The internal surface of the bone is lined by a connective tissue membrane called the endosteum.

4. **Structure of Short, Flat, and Irregular Bones**

a) Short, flat, and irregular bones consist of thin plates of periosteum-covered compact bone on the outside, and endosteum-covered spongy bone inside, which houses bone marrow between the trabeculae.

5. **Location of Hematopoietic Tissue in Bones**

a) Hematopoietic tissue of bones, red bone marrow, is located within the trabecular cavities of the spongy bone in flat bones, and in the epiphyses of long bones.

b) Red bone marrow is found in all flat bones, epiphyses, and medullary cavities of infants, but in adults, distribution is restricted to flat bones and the proximal epiphyses of the humerus and femur.

B. Microscopic Anatomy of Bone (pp. 181-182; Figs. 6.5, 6.6)

1. The structural unit of compact bone is the osteon, or Haversian system, which consists of concentric tubes of bone matrix (the lamellae) surrounding a central Haversian canal that serves as a passageway for blood vessels and nerves.

a) Perforating, or Volkmann's, canals lie at right angles to the long axis of the bone, and connect the blood and nerve supply of the periosteum to that of the central canals and medullary cavity.

b) Osteocytes occupy lacunae at the junctions of the lamellae, and are connected to each other and the central canal via a series of hair-like channels, canaliculi.

c) Circumferential lamellae are located just beneath the periosteum, extending around the entire circumference of the bone, while interstitial lamellae lie between intact osteons, filling the spaces in between.

2. Spongy bone lacks osteons but has trabeculae that align along lines of stress, which contain irregular lamellae.

C. Chemical Composition of Bone (pp. 182-184)

1. Organic components of bone include cells (osteoblasts, osteocytes, and osteoclasts) and osteoid (ground substance and collagen fibers), which contribute to the flexibility and tensile strength of bone.

2. Inorganic components make up 65% of bone by mass, and consist of hydroxyapatite, a mineral salt that is largely calcium phosphate, which accounts for the hardness and compression resistance of bone.

V. Bone Development (pp. 184-187; Figs. 6.7-6.10)

A. Formation of the Bony Skeleton (pp. 184-186; Figs. 6.7, 6.8)

1. Intramembranous ossification forms membrane bone from fibrous connective tissue membranes, and results in the cranial bones and clavicles.

2. In endochondral ossification bone tissue replaces hyaline cartilage, forming all bones below the skull except for the clavicles.

a) Initially, osteoblasts secrete osteoid, creating a bone collar around the diaphysis of the hyaline cartilage model.

b) Cartilage in the center of the diaphysis calcifies and deteriorates, forming cavities.

c) The periosteal bud invades the internal cavities and spongy bone forms around the remaining fragments of hyaline cartilage.

d) The diaphysis elongates as the cartilage in the epiphyses continues to lengthen and a medullary cavity forms through the action of osteoclasts within the center of the diaphysis.

e) The epiphyses ossify shortly after birth through the development of secondary ossification centers.

B. Postnatal Bone Growth (pp. 186-187; Figs. 6.9-6.10)

1. Growth in length of long bones occurs at the ossification zone through the rapid division of the upper cells in the columns of chondrocytes, calcification and deterioration of cartilage at the bottom of the columns, and subsequent replacement by bone tissue.

2. Growth in width, or thickness, occurs through appositional growth due to deposition of bone matrix by osteoblasts beneath the periosteum.

3. Hormonal Regulation of Bone Growth

a) During infancy and childhood, the most important stimulus of epiphyseal plate activity is growth hormone from the anterior pituitary, whose effects are modulated by thyroid hormone.

b) At puberty, testosterone and estrogen promote a growth spurt, but ultimately induct the closure of the epiphyseal plate.

VI. Bone Homeostasis: Remodeling and Repair (pp. 187-193; Figs. 6.10-6.13; Table 6.2)

A. Bone Remodeling (pp. 188-190; Figs. 6.10-6.12)

1. In adult skeletons, bone remodeling is balanced bone deposit and removal, bone deposit occurs at a greater rate when bone is injured, and bone resorption allows minerals of degraded bone matrix to move into the blood.

2. Control of Remodeling

a) The hormonal mechanism is mostly used to maintain blood calcium homeostasis, and balances activity of parathyroid hormone and calcitonin.

b) In response to mechanical stress and gravity, bone grows or remodels in ways that allow it to withstand the stresses it experiences.

B. Bone Repair (pp. 190-193; Fig. 6.13; Table 6.2)

1. Fractures are breaks in bones, and are classified by: the position of the bone ends after fracture, completeness of break, orientation of the break relative to the long axis of the bone, and whether the bone ends penetrate the skin.

2. Repair of fractures involves four major stages: hematoma formation, fibrocartilaginous callus formation, bony callus formation, and remodeling of the bony callus.

VII. Homeostatic Imbalances of Bone (pp. 193-198; Fig. 6.14)

A. Osteomalacia and Rickets (p. 193)

1. Osteomalacia includes a number of disorders in adults in which the bone is inadequately mineralized.

2. Rickets is inadequate mineralization of bones in children caused by insufficient calcium or vitamin D deficiency.

B. Osteoporosis refers to a group of disorders in which the rate of bone resorption exceeds the rate of formation (pp. 193-195, Fig. 6.14).

1. Bones have normal bone matrix, but bone mass is reduced and the bones become more porous and lighter increasing the likelihood of fractures.

2. Older women are especially vulnerable to osteoporosis, due to the decline in estrogen after menopause.

3. Other factors that contribute to osteoporosis include a petite body form, insufficient exercise or immobility, a diet poor in calcium and vitamin D, abnormal vitamin D receptors, smoking, and certain hormone-related conditions.

C. Paget's disease is characterized by excessive bone deposition and resorption, with the resulting bone abnormally high in spongy bone. It is a localized condition that results in deformation of the affected bone (pp. 195-198).

VIII. Developmental Aspects of Bones: Timing of Events (p. 198; Fig. 6.15)

A. The skeleton derives from embryonic mesenchymal cells, with ossification occurring at precise times. Most long bones have obvious primary ossification centers by 12 weeks gestation.

B. At birth, most bones are well ossified, except for the epiphyses, which form secondary ossification centers.

C. Throughout childhood, bone growth exceeds bone resorption; in young adults, these processes are in balance; in old age, resorption exceeds formation.

Cross References

Additional information on topics covered in Chapter 6 can be found in the chapters listed below.

1. Chapter 2: Calcium salts
2. Chapter 4: Bone (osseous tissue); chondroblasts; collagen fibers; fibroblasts; fibrocartilage; hyaline cartilage; proteoglycans
3. Chapter 7: Individual bones that make up the skeleton; identifying marks of individual bones
4. Chapter 8: Articular cartilage and joint structure
5. Chapter 16: Gigantism and dwarfism as related to bone growth and length; effects of parathyroid hormone and calcitonin on bone homeostasis
6. Chapter 17: Hematopoietic tissue

Laboratory Correlations

1. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Cat and Fetal Pig Versions*. Eighth Edition Updates. Benjamin Cummings, 2006.
   Exercise 9: Overview of the Skeleton—Classification and Structure of Bones and Cartilages
2. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Main Version*. Seventh Edition Update. Benjamin Cummings, 2006.
   Exercise 9: Overview of the Skeleton—Classification and Structure of Bones and Cartilages