Chapter 6 Outline

I. INTRODUCTION

A. Bone is made up of several different tissues working together: bone, cartilage, dense connective tissue, epithelium, various blood forming tissues, adipose tissue, and nervous tissue.

B. Each individual bone is an organ; the bones, along with their cartilages, make up the skeletal system.

II. FUNCTIONS OF THE SKELETAL SYSTEM

A. Bones *support* the soft tissues and provide attachment sites for muscles, thereby serving as the structural framework for the body.

B. Many of the body's internal organs are *protected* by bony coverings.

C. Bones assist skeletal muscles to produce *movement.*

D. Bones *store and release several minerals*, especially calcium and phosphorus, to help maintain mineral homeostasis.

E. *Hemopoiesis*, blood cell formation, occurs in the red marrow of bones.

F. Yellow marrow of adult bones serves as a site of *triglyceride storage*.

III. STURCTURE OF BONE

A. The structure of bone can be analyzed by studying a long bone.

B. A typical long bone consists of numerous parts.

1. The *diaphysis* is the shaft of the long bone.
2. The *epiphyses* are the ends of the bone
3. The *metaphyses* are the areas between the epiphysis and diaphysis and include the epiphyseal plate in growing bones.
4. Hyaline cartilage (*articular cartilage*) at the ends of the bones reduces friction and absorbs shock at freely moveable joints.

5. The *periosteum* is a connective tissue covering of the surface of the bone which contains osteogenic cells, protects bone, assists in fracture repair, helps nourish bone tissue, and serves as an attachment point for ligaments and tendons.
6. The space within the diaphysis is the *marrow cavity*.
7. The *endosteum* is the lining of the medullary cavity.

IV. HISTOLOGY OF BONE TISSUE

A. *Bone (osseous) tissue* consists of widely separated cells surrounded by large amounts of matrix.

B. There are four principal types of bone cells.
   1. *Osteogenic cells* undergo cell division and develop into osteoblasts.
   2. *Osteoblasts* are bone-building cells.
   3. *Osteocytes* are mature bone cells and the principal cells of bone tissue.
   4. *Osteoclasts* are derived from monocytes and serve to break down bone tissue.

C. The matrix of bone contains inorganic salts, primarily hydroxyapatite (calcium phosphate and calcium carbonate), some magnesium hydroxide, fluoride and sulfate, and collagen fibers.
   1. These and a few other salts are deposited in a framework of collagen fibers, a process called *calcification* or *mineralization.*
   2. Mineral salts confer hardness on bone while collagen fibers give bone its great tensile strength.
   3. The process of calcification occurs only in the presence of collagen fibers.

D. Depending on the size and distribution of the spaces between the hard components of bone, the regions of a bone may be categorized as compact or spongy.
   1. Compact Bone
      a. *Compact bone* is arranged in units called *osteons* or *Haversian systems*.

b. Osteons contain blood vessels, lymphatic vessels, nerves, and osteocytes along with the calcified matrix.

c. Osteons are aligned in the same direction along lines of stress. These lines can change as the stresses on the bone changes.

2. Spongy Bone

a. Spongy (cancellous) bone does not contain osteons. It consists of trabeculae surrounding many red marrow filled spaces.

b. It forms most of the structure of short, flat, and irregular bones, and the epiphyses of long bones.

c. Spongy bone tissue is light and supports and protects the red bone marrow.

V. BLOOD AND NERVE SUPPLY OF BONE

A. Bone is richly supplied with blood.

B. The arterial supply to bone involves several vessels.

1. The *periosteal arteries* pass through perforating (Volkmann's) canals to a multitude of vessels that supply the outer compact bone region.

2. The *nutrient artery* passes through the nutrient canal and sends branches into the central Haversian canals to provide for osteocytes. It enters the medullary cavity to supply the marrow.

3. Metaphyseal and epiphyseal arteries supply the corresponding regions of the long bones.

C. Veins that carry blood away from long bones are evident in three places.

1. One or two *nutrient veins* follow the nutrient artery in the diaphysis.

2. *Epiphyseal* and *metaphyseal veins* accompany epiphyseal and metaphyseal arteries in the epiphysis.

3. *Periosteal veins* exit with their periosteal arteries in the periosteum.

D. *Nerves* follow vessels into bone tissue and the periosteum where they sense damage and transmit pain messages.

VI. BONE FORMATION

A. Bone formation is termed *osteogenesis* or *ossification* and begins when mesenchymal cells provide the template for subsequent ossification. Two types of ossification occur.
    1. *Intramembranous ossification* is the formation of bone directly from or within fibrous connective tissue membranes.
    2. *Endochondrial ossification* is the formation of bone from hyaline cartilage models.

B. Intramembranous ossification forms the flat bones of the skull and the mandible.
    1. An ossification center forms from mesenchymal cells as they differentiate to osteoblasts and lay down osteoid matrix.
    2. The matrix surrounds the cell and then calcifies as the osteoblast becomes an osteocyte.
    3. The calcifying matrix centers join to form bridges of trabeculae that constitute spongy bone with red marrow between.
    4. The periosteum first forms a collar of spongy bone that is then replaced by compact bone.

C. *Endochondrial ossification* involves replacement of cartilage by bone and forms most of the bones of the body. Be sure to know the details of the steps of endochondral ossification . You should also know the difference between appositional and interstitial growth. The following is just a general outline.
    1. The first step in endochondral ossification is the development of the *cartilage model*.
    2. Step two is the *growth of the cartilage model*.
    3. In step three, the *primary ossification ce*nter develops in the diaphysis.
    4. Step four involves the *development of secondary ossification centers* in the epiphysis.
    5. The final process is the *formation of articular cartilage and the epiphyseal plate*.

VII. BONE GROWTH

A. Growth in Length

1. To understand how a bone grows in length, one needs to know details of the epiphyseal or growth plate.
2. The *epiphyseal plate* consists of four zones: the zone of resting cartilage, zone of proliferation cartilage, zone of hypertrophic cartilage, and zone of calcified cartilage. You should know what is going on in each of these zones. The activity of the epiphyseal plate is the only means by which the diaphysis can increase in length.
3. When the epiphyseal plate closes, is replaced by bone, the epiphyseal line appears and indicates the bone has completed its growth in length.

B. Growth in Thickness

1. Bone can grow in thickness or diameter only by *appositional growth*.
2. Bone grows in diameter as a result of *interstitial* and *appositional* addition of new bone tissue by osteoblasts around the outer surface of the bone and to a lesser extent internal bone dissolution by osteoclasts in the bone cavity.

C. Factors Affecting Bone Growth

1. Adequate dietary intake of minerals and vitamins is necessary for growth and maintenance of bone.
    a. Calcium and phosphorus are needed for bone growth in large concentrations, with other minerals needed in smaller amounts.
    b. Vitamins C, K, B_{12}, and A are needed for bone growth.
2. The most important hormones for stimulation of bone growth during childhood are the *insulinlike growth factors* (IGFs), which are stimulated by human growth hormone (hGH).
3. Thyroid hormones and insulin are also necessary hormones for bone growth.

4. At puberty the sex hormones, estrogen and testosterone, stimulate sudden growth and modifications of the skeleton to create the male and female forms.

VII. BONES AND HOMEOSTASIS

A. Bone Remodeling

1. *Remodeling* is the ongoing replacement of old bone tissue by new bone tissue.
2. Old bone is constantly destroyed by osteoclasts, whereas new bone is constructed by osteoblasts.

B. Fracture and Repair of Bone

1. A *fracture* is any break in a bone.
2. Common fractures include open (compound) fracture, closed (simple) fracture, comminuted fracture, greenstick fracture, impacted fracture, Pott's fracture, and Colles's fracture.
3. A stress fracture is a series of microscopic fissures in bone that forms without any evidence of injury to other tissues.
4. Fracture repair involves formation of a clot called a *fracture hematoma*, organization of the fracture hematoma into granulation tissue called a *procallus* (subsequently transformed into a *fibrocartilaginous* [soft] *callus*), conversion of the fibrocartilaginous callus into the spongy bone of a *bony* (hard) *callus*, and, finally, remodeling of the callus to nearly original form.

C. Bone's Role in Calcium Homeostasis

1. Bone is the major reservoir for calcium ions (Ca^{2+}) in the body; the blood level calcium ions (Ca^{2+}) are very closely regulated due to calcium's importance in cardiac, nerve, enzyme, and blood physiology.

2. An important hormone regulating Ca^{2+} exchange between bone and blood is *parathyroid hormone* (PTH), secreted by the parathyroid gland. It increases blood calcium ion levels.
3. Another hormone that contributes to the homeostasis of blood Ca^{2+} is *calcitonin* (CT). It is secreted by the thyroid gland and decreases blood Ca^{2+} levels.

IX. EXERCISE AND BONE TISSUE

A. Within limits, bone has the ability to alter its strength in response to mechanical stress by increasing deposition of mineral salts and production of collagen fibers.

B. Removal of mechanical stress weakens bone through demineralization (loss of bone minerals) and collagen reduction.

C. Weight-bearing activities, such as walking or moderate weightlifting, help build and retain bone mass.