The objectives

By the end of lecture, the student should be able to

1-Define bones, and its functions .

2- Be able to distinguish between the different bone cells

3- Classify the bones.

4- Describe the endochondral and intramembranous ossification.

3- Bone

Bone is the primary constituent of the adult skeleton. Bone tissue ***supports fleshy structures, protects vital organs s***uch as those in the cranial and thoracic cavities, and harbors the bone marrow, where blood cells are formed. Bone also serves as a ***reservoir of calcium, phosphate, and other ions*** that can be released or stored in a controlled fashion to maintain constant concentrations of these important ions in body fluids.

In addition, bones form ***a system of levers that multiply the forces generated during skeletal muscle contraction*** and transform them into bodily movements. This mineralized tissue therefore confers mechanical and metabolic functions to the skeleton.

Bone is a specialized connective tissue composed of calcified intercellular material, the **bone matrix,** and three cell types:

- **Osteocytes** : which are found in cavities (**lacunae**) between layers (lamellae) of bone matrix .
- **Osteoblasts**: which synthesize the organic components of the matrix.
- **Osteoclasts**: which are multi-nucleated giant cells involved in the resorption and remodeling.

Bone Cells

1-Osteoblasts

Osteoblasts are responsible for the ***synthesis of the organic components of bone matrix***, consisting of type I collagen fibers, proteoglycans, and several glycoproteins including osteonectin. Osteoblasts are located exclusively at the surfaces of bone matrix, usually side by side in a layer somewhat resembling a simple epithelium. Osteoblast activity is stimulated by parathyroid hormone (PTH).

A fundamental characteristic of bone is the arrangement of:

· **Lamellae**: Layers of mineralized bone matrix.

· **Lacunae**: Small spaces between or within lamellae, each containing an **osteocyte** (bone cell).

· **Canaliculi**: Tiny canals radiating from lacunae, allowing communication and nutrient/waste exchange between osteocytes.

· **Osteons (Haversian systems)**: The primary structural units of compact bone, formed by concentric lamellae arranged around a central canal (Haversian canal) that houses blood vessels.

Osteons vary in size and consist of 8 to 15 concentric lamellae that surround a wide space occupied by blood vessels Fig.1.

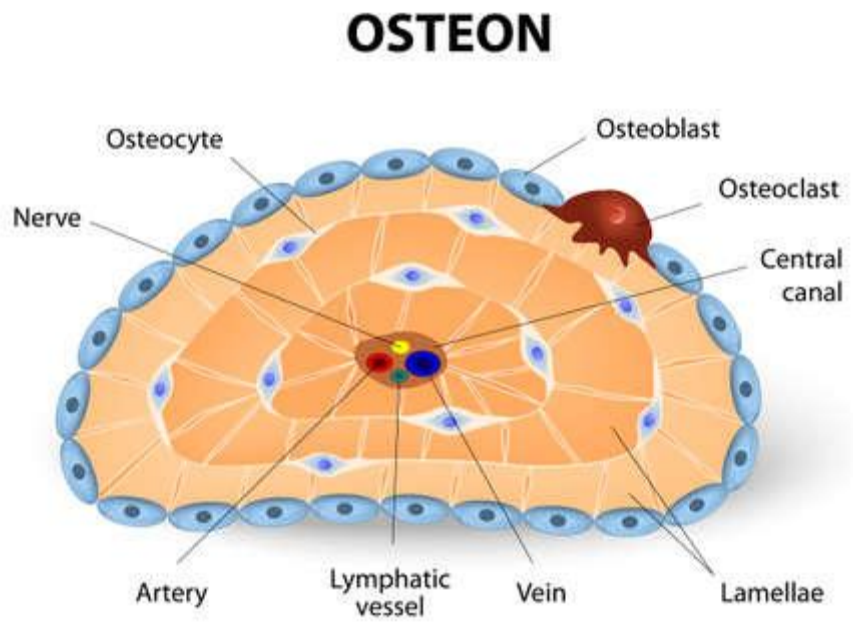

Fig. 1 The osteon structure

2- **Osteocytes**: are the primary cells found in mature bone and take the shape of the lacunae in which they are housed. They differ from osteoblasts, which are bone-forming cells.

a.Osteocytes are mature bone cells housed in their own lacunae .

b. They have narrow cytoplasmic processes that extend through canaliculi in the calcified matrix .

c. They maintain communication with each other via gap junctions between their processes.

d. They contain abundant heterochromatin, a paucity of RER, and a small Golgi complex.

3- Osteoclasts : are large, motile, multinucleated cells . The large size and multinucleated condition of osteoclasts is due to their origin from the fusion of bone marrow-derived cells. Osteoclast activity is stimulated indirectly by parathyroid hormone and vitamin D to increase bone resorption and elevate blood calcium levels. Osteoclasts have calcitonin receptors and their activity is reduced by the presence of calcitonin thereby reducing blood calcium levels. In areas of bone undergoing resorption, osteoclasts lie within enzymatically etched depressions or crypts in the matrix known as **resorption bays** (formerly called **Howship lacunae**).

In active osteoclasts, the surface against the bone matrix is folded into irregular projections, which form a **ruffled border.** Formation of the ruffled borders is related to the activity of osteoclasts. Surrounding the ruffled border is a clear cytoplasmic zone rich in actin filaments which is the site of adhesion to the bone matrix. The cytoplasm, usually weakly to moderately acidophilic, contains multiple Golgi complexes and centriole pairs and numerous mitochondria and lysosomes. The cell surface adjacent to the bone shows a ruffled border, a surface modification unique to osteoclasts; osteoclasts that lack a ruffled border do not participate in bone resorption. Figure 2 shows the main structure of the bone.

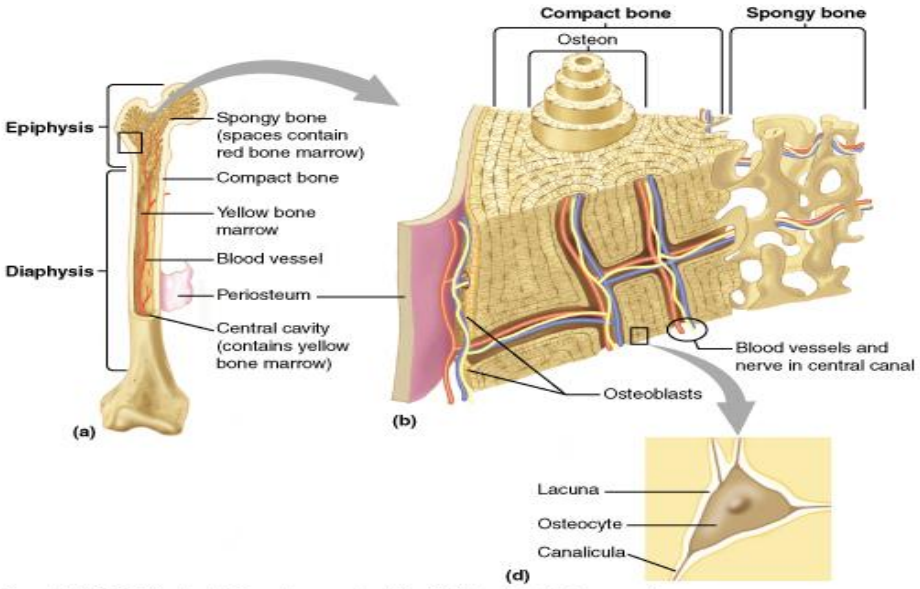

Fig. 2 The structure of the bone

Difference Between Osteons and Osteocytes

Osteons (Haversian Systems):

Definition: Structural units of compact bone.

Structure: Cylindrical structures that run parallel to the long axis of the bone.

Components:

Central (Haversian) canal: Contains blood vessels and nerves.

Concentric lamellae: Layers of calcified matrix surrounding the canal.

Lacunae: Small spaces between lamellae where osteocytes reside.

Canaliculi: Tiny canals connecting lacunae for nutrient and waste exchange.

Function: Provide strength and support; allow blood supply and communication within compact bone.

Osteocytes:

Definition: Mature bone cells derived from osteoblasts.

Location: Found within lacunae inside osteons and other parts of bone.

Function:

- Maintain bone matrix.
- Regulate mineral content.
- Communicate with other bone cells via canaliculi.
- Sense mechanical stress and signal for bone remodeling.

Types of Bone: Classification of bone is based on both gross and microscopic properties.

1. Gross observation of cross-sections of bone reveals two types:

A. Spongy (cancellous) bone, which is composed of interconnected trabeculae. Bony trabeculae surround cavities filled with bone marrow. The trabeculae contain osteocytes and are lined on both surfaces by a single layer of osteoblasts. Spongy bone is always surrounded by compact bone.

B. Compact (dense) bone has no trabeculae or bone marrow cavities.

2. Microscopic observation of bone reveals two types:

A. Primary bone, also known as immature or woven bone. The main characteristics are :

(1) Primary bone contains many osteocytes and large, irregularly arranged

type I collagen bundles.

(2) It has a low mineral content.

(3) It is the first compact bone produced during fetal development and bone repair.

(4) It is remodeled and replaced by secondary bone except in a few places (e.g., tooth sockets, near suture lines in skull bones, and at insertion sites of tendons).

B. Secondary bone, is also known as mature or lamellar bone. The main features are:

(1) Secondary bone is the compact bone of adults.

(2) It has a calcified matrix arranged in regular layers, or lamellae. Each lamella is 3 to 7 µm thick.

(3) It contains osteocytes in lacunae between, and within, lamellae.

Osteogenesis

The process of the formation of bones is known as ossification or osteogenesis. Osteoblasts are the cells involved in the bone formation.

Bone can be formed initially by either of two ways:

1- **Intramembranous ossification,** in which osteoblasts differentiate directly from mesenchyme and begin secreting osteoid.

2- **Endochondral ossification**, in which the matrix of preexisting hyaline cartilage is eroded and replaced by osteoblasts producing osteoid.

In both processes, the bone tissue that appears first is primary or woven. Primary bone is a temporary and is soon replaced by the definitive secondary lamellar bone.

Nutrition greatly affects bone development. **Low-protein diets** result in a deficiency of amino acids essential for collagen synthesis by osteoblasts. **Lack of calcium**, either from a low intake or inadequate absorption by the small intestine (due to lack of vitamin D) results in poorly calcified bone, which leads to rickets in children and osteomalacia in adults. **Vitamin D** is also necessary for ossification, and hypervitaminosis D causes bone resorption. **Vitamin A** deficiency inhibits bone formation and growth, while excessive amounts of vitamin A accelerate the ossification of the epiphyseal plates. In either case, smaller stature results. **Vitamin C** is necessary for collagen formation; its deficiency results in scurvy, characterized by poor bone growth and inadequate repair after fractures.

MEDICAL APPLICATION

- Cancer originating directly from bone cells (a primary bone tumor) is fairly uncommon (0.5% of all cancer deaths), although a cancer called osteosarcoma can arise in osteoprogenitor cells. The skeleton is often the site of secondary, metastatic tumors, however, arising when cancer cells move into bones via small blood or lymphatic vessels from malignancies in other organs, most commonly the breast, lung, prostate gland, kidney, or thyroid gland.
- In the genetic disease osteopetrosis, which is characterized by dense, heavy bones (“marble bones”), the osteoclasts lack ruffled borders and bone resorption is defective. This disorder results in overgrowth and thickening of bones. The defective osteoclasts in most patients with osteopetrosis have mutations in genes for the

cells' proton-ATPase pumps or chloride channels.