Bones and Skeletal Tissues Outline

6.1 Hyaline, elastic, and fibrocartilage help form the skeleton (pp. 172–174; Fig. 6.1)

A. Basic Structure, Types, and Locations (pp. 173–174; 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. 175)

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

6.2 Bones perform several important functions (pp. 175)

A. Bones support the body, surround and protect soft or vital organs, allow movement, store minerals such as calcium and phosphate, house hematopoietic tissue and fat in specific marrow cavities, and produce hormones. (p. 175)

6.3 Bones are classified by their location and shape (pp. 174–175; Figs. 6.1–6.2)

A. There are two main divisions of the bones of the skeleton: the axial skeleton, and the appendicular skeleton. (pp. 175–176; Fig. 6.1)

1. The axial skeleton consists of the skull, vertebral column, and rib cage; the appendicular skeleton consists of the bones of the upper and lower limbs, and the girdles that attach them to the axial skeleton.

B. Bones are classified by their shape. (pp. 176–177; 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 and wrist and ankle bones.
2. Short bones are somewhat cube shaped and include the carpals, tarsals, and patellas.
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 hip bones.

6.4 The gross structure of all bones consists of compact bone sandwiching spongy bone (pp. 177–183; Figs. 6.3–6.7; Table 6.1)

A. Gross Anatomy (pp. 177–179; Figs. 6.3–6.4; Table 6.1)

1. 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.

2. Structure of Short, Irregular, and Flat Bones
   a. Short, irregular, and flat 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.
3. Structure of a Typical Long Bone
   a. Long bones have a tubular diaphysis, 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, and a thin layer of articular cartilage.
   c. The epiphyseal line is located between the epiphyses and diaphysis and is a remnant of the epiphyseal plate, the hyaline cartilage that provides lengthwise growth of bone.
   d. The external surface of the bone is covered by the periosteum, the location of osteogenic cells.
   e. The internal surface of the bone is lined by a connective tissue membrane called the endosteum, a location of osteogenic cells within the bone.
4. Hematopoietic Tissue in Bones
   a. Red bone marrow is located within the trabecular cavities of the spongy bone in long bones and in the diploë of flat bones.
   b. In long bones, red bone marrow is found in all medullary cavities and all areas of spongy bone of infants, but in adults, distribution is restricted to the proximal epiphyses of the humerus and femur.
5. 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.

B. Microscopic Anatomy of Bone (pp. 179–183; Figs. 6.5–6.7)

1. Bone tissue contains five types of cells: bone stem cells, called osteogenic cells, osteoblasts that secrete bone matrix, osteocytes and bone lining cells that monitor and maintain bone matrix, and osteoclasts that are involved in bone resorption.
2. The structural unit of compact bone is the osteon, or Haversian system, a series 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. Lacunae, small holes housing the osteocytes, are found 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. Lamellae located just beneath the periosteum and extending around the entire circumference of the bone are called circumferential lamellae, while interstitial lamellae lie between intact osteons, filling the spaces in between.

3. Spongy bone lacks osteons but has trabeculae that align along lines of stress, which contain irregular lamellae and osteocytes connected with canaliculi.

C. Chemical Composition of Bone (p. 183)

1. Organic components of bone include cells 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 hydroxyapatites, mineral salts (largely calcium phosphates), that account for the hardness and compression resistance of bone.

6.5 Bones develop either by intramembranous or endochondral ossification (pp. 183–187; Figs. 6.8–6.11)

A. Formation of the Bony Skeleton (pp. 183–185; Figs. 6.8–6.9)

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

B. Postnatal Bone Growth (pp. 185–187; Figs. 6.10–6.11)

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, ultimately resulting in the closure of the epiphyseal plate.

6.6 Bone remodeling involves bone deposit and removal (pp. 187–192; Figs. 6.12–6.13; Table 6.2)

A. Bone Deposit (p. 187)

1. An osteoid seam of gauzy-looking bone indicates the area of new bone deposition; it is separated from older mineralized bone by a transition zone called a calcification front.

B. Bone Resorption (pp. 187–188)
1. In adult skeletons, bone deposit and resorption occur beneath the periosteum and endosteum; bone remodeling is balanced bone deposit and resorption.

C. Control of Remodeling (pp. 188–189; Figs. 6.12–6.13)
1. Hormonal control of remodeling is mostly used to maintain blood calcium homeostasis and balances activity of parathyroid hormone and calcitonin.
2. Wolff's law states that bone grows or remodels in ways that allow it to withstand the stresses it experiences, due to factors such as mechanical stress and gravity.

6.7 Bone repair involves hematoma and callus formation, and remodeling

A. Fractures are breaks in bones and are classified by the position of the bone ends after fracture, completeness of break, and whether the bone ends penetrate the skin. (p. 190)

B. Repair of fractures involves four major stages: hematoma formation, fibrocartilaginous callus formation, bony callus formation, and remodeling of the bony callus. (pp. 190–192; Fig. 6.14; Table 6.2)

6.8 Bone disorders result from abnormal bone deposition and resorption (pp. 192–193; Figs. 6.15-6.16)

A. Osteomalacia and Rickets (p. 192)
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 in the diet or by a vitamin D deficiency.

B. Osteoporosis refers to a group of disorders in which the rate of bone resorption exceeds the rate of formation (pp. 192–193, Fig. 6.15).
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, random 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 (p. 193; Fig. 6.16).

Developmental Aspects of Bones (pp. 193–194; Fig. 6.17)

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 after conception (pp. 193–194; Fig. 6.17).

B. At birth, most bones are well ossified: After birth, bones form secondary ossification centers, but epiphyseal plates remain throughout childhood, as the site of longitudinal bone growth. (p. 194).

C. Throughout childhood, bone growth exceeds bone resorption; in young adults, these processes are in balance; in old age, resorption exceeds formation (p. 194).