Ch 6 Skeletal System

I. Functions of the Skeletal System
   A. The skeletal system consists of:
      1. bones, cartilage, tendons and ligaments
   B. Living bone is not “Gr. dried up”
      1. It is dynamic and adaptable
   C. Functions of the skeletal system:
      1. **Support**
         a. Forms a ridged framework to which soft tissues and organs are attached.
         b. **Bone:**
            c. **Cartilage:**
               d. **Ligaments:**
      e. **Tendons:**
   2. **Protection** (protects the organs it surrounds)

3. **Movement**
   a. Bones act as levers
   b. Joints permit and control movement
   c. Smooth cartilage allows joints to move freely
   d. Ligaments prevent excessive movement.

4. **Storage (minerals and fats)**
   a. Some minerals are taken from the blood and stored in bone
   b. Calcium and phosphorous
   c. Fat

5. **Blood Cell production (hemopoiesis)**
   a. Bone marrow gives rise to blood cells.
   b. Adult bones produce 2.5 million RBCs each second.

II. Cartilage
   A. Three types of cartilage: hyaline, fibro and elastic cartilage.
      1. All provide support
      2. Hyaline most intimately associated with bone.
      3. Most bones in the body develop from hyaline cartilage.
         a. Growth
         b. Repair
   B. Hyaline cartilage consists of specialized cells that produce a matrix surrounding the cells.
      1. **Chondroblasts**
      2. **Chondrocytes**.
3. Lacunae
4. Collagen fibers (for strength)
5. Proteoglycans (trap water).

C. The perichondrium surrounds cartilage.
   1. The outer layer is made up of dense irregular connective tissue containing fibroblasts.
   2. The inner layer contains few fibers and has chondroblasts.
   3. Blood vessels penetrate the outer layer but do not enter the matrix.

4. Articular cartilage has no perichondrium, blood vessels or nerves.

D. Cartilage grows by appositional and interstitial growth.
   1. Appositional growth: chondroblasts in the perichondrium lay down new matrix on the outside of the tissue.
   2. Interstitial Growth: Chondrocytes within the tissue divide and add more matrix from the inside.

III. Bone Anatomy
   A. Bone shapes
      1. Bones are classified by shape.
         a. Long bones:
         b. Short bones:
         c. Flat bones:
         d. Irregular bones:

   B. Structure of a long bone
      1. Three components: diaphysis, epiphysis and epiphyseal plate.
         a. Diaphysis
         b. Epiphyses are the ends of bones
         c. Epiphyseal plate is the site of bone growth in length
            (1)
            (2) Epiphyseal line:
      2. The medullary cavity is a space within the diaphysis
         a. Red marrow:
         b. Yellow marrow:
      3. The periosteum covers the outer surface of bone.
         a. The outer layer
            (1) Dense fibrous irregular collagenous connective tissue
            (2) contains blood vessels and nerves.
         b. The inner layer
            (1) Single layer of bone cells
            (2) contains osteoblasts, osteoclasts and osteoprogenitor cells.
c. **Perforating fibers**
   (1) penetrate the periosteum (bundles of collagen fibers)
   (2) hold the periosteum, ligaments and tendons in place.

4. **Endosteum** - lines cavities medullary cavity and smaller cavities of smaller bones
   a. Single layer contains osteoblasts, osteoclasts and osteoprogenitor cells.

C. **Structure of Flat, Short and Irregular Bones**
   1.

IV. **Bone Histology**
   A. **Bone matrix**
      1. Collagen
      2. Hydroxyapatite
         a. Contains Ca++ and phosphate

   B. **Bone cells**
      1. **Osteoblasts** produce bone matrix and become osteocytes.
         a. Synthesize and secrete non mineralized bone matrix.
         b. Most abundant in areas of high metabolism within bone.
         c. Form vesicles that accumulate Ca++ and PO$_4$
            (1) **hydroxyapatite crystals**
            (2) **Ossification or Osteogenesis**
      2. **Osteocytes** are Mature bone cells
         a. located in lacunae and connected by canaliculi
         b. Secrete bone tissue around themselves
         c. Maintain bone
         d. Regulate Ca++ release
      3. **Osteoclasts**
         a. Large multinucleated cells
         b. Enzymatically break down bone.
         c. Important in growth and remodeling.

   4. **Origin of Bone Cells**
      a. **Osteoblasts** originate from osteoprogenitor cells in mesenchyme/ periosteum.
      b. **osteoclasts** originate from stem cells in red bone marrow.

Bone Types
   C. **Woven Bone**
      1. First formed during fetal development or during repair of a fracture.
      2. Has collagen fibers oriented in many different directions.
      3. Remodeled

D. **Lamellar Bone**
   1. Lamellar bone is mature bone that is arranged in thin layers called lamellae.
      a.
2. **Two kinds of lamellar bone**: cancellous and compact bone.

3. **Cancellous Bone** (spongy bone) has many spaces
   a. *trabeculae* -
      (1) form a lattice
      (2) Structure:

   b. **Stress lines**:
      (1) The trabeculae are oriented along *lines of stress* and provide structural strength.

4. **Compact Bone** is dense with few spaces
   a. *Concentric lamellae*
   b. **haversian canals**
      (1) Haversian canals contain:
   c. *lamellae* surround central canals in rings forming osteons.
   d. **Osteon** consists of:
      (1) a single *haversian canal* and its contents.
      (2) the associated *concentric lamellae*
      (3) osteocytes in lacunae with *canaliculi*
   e. **Interstitial lamellae**:

f. **Circumferential lamellae**

g. **Volkman’s canals or perforating canals**

h. Canals within compact bone provide means for the exchange of gases, nutrients, and waste products.
   (1) Nutrients are transported through the cytoplasm of osteocytes inside the canaliculi to the most peripheral cells within the osteon.

V. **Bone Development**

A. During fetal development there are two types of bone formation- intramembranous and endochondral ossification.
   1. **Intramembranous** ossification: bone development in connective tissue membranes
   2. **Endochondral** ossification in cartilage.
   3. Both methods produce woven bone initially that is later remodeled.

B. **Intramembranous ossification**
   1. Begins at ~8 weeks during development and continues until age 2.
   2. Bones that develop from membranes:
      a. Many skull bones,
      b. part of mandible,
      c. diaphyses of the clavicles develop.
3. **Process** of intramembranous ossification
   a. Embryonic mesenchyme (embryonic tissue layer) forms a collagen membrane containing osteoprogenitor cells.
   b. Osteoprogenitor cells become osteoblasts at centers of ossification.
      (1) Internally, within the membrane, the osteoblasts produce bone along the membrane fibers to form cancellous bone.
      (2) Externally, beneath the periosteum, the periosteal osteoblasts lay down compact bone to form the outer surface of the bone.

4. Fontanels or soft spots are found between developing bones of the skull and are areas of membrane that are not ossified at birth.
   a. Bones usually grow together and fontanels are closed by about 2 years of age.

C. **Endochondral ossification**
   1. Most bones develop from a cartilage model.
   2. The cartilage is calcified and chondrocytes die.
      a. Osteoblasts form bone on the calcified cartilage producing cancellous bone.
   3. An outer surface of compact bone is formed beneath the periosteum by osteoblasts.
   4. Primary ossification centers form in the diaphysis during fetal development.
      a. Secondary ossification centers form in the epiphyses.
   5. Articular cartilage on the ends of bones and the epiphyseal plate is cartilage that does not ossify.

VI. Bone Growth
   A. Begins formation at ~ the end of the fourth week of development.
      1. Starts to ossify at 8 weeks and might not finish until 18-20 years of age.
   B. Bones that develop through the process of endochondral ossification:
      1. bones at the base of the skull,
      2. part of the mandible,
      3. epiphyses of the clavicle, and
      4. most of the remaining skeletal system
   C. Process of endochondral ossification.
      1. Embryonic mesenchyme becomes chondroblasts that produce a cartilage template which is surrounded by the perichondrium.
      2. Chondrocytes hypertrophy, the cartilage is calcified and the chondrocytes die.
      3. The perichondrium becomes the periosteum when osteoprogenitor cells within the periosteum become osteoblasts.
      4. Blood vessels and osteoblasts from the periosteum invade the calcified cartilage template
         a. Internally these osteoblasts produce bone matrix at primary ossification centers (and later at secondary ossification centers).
         b. Externally the peristeal osteoblasts produce bone.
      5. Endochondral bone is remodeled and is indistinguishable from intramembranous bone.

D. Growth at the Epiphyseal Plate
E. Growth at Articular Cartilage

F. Other Bone Growth
   1. Appositional bone growth

G. Factors Affecting Bone Growth
   1. Genetic factors:
   2. Nutrition
   3. Hormones
      a. Growth hormone, thyroid hormone, estrogen, and testosterone stimulate bone growth.
      b. Estrogen and testosterone
      c. Thyroid hormone
      d. Growth hormone
         (1) Giantism -
         (2) Acromegaly-
         (3) Dwarfism -
            (a) Pituitary dwarfism:
            (b) Achondroplastic dwarfism:
VII. Bone Remodeling
A. Remodeling is the removal of bone by osteoclasts and deposition of new bone by osteoblasts.
B. Remodeling functions:
1.  
2.  
3.  
C. Bone adjusts by adding new bone and by realignment of bone through remodeling.
1.  
2.  
D. Process of remodeling
1. Osteoclast enter the osteon through the blood supply in the haversian canal.
2. Once inside the osteon, osteoclasts tear down the osteon by enlarging the haversian canal.
3. New osteons will later be formed by osteoblasts.
4. This process leaves portions of older osteons called interstitial lamellae.

VIII. Bone Repair
A. Five steps to bone repair:
1. Hematoma formation
2. Internal callus formation
3. External callus formation
4. Cartilage ossification
5. Remodeling of bone

B. Types of fractures
1. Simple (closed)
2. Compound (open)
3. Partial (fissured) fracture
4. Complete
5. Greenstick
6. Comminuted fracture
7. Impacted
8. Transverse fracture
9. Oblique fracture
10. Spiral fracture
11. Avulsion

IX. Calcium Homeostasis
A. Bone is the major site of Ca++ storage in the body.
   1. Ca++ is necessary for muscle contraction, hormone action and nerve function.
      a. Hypocalcemia (low blood Ca++) can result in hyperexcitability of nerves and muscle.
          (1) may lead to muscle spasm.
   2. Calcium moves into bone as osteoblasts build new bone and out of bone as osteoclasts break down bone
B. When osteoblast and osteoclast activity is balanced, the movement of calcium into and out of bone is balanced.
   1. Low blood calcium levels increase osteoclast activity.
      a. Net movement of calcium from the bone into the blood.
   2. High blood calcium levels decrease osteoclast activity and increase osteoblast activity.
      a. Net movement of calcium into bone and blood calcium levels decrease.
C. Hormones that regulate Calcium levels:
   1. Parathyroid hormone (PTH)
      a. Produced by the parathyroid glands
         (1) Anatomy and Location of the parathyroid gland:
         b. Functions:
            (1) Stimulates osteoclast to digest boney matrix and reabsorption of calcium in kidneys.
            (2) enhances reabsorption of calcium from intestine. This is an indirect effect. PTH enhances the transformation of vitamin D from its inactive state to an active one. Vitamin D then enhances calcium absorption from intestine.
c. Regulation:
   (1) A decrease in blood calcium initiates an increase in PTH release
   (2) Inhibited by rising blood calcium levels.

d. Mechanism of action:
   (1) **Does not work directly** on osteoclasts (no receptors)
      (a) Acts directly on **osteoblasts** to:
         i) produce osteoclast-stimulating factor.
            a) increases the activity and number of osteoclasts.
         ii) osteoblast releases enzymes that result in the breakdown of the layer of unmineralized organic bone matrix covering bone.
            a) mineralized bone matrix therefore becomes available to osteocytes.
   (2) Increasing calcium uptake in the small intestine.

(3) Increases reabsorption of calcium from urine in the kidneys which reduces calcium loss in the urine.

e. Hypersecretion:
   (1) Hyperparathyroidism -
      (a) rare leads to leaching of minerals from bones, abnormally high calcium levels in blood, depressed nervous system, slow and abnormal reflexes, weakness of skeletal muscles, formation of kidney stones.
      (b) Boney deposits may form in other soft tissue.

f. Hyposecretion:
   (1) Hypothyroidism -
      (a) may result from gland trauma or removal. Symptoms are hypereexcitability, tetany, loss of sensation, muscle twitches, laryngeal paralysis, and eventually death from respiratory paralysis.

2. **Calcitonin**
   a. **Function**: is a hormone secreted from the thyroid gland and has the opposite effect of PTH.
   b. Regulation: Increase in blood Ca++ causes the release of calcitonin
   c. Mechanism of action:
      (1) Decreases osteoclast activity
      (2) It lengthens the life span of osteoblasts
   d. Result is a decrease in blood Ca++ levels and Ca++ deposition in the bones.

X. **Osteoporosis**
   A. Occurs when the rate of bone resorption exceeds the rate of bone formation.
      1. Bones become weak and porous and
2. Prone to fracture and deformation.
3. Occurrence increases with age (starts at 40).
   a. Women can lose up to 50% of their bone mass. Men up to 25%.
5. Estrogen inhibits the effect of PTH on osteoclast activity
   a. Postmenopausal women that don’t take estrogen supplements therefore have a
clearer incidence of osteoporosis.
   b. Result is deformation of bone especially in vertebrae - decrease in height and
development of kyphosis (dowager’s hump)
   c. Smoking, extreme exercise, and anorexia nervosa can also cause decreased estrogen
levels and therefore osteoporosis.
6. A decrease in testosterone as men age has the same effect as decrease in estrogen
   a. Decrease doesn’t become significant until age 65.
   b. Men have more bone mass to start and therefore are less affected.
7. Inadequate Ca++, vitamin D and vitamin C intake increase the risk of osteoporosis.
8. Treatment
   a. Exercise
      (1) increase bone mass - inactivity decreases bone mass.
   b. Ca++, Vitamin D and C supplements.
   c. Calcitonin nasal spray - inhibits osteoclast activity.
   d. Alendronate - biphosphonate bind to hydroxyapatite and inhibit bone resorption.