I. Structures of the Skeletal System

A. Functions of Skeletal System
   1. Support
   2. Protection
   3. Movement
   4. Storage (calcium, phosphorus, adipose)
   5. Production or red blood cells

B. Types of bones
   1. **Long bones**: are greater in length than width. Include bones of the appendages.
   2. **Short bones**: somewhat cube shaped. Include carpal and tarsal bones.
   3. **Flat bones**: generally thin bones. Include most skull bones; sternum and ribs; and scapula.
   4. **Irregular bones**: complex shapes. Include vertebrae; hip bones; and some facial bones.

C. Structure of bones (long bones):
   1. Diaphysis
      a. The shaft of a long bone.
      b. Composed of compact bone surrounding a **marrow cavity**.
   2. Epiphyses
      a. The distal and proximal ends of a long bone.
      b. Primarily composed of spongy bone covered with a shell of compact bone.
      c. The ends of the epiphyses are covered by **articular cartilage** (hyaline).
   3. Epiphyseal plate (growth plate)
      a. Where the diaphysis joins the epiphyses.
      b. Consists of a layer of hyaline cartilage that allows the diaphysis to grow in length.
      c. As growth stops this cartilage is converted to bone and the previous epiphyseal plate is now known as an **epiphyseal line**.
   4. Periosteum
      a. Dense irregular connective tissue that surrounds the surface of the bone tissue, except at the articular cartilage where the bone is involved in a joint.
         i. The only bone in the body not involved in a joint is the hyoid bone, therefore it will have periosteum over the entire surface.
      b. Serves as an attachment point for tendons and ligaments.
      c. There are osteoblasts and osteoclasts deep to the periosteum that constantly rework the surface of the bone to meet the changing stresses. These cells are also important for growth of the bone in width or thickness.
   5. Medullary cavity (Marrow cavity)
      a. A space within the diaphysis that is filled with **yellow marrow** (adipose).
      b. A thin membrane lines the cavity (**endosteum**) containing osteoblasts and osteoclasts.

II. Development of the Skeletal System

A. The embryonic skeleton is originally composed of dense connective tissue membranes and cartilage. These structures act as a framework upon which bony tissue can be deposited.

B. Intramembranous bone formation

1. Formation of bone directly on or within fibrous connective tissue membranes.
2. Occurs in formation of the skull bones and the mandible.
3. Begins with fibroblasts laying down a membrane of dense connective tissue.
4. At the 8th week of development some fibroblasts in the interior of the membrane cluster into **ossification centers** and become osteoblasts.
5. These osteoblasts secrete the organic matrix (calcium salts) onto the dense connective tissue fibers to form trabeculae (thin strands of bone).
6. These trabeculae interconnect to form spongy bone that ultimately fills with red bone marrow.
7. At the periphery of the newly formed spongy bone the original membrane becomes the periosteum.
8. Eventually osteoblasts and osteoclasts rework the edges of the spongy bone to form a shell of compact bone around the spongy bone.

C. Endochondral bone formation

1. Formation of bone within hyaline cartilage.
2. Most bones of the body are formed in this way.
3. Begins with chondroblasts forming a hyaline cartilage model of the future bone.
4. Fibroblasts will lay down a dense connective tissue membrane around the cartilage forming a **perichondrium**.
5. At the diaphysis, cells beneath the perichondrium deposit a collar of compact bone.
6. A **primary ossification center** begins to develop within the diaphysis.
    a. Chondrocytes begin to grow in size and begin to deposit calcium salts onto the remaining cartilage.
    b. Eventually the chondrocytes burst and die increasing the pH of the surrounding matrix.
    c. As the chondrocytes die it leaves the lacunae (spaces) behind forming small cavities within the cartilage.
    d. Now that the cartilage has spaces a blood vessel invades the cartilage bringing in osteoblasts that complete spongy bone formation.
    e. Now that there is bone within the diaphysis the previous perichondrium is referred to as a periosteum.
    f. Eventually osteoclasts begin to break down the newly formed spongy bone within the diaphysis forming a medullary (marrow) cavity that fills with red bone marrow.
    g. Osteoclasts and osteoblasts rework the edges of the spongy bone to form compact bone at the diaphysis.
7. A **secondary ossification center** begins to develop at the epiphyses.
    a. Replicates the primary center, but a marrow cavity is not formed leaving spongy bone in the epiphyses.
    b. Some of the original hyaline cartilage will remain at the ends of the epiphyses to form the **articular cartilage** and also between the diaphyses and epiphyses to form the **epiphyseal plates**.
    c. The edge of the spongy bone is eventually reworked to form a shell of compact bone around the spongy bone.

D. Bone growth
   1. Bone growth in length occurs at the epiphyseal plates.
      a. The cartilage at the epiphyses grows outward.
      b. This cartilage closest to the diaphysis is replaced by bone tissue.
      c. This process continues until the end of puberty when the plate completely ossifies becoming an epiphyseal line.
   2. Bone growth in width occurs as osteoblasts under the periosteum lay down compact bone at the diaphyses.
      a. Simultaneously osteoclasts break down the bone adjacent to the medullary cavity so the bone thickness remains constant.
   3. Achondroplasia (achondroplastic dwarfism)
      a. A genetic disorder that causes excessively shortened appendages.
      b. Results from defective cartilage formation and abnormal calcification.

E. Factors which affect and control bone growth
   1. Vitamin D
      a. Needed for the absorption of calcium and phosphorus from digestive tract.
      b. A deficiency as a child results in **rickets**. Characterized by deformed legs, ribs, sternum and vertebrae.
      c. A deficiency as an adult results in **osteomalacia**. Bones undergo decalcification and become weakened.
   2. Growth hormone
      a. Produced by the pituitary gland.
      b. Indirectly stimulates mitosis of cartilage at the epiphyseal plates resulting in bone growth in length.
      c. Too much growth hormone before puberty results in **giantism**.
      d. Too much growth hormone after puberty result in **acromegaly**. Characterized by an increase in size of facial features, hands and feet.
      e. Too little growth hormone before puberty results in **pituitary dwarfism**.
         i. Too little growth occurs before ossification of the epiphyseal plates. Results in a person of short stature with normal proportions.
   3. Thyroxine
      a. Produced by the thyroid gland.
      b. Stimulates the replacement of cartilage with bone.
   4. Parathyroid hormone
      a. Produced by the parathyroid gland in response to **low** levels of blood calcium.
      b. Stimulates osteoclasts to break down bone and inhibits osteoblasts from building bone thereby **increasing** blood levels of calcium.
   5. Calcitonin
      a. Produced by the thyroid gland in response to **high** levels of blood calcium.
      b. Stimulates osteoblasts to build bone and inhibits osteoclasts from breaking down bone thereby **decreasing** blood levels of calcium.
   6. Sex hormones
      a. Include testosterone and estrogen.
      b. Promote the formation of bone resulting in bone growth in adolescence and bone maintenance in adults.
      c. During puberty, high levels terminate bone growth.

d. Estrogen has a stronger effect so females tend to terminate growth sooner.
e. **Osteoporosis**: an abnormally large amount of calcium salts are lost from the bones resulting in a significant loss of bone mass and increased susceptibility to bone fracture.
    i. In females, low estrogen levels make the bones more susceptible to parathyroid hormone stimulating osteoclast activity and inhibiting osteoblast activity.
    ii. Other risk factors include smoking, an inactive lifestyle, a diet low in calcium and Vitamin D.

7. Weight bearing exercise
    a. Bone thickens where muscles pull on bone.
    b. Bone that bears weight thickens along lines of stress.
    c. **Note**: astronauts lost 20% of their bone mass in 8 days without gravity.

III. Joints

A. Fibrous Joints
1. Permit little or no movement
2. Have dense fibrous connective tissue connecting the bones together.
3. Include:
    a. **Sutures**: Unite the bones of the skull.
    b. **Gomphoses**: Teeth within the sockets of the gums.
    c. **Syndesmoses**: Distal joint between the radius and ulna.

B. Cartilagenous Joints
1. Permit little or no movement
2. Have either hyaline or fibrocartilage connecting the bones together.
3. Include:
    a. **Synchondrosis**:
        i. The connecting material is hyaline cartilage.
        ii. Include epiphyseal plates
    b. **Sympheses**:
        i. The connecting material is a disc of fibrocartilage.
        ii. Include the pubic symphysis and intervertebral joints.

C. Synovial Joints
1. Freely moveable joints.
2. Characteristics:
    a. The joint is surrounded by an **articular capsule**.
        i. Includes an outer fibrous capsule composed of dense irregular connective tissue.
        ii. Lined by an inner **synovial membrane**.
        iii. Inside of the capsule is a space known as a **synovial cavity**.
        iv. This cavity is filled with **synovial fluid** that is produced by the synovial membrane.
        v. This fluid is important for lubrication and supplying nutrients to the articular cartilage.
    b. Include:
        i. **Hinge joints**: knee, elbow, ankle, phalangeal joints in fingers and toes.

ii. **Pivot joints**: between atlas and axis, proximal joint between radius and ulna.
iii. **Saddle joints**: thumb joint
iv. **Condyloid joint**: wrist, joint between metacarpals and phalanges.
v. **Ball and socket joint**: shoulder and hip
vi. **Gliding (planar**): intertarsal, intercarpal, acromioclavicular

D. Joint classification by the amount of movement allowed.
1. Immovable joints can be categorized as **synarthroses**.
2. Slightly moveable joints can be categorized as **amphiarthroses**.
3. Freely moveable joints can be categorized as **diarthrotic**.