Functions of Bones and Bone Tissue

1. **Support** - Bones of the feet, legs, pelvis, and vertebral column support the major weight of the body.

2. **Protection** - Bones enclose or partially enclose and protect organs of the body. Cranial bones (skull) enclose and protect the brain. The bony thorax (ribs and sternum) partially enclose and protect the heart and lungs.

3. **Body movement** - Bones form a place of attachment for skeletal muscles. When skeletal muscles contract they pull on the bones, producing movement. The types of movement are determined by the arrangement of bones and the structure of the joints.

4. **Storage** - The bone matrix mainly stores the minerals calcium and phosphorus. It also stores sodium, potassium, magnesium, sulfur, and copper. Yellow bone marrow stores fat.

5. **Hematopoiesis** (blood cell formation) - Hematopoiesis occurs in the marrow or medullary cavities of bones. Red bone marrow functions in the formation of erythrocytes (red blood cells), leukocytes (white blood cells), and platelets. The marrow is red because of the hemoglobin (red pigment) contained in the erythrocytes. Red bone marrow is present in the bone cavities of an infant, and with increasing age, more and more red bone marrow is replaced by yellow bone marrow which functions in fat storage. In adults, red bone marrow is found in the spongy bone of the ribs, sternum, vertebrae, os coxa (pelvic bones) and in the head of the humerus and femur.
Bones

There are two types of bone based on the amount of bone or osseous tissue and spaces or cavities within the tissue.

1. compact or lamellar bone - Compact bone is dense with few spaces or cavities and is composed of structural units called osteons or Haversian systems. Osteons contain concentric rings of matrix called lamella which contain collagen fibers. In the center is a Haversian canal containing small blood vessels and nerve fibers. Volkmann’s canals run at right angles to the Haversian canal and interconnect the blood vessels and nerve fibers of the osteons. Mature bone cells or osteocytes are located in spaces called lacunae where each ring of lamella joins the next. Osteocytes communicate with nearby cells and exchange nutrients through canaliculi ("little canals") which run from one osteocyte to another.

2. spongy or cancellous bone - Spongy bone lacks Haversian systems and has numerous spaces and cavities. It consists of an irregular lattice or network of thin, flat plates of bone called trabeculae ("little beams"). The spaces between the trabeculae of some bones are filled with red bone marrow. The trabeculae contain irregularly arranged lamella and osteocytes which are connected to one another by canaliculi.

Classification of Bones

Bones are classified according to shape.

1. long bones - they are longer than they are wide, such as the humerus, ulna, radius, femur, tibia, fibula, metacarpals, and metatarsals. Long bones are composed mainly of compact bone.

2. short bones - they are roughly cubelike or as tall as they are wide, such as the carpals and tarsals. Short bones contain mostly spongy bone covered by a layer of compact bone.

3. flat bones - they are thin, flattened and slightly curved bones, such as the ribs, sternum, scapula, and cranial bones (frontal, parietal, occipital, temporal). Flat bones are composed of two parallel surfaces of compact bone and a central area of spongy bone called the diploe.

4. irregular bones - they are of various shapes, such as the vertebrae, ethmoid bone, sphenoid bone, sacrum, and os coxa. Irregular bones are composed of mainly spongy bone with thin surface layers of compact bone.
Structure of Long Bones

1. **Epiphyses** - The ends of the long bones which form a joint or articulate with another bone. The interior is composed of spongy bone with a layer of compact bone on the outside.

2. **Diaphysis** - The diaphysis, or shaft, is the area between the epiphyses. A thick collar of compact bone surrounds a yellow marrow cavity or medullary cavity in adults.

3. **Epiphyseal line** - Between the epiphyses and the diaphysis of young bones is an area of cartilage known as the epiphyseal plate. It is a growth area that allows long bones to lengthen. When bone growth ends the cartilage is replaced by bone and is called the epiphyseal line.

4. **Periosteum** - The periosteum is a dense, white covering on the diaphysis and it consists of two layers.
   a. **fibrous layer** - The fibrous layer is the outer layer of dense, irregular connective tissue containing blood vessels, lymphatic vessels and nerve fibers.
   b. **osteogenic layer** - The osteogenic layer is the inner layer containing elastic fibers, blood vessels, osteoblasts (bone-forming cells), and osteoclasts (bone-destroying cells).

   The periosteum is attached to the bone by collagen fibers called Sharpey's fibers that extend from the fibrous layer into the bone matrix.

   The periosteum functions in the formation and repair of bone tissue and nutrition of bone tissue, and it provides a place of attachment for tendons and ligaments.

5. **Endosteum** - The endosteum is composed of delicate connective tissue which contains osteoblasts and osteoclasts. It covers the internal surfaces, spaces and cavities of the bone, and it lines the trabeculae of spongy bone.

6. **Articular cartilage** - The articular cartilage covers the surface of the epiphyses where they articulate with other bones. It is composed of hyaline cartilage and functions in facilitating joint movement and it cushions the ends of the bones and absorbs stress during joint movement.

   Short, flat and irregular bones do not have a diaphysis or epiphyses. They consist of thin plates of compact bone covered with periosteum surrounding spongy bone covered with endosteum.
Bone Development

Bone development or formation is called osteogenesis or ossification. The skeleton of a human embryo is composed of fibrous membranes and hyaline cartilage. Ossification begins around the sixth or seventh week of embryonic life and continues through adulthood as bone growth and remodeling.

There are two types of ossification.

1. Intramembranous ossification

Bone formation occurs within fibrous membranes forming a membrane bone. Flat bones of the skull, parts of the mandible and the clavicle are formed by intramembranous ossification.

   a. Embryonic connective tissue cells called mesenchymal cells form fibrous connective tissue membranes.

   b. About the 8th week of development, mesenchymal cells form clusters in the membrane called ossification centers.

   c. The mesenchymal cells differentiate into osteoblasts which secrete a matrix called the osteoid and is composed of collagenous fibers.

   d. Calcium salts are deposited in the matrix and is referred to as calcification.

   e. The calcified matrix becomes the trabeculae and they fuse to form a network which encloses blood vessels. The network of trabeculae forms woven bone.

   f. Osteoblasts trapped in lacunae become mature bone cells called osteocytes. They lose their ability to form bone.

   g. Cells in the membrane tissue surrounding the developing bone form the periosteum.

   h. The mesenchyme cells of the osteogenic layer of the periosteum become osteoblasts which secrete osteoid along the surfaces of the trabeculae. The trabeculae grow thicker and thicker until continuous plates of bone are produced, forming the bone collar and the woven bone is replaced by compact or lamellar bone.

   i. In the center of the bone trabeculae remain, forming spongy bone. The vascular tissue of the spongy bone differentiates into red bone marrow, filling the spaces between the trabeculae and forming the diploe.
2. Endochondral ossification

Bone formation occurs from hyaline cartilage producing a cartilage bone. Endochondral ossification occurs in most of the bones and involves the breaking down and replacement of hyaline cartilage with bone.

a. In long bones, during the third month of development, a hyaline cartilage model of the future bone is produced. The model is covered by a fibrous connective tissue membrane called the perichondrium.

b. Blood vessels penetrate the perichondrium stimulating the chondroblasts (cartilage forming cells) to become osteoblasts in the center of the developing diaphysis.

c. Once the perichondrium starts producing bone, it is called the periosteum.

d. Simultaneous with bone collar formation, chondrocytes (cartilage cells) in the center of the diaphysis begin to enlarge and the region is called the primary ossification center.

e. The cartilage matrix begins to calcify, and is impermeable to the diffusion of nutrients. The chondrocytes die, the matrix breaks down and cavities form.

f. The cavities are penetrated by periosteal buds which consist of blood vessels, nerve fibers, lymphatic vessels, red marrow cells, osteoblasts, and osteoclasts.

g. The osteoblasts secrete osteoid around the remaining cartilage forming trabeculae and spongy bone.

h. The primary ossification center enlarges toward the epiphyses and osteoclasts break down the newly formed spongy bone producing a medullary or marrow cavity in the center of the diaphysis.

i. Osteoblasts of the periosteum deposit layers of compact bone around the diaphysis which thickens and lengthens the bone collar. Ossification of the diaphysis ends when the medullary cavity is formed.

j. During the fetal period, the epiphyses consist of cartilage. Secondary ossification centers appear in the epiphyses shortly before, or soon after, birth.

k. The cartilage in the middle of the epiphyses calcifies, dies, cavities form, and a periosteal bud enters the cavities.
1. Osteoblasts secrete osteoid around the remaining cartilage fragments.

Secondary ossification is similar to primary ossification except that the spongy bone is retained and no medullary cavity is formed. At the completion of secondary ossification, hyaline cartilage remains as a covering over the articular surfaces of the epiphyses as articular cartilage and as a growth plate between the epiphyses and the diaphysis known as the epiphyseal plate.

**Bone Growth**

From childhood to about the age of 18 in females and 21 in males, *longitudinal bone growth* occurs at the epiphyseal plate.

The epiphyseal plate has four regions:

1. The cells at the epiphysis side of the plate divide rapidly by mitosis and form stacks of column-shaped cells, which lengthens the bone.

2. The region below the dividing cells contain older chondrocytes which enlarge and the surrounding hyaline cartilage matrix calcifies.

3. In the third region, the chondrocytes die and the matrix deteriorates, forming thin plates of calcified cartilage between the epiphyses and the diaphysis.

4. The fourth region, on the diaphysis side of the plate, contains osteoblasts which secrete osteoid along the plates of remaining cartilage, forming trabeculae. The spongy bone that results is digested by osteoclasts and the medullary cavity lengthens as the bone lengthens on the epiphyseal side of the plate.

In early adulthood the cartilage cells of the epiphyseal plate divide less and less often and the plate becomes thinner and thinner until it is replaced by bone tissue, forming the epiphyseal line.

Growth in diameter, or *appositional growth*, occurs along with growth in length. Osteoblasts in the periosteum form new bone tissue around the outer surface of the bone. At the same time, osteoclasts destroy the bone lining the medullary cavity and the cavity increases in diameter. The cavity later fills with marrow. Appositional bone growth ends when the epiphyseal line forms.
At the end of bone growth, spongy bone remains in the central portions of the epiphyses and diaphysis and the only cartilage that remains is the articular cartilage on the surface of the epiphyses.

Normal bone growth in the young and bone replacement in adults involves bone remodeling in which osteoblasts form new bone and osteoclasts destroy and resorb old bone tissue.

Regulation of Bone Growth and Remodeling

Bone growth and remodeling are regulated by mechanical stress and hormones.

Mechanical stress occurs where bones function in weight-bearing and where muscles attach to bones. The force of heavy, active muscles pulling on bones stimulates bone growth at the place of attachment (gluteal muscle attaches to the gluteal tuberosity of the femur).

There are four types of hormones involved in bone growth and remodeling:

1. growth hormone (GH) - It is produced by the pituitary gland and is responsible for general bone growth and it stimulates the cartilage of the epiphyseal plate to grow.

2. sex hormones - Sex hormones increase the formation and activity of osteoblasts and promote the formation of new bone. They also cause degeneration or breakdown of the cartilage cells in the epiphyseal plate.

3. parathyroid hormone (PTH) - PTH is produced by the parathyroid glands and functions in increasing osteoclast formation and activity.

4. calcitonin (CT) - CT is produced by the thyroid gland and functions in inhibiting osteoclast formation and activity.

Parathyroid hormone and calcitonin work together to maintain the calcium level in the blood. When the level of calcium in the blood decreases, PTH is produced. Osteoclast activity increases, the bone matrix breaks down, and calcium is released into the blood. As the calcium level of the blood increases, the production of PTH is inhibited and the production of CT is stimulated. CT inhibits osteoclast activity and calcium is reabsorbed by the bone matrix. As the calcium level in the blood decreases, the production of CT is inhibited and the production of PTH is stimulated.