CHAPTER 6

LECTURE 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 physically protected by bony coverings.

C. Bones assist skeletal muscles to produce *movement* of body parts.

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 (Figure 6.1).

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, that articulate with adjacent bones.
3. The *metaphyses* are the areas between the epiphysis and diaphysis. It includes the epiphyseal plate, which the site of bone elongation, 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 which promotes bone growth in width, 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* which contains yellow marror, or adipose connective tissue
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.(Figure 6.2)
   1. *Osteogenic cells* undergo cell division and develop into osteoblasts.
   2. *Osteoblasts* are bone-building cells, promoting bone deposition
   3. *Osteocytes* are mature bone cells, derived from osteoblasts, that maintain bone tissue.
   4. *Osteoclasts* are derived from monocytes and serve to break down, or resorb, bone tissue.

C. The matrix of bone contains inorganic salts, primarily hydroxyapatite and some calcium carbonate, 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 (Figure 6.1).
   1. Compact Bone
      a. *Compact bone* is arranged in units called *osteons* or *Haversian systems* (Figure 6.3a) and is found on the outside of bones.
      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 but, instead, consists of trabeculae surrounding many red marrow filled spaces (Figure 6.3b).
      b. It forms most of the interior structure of short, flat, and irregular bones, and the epiphyses of long bones.

c. Spongy bone tissue is light and provides open spaces for the red bone marrow and, as such, is the site of hemopoesis..

3. A bone scan is a diagnostic procedure that can detect certain bone abnormalities or disorders (Clinical Application).

V. BLOOD AND NERVE SUPPLY OF BONE

A. Bone is richly supplied with blood (Figure 6.4).

B. The arterial supply to bone involves several vessels.

1. The *periosteal arteries* pass through Volkmans' canals to a multitude of vessels that supply the outer compact bone region (Figure 6.4).
2. The *nutrient artery* passes through the nutrient canal and sends branches into the central Haversian canals to provide nutrients for osteocytes (Figure 6.4).
3. The artery continues into the medullae to supply blood for the marrow and osteocells via the *epiphyseal artery*. (Figure 6.4)

C. Veins that carry blood away from long bones are evident in three places. (Figure 6.4)

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 embryonic 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. *Endochondral ossification* is the formation of bone from hyaline cartilage models.

B. Intramembranous ossification forms the flat bones of the skull and the mandible (Figure 6.5).

1. An ossification forms from mesenchymal cells as they convert 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. *Endochondral ossification* involves replacement of cartilage by bone and forms most of the bones of the body (Figure 6.6).
   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. Cartilage is being removed and replaced by bone
   4. Step four results in the formation of a medulary cavity
   5. Step five involves the *development of secondary ossification centers* in the epiphysis.
   6. The final process is the *formation of articular cartilage and the epiphyseal plate*.

D. 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 (Figure 6.7).
   3. The activity of the epiphyseal plate is the only means by which the diaphysis can increase in length.
   4. When the epiphyseal plate closes, is replaced by bone, the epiphyseal line appears and indicates the bone has completed its growth in length.

E. Growth in Thickness
   1. Bone can grow in thickness or diameter only by *appositional growth* at the periosteum
   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 (figure 6.8).
   3. **Clinical Connection**: Remodeling and orthodontics, stressing the teeth causes the bones in the jaw to remodel.
   4. **Clinical Connection**: Paget's Disease, an imbalance in growth between osteoclasts and osteoblasts resulting in bone that is misshaped and brittle.

F. 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.
3. Remodeling allows teeth to be moved during orthodontia.

G. Factors Affecting Bone remodeling and 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.
5. **Clinical Connection**: Hormonal abnormalities can affect growth in height
6. Refer to Table 6.1 for a summary of factors that influence bone metabolism.

H. Fracture and Repair of Bone

1. A *fracture* is any break in a bone
2. Steps in repair of a bone fracture are shown in figure 6.9
3. Common fractures include (table 6.1) open (compound) fracture, comminuted fracture, greenstick fracture, impacted fracture, Pott's fracture, and Colles's fracture.
4. A stress fracture is a series of microscopic fissures in bone that forms without any evidence of injury to other tissues.
5. Fracture repair (Figure 6.9) 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.
6. Treatments for fractures include the anatomic realignment of the bone fragments, immobilization to maintain realignment, and restoration of function.

VII. BONE'S ROLE IN CALCIUM HOMEOSTASIS

A. 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.
B. 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 (Figure 6.10)
C. 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.

VIII. 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.

IX. AGING AND BONE TISSUE

A. Of two principal effects of aging on bone, the first is the loss of calcium and other minerals from bone matrix (demineralization), which may result in osteoporosis.
B. The second principal effect of aging on the skeletal system is a decreased rate of protein synthesis, resulting in decreased production of matrix components (mostly collagen) and making bones more susceptible to fracture.
C. Refer to Table 6.2 for a summary of factors that influence bone metabolism.

X. DISORDERS: HOMEOSTATIC IMBALANCES

A. *Osteoporosis* is a decrease in the amount and strength of bone tissue owing to decreases in hormone output. In osteoporosis, bone resorption outpaces bone formation.
B. *Rickets* and *osteomalacia* are disorders in which bones fail to calcify.

XI. MEDICAL TERMINOLOGY

A. Alert students to the medical terminology associated with skeletal tissue.