THE BONE

- Bone tissue supports fleshy structure & protects vital organs such as cranial & thoracic cavities ,and harbors the bone marrow
- is highly vascularized & metabolically very active .
- It serves as a reservoir of calcium phosphates , and other ions
- Give the mechanical & metabolic functions to skeleton
- Bone tissue composes of bone matrix & three types of cells Osteocytes, Osteoblasts & Osteoclasts.

BONE CELL

Osteoblasts. Are responsible for the synthesis of the organic components of bone matrix , (collagen , proteoglycan and glycoproteins).# They are located at the surface of bone tissue their shape ranged between cuboidal to columnar to flatten shape according to their activity. Osteoblasts are gradually surrounded by new matrix and become Osteocytes and lacuna is formed .Matrix compoents are secreted at the cell surface , called Osteoid (not yet calcified).

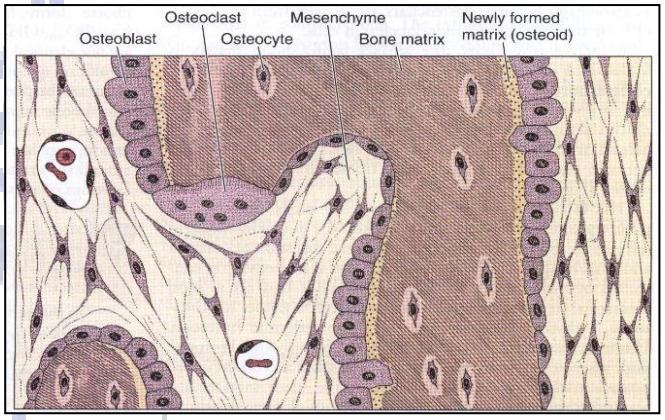


Fig.8-3 : Events that occur during intramembranous ossification. Osteoblasts are synthesizing collagen, which forms a strand of matrix that traps cells. As this occurs, the osteoblasts gradually differentiate to become osteocytes. The lower part of the drawing shows an osteoblast being trapped in newly formed bone matrix.

Osteocytes : Derive from Osteoblasts , lie in lacunae , situated between lamellae of matrix .Only one osteocyte is found in each lacuna .
They have a thin cylindrical matrix canaliculi by which the molecules are passed from cell to cell. Some molecular exchange between cells takes place through extra cellular substance

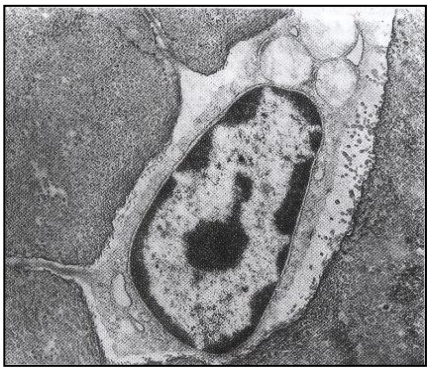


Fig.8-1 : Section of bone tissue showing an osteocyte with its cytoplasmic processes surrounded by matrix. The ultrastructure of the cell nucleus and cytoplasm is compatible with a low level of protein synthesis.

Osteoclast

- Are very large ,branched motile cells contain from 5-50 or more nuclei

They lie within enzymatically etched depressions in the matrix known as **howship's lacunae**, are derived from the fusion of bone marrow_ derived mononucleotide cells.

- In active, the surface-forming bone matrix is folded into irregular projections, forming a Ruffled border

- Clear zone is cytoplasmic zone that surround the ruffled border, which is devoid of organelles, yet rich in actin filament .This zone is a site of adhesion of the osteoclast to bone matrix, in which bone resorption occurs

❶ They secretes collagenas and other enzymes

❷ pump proton into the microenvironment .Their activity is controlled by cytokines and hormone

- Ruffled borders are related to the activity, of osteoclasts

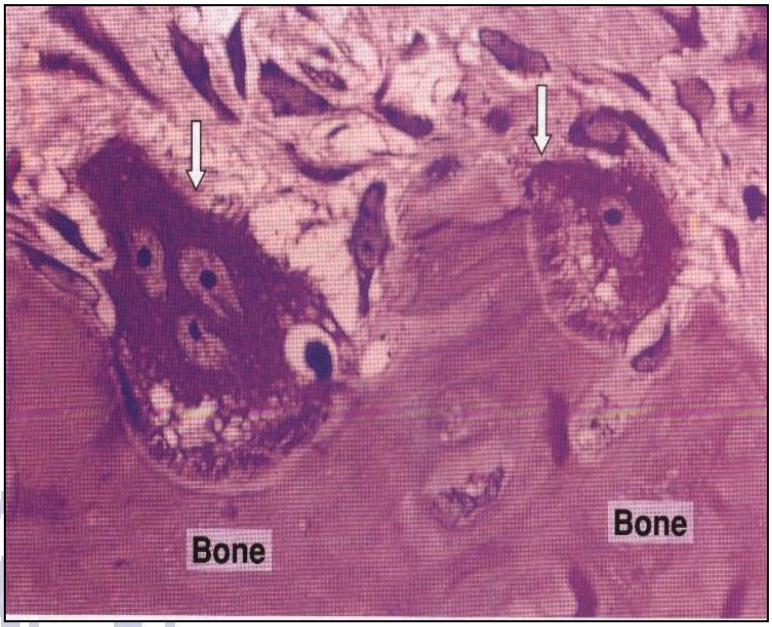


Fig.8.4 : Section showing three osteoclasts (arrows) digesting bone tissue. The osteoclast is a large cell with several nuclei and a ruffled border close to the bone matrix. Note the clear compartment where the process of bone erosion occurs. This compartment is acidified by a proton pump localized in the osteoclast membrane. It is the place of decalcification and matrix digestion and can be compared to a giant extracellular lysosome. Chondroclasts found in eroded regions of epiphyseal calcified cartilage are similar in shape to osteoclasts.

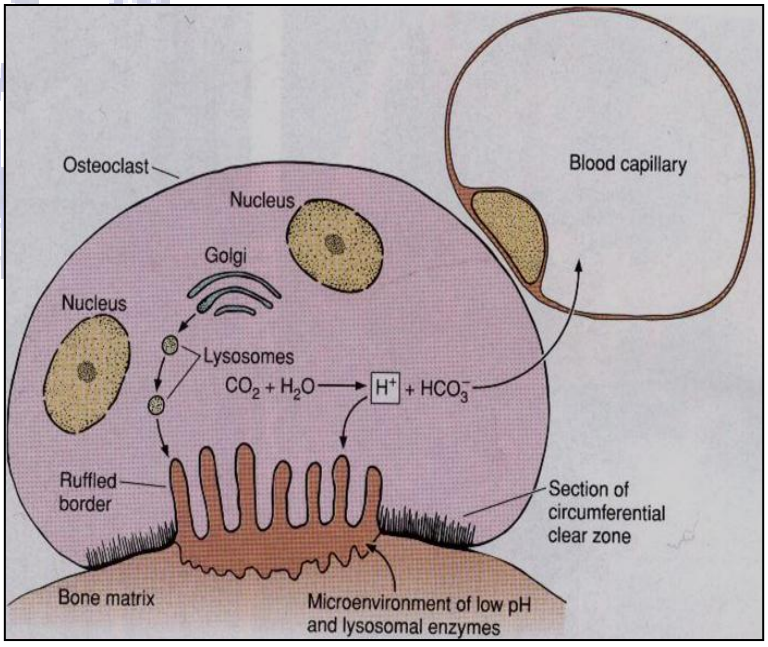


Fig.8.5 : Bone resorption. Lysosomal enzymes packaged in the Golgi complex and hydrogen ions produced are released into the confined microenvironment created by the attachment between bone matrix and the osteoclast's peripheral clear zone. The acidification of this confined space facilitates the dissolution of calcium phosphate from bone and is the optimal pH for the activity of lysosomal hydrolases. Bone matrix is thus removed and the products of bone resorption are taken up by the osteoclast's cytoplasm, probably digested further, and transferred to blood capillaries.

Bone matrix

- **Inorganic** matter represents 50% of dry weight of bone matrix : calcium& phosphorus are especially abundant ,bicarbonate , citrate ,magnesium, potassium & sodium are also found Calcium & Phosphorus Hydroxyapatite crystals with Ca10(PO4)6 (OH)2 ⟶
- The **organic** matter in bone matrix is a type I collagen& ground substance (proteoglycan aggregates & glycoprotein).
- Mineral & collagen fibers is responsible for the hardness & resistance of bone tissue.
- After decalcified the bone ,its shape is preserved, but it becomes as flexible as a tendon .

- Removable the collagenous – also leaves the bone with its original shape however, it becomes fragile, breaking & crumbling easily when handle.

Medical application

Osteomalacia , in which mineralization is impaired .

Osteopetrosis The genetic disease ,which is characterized by dense, heavy bones, the osteoclasts lack ruffled borders ,and resorption is defective

Periosteum & endosteum

- The **periosteum** consists of an outer layer of collagen fibers & fibroblasts .Sharpey's fibers ,penetrate the bone matrix ,bining the periosteum to bone . In the inner ,cellular layer of the periosteum is composed of fibroblast like cells called *Osteoprogenitor cells* ,they have a potential to divide by mitosis & differentiate into Osteoblasts. Osteoprogenitor cells play a prominent role in bone growth & repair
- The **endosteum** lines all internal cavities within the bone & is composed of a single layer of flattened Osteoprogenitor cells & very small amount of connective tissue .
- **The principle functions of periosteum & endosteum** are nutrition of osseous tissue & provision of a continuous supply of new osteoblast for repair or growth of bone .

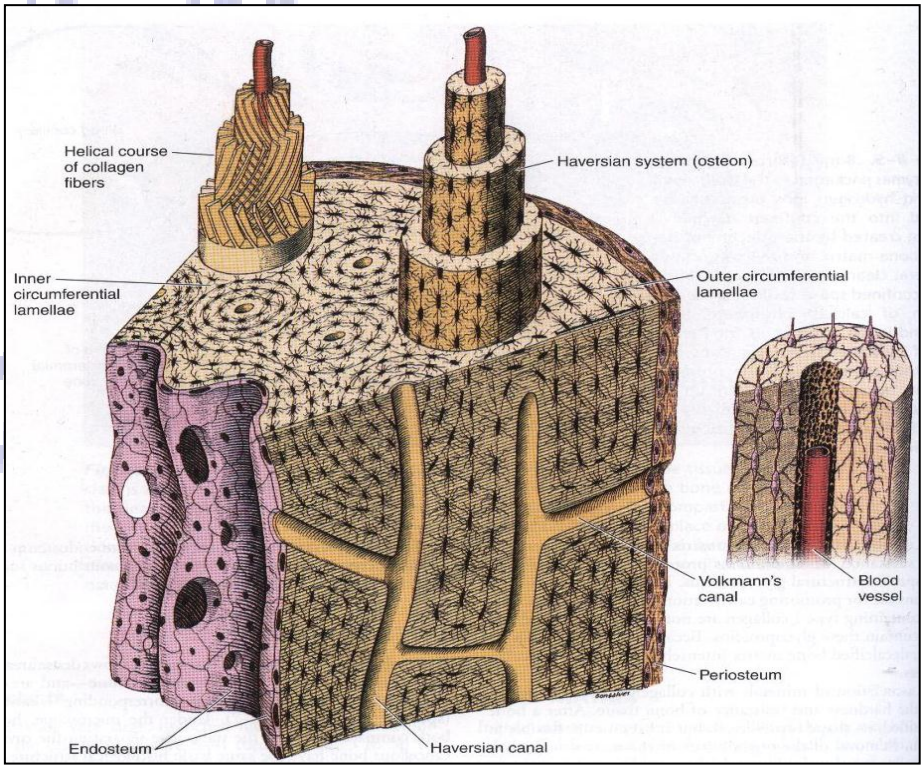


Fig.8.6 : Schematic drawing of the wall of a long-bone diaphysis showing three types of lamellar bone: haversian system and outer and inner circumferential lamellae. (For interstitial lamellae, see Figure 8â€“10.) The protruding haversian system on the left shows the orientation of collagen fibers in each lamella. At the right is a haversian system showing lamellae, a central blood capillary (there are also small nerves, not shown), and many osteocytes with their processes.

Types of bone

There are two principle types of bones Compact bone which shows dense area without cavities ,and Cancellous bone which shows area with numerous interconnecting cavities .

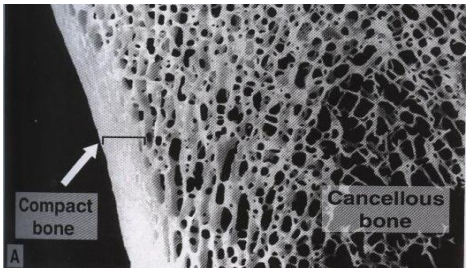


Fig.8.7 : A: Thick section of bone illustrating the cortical compact bone and the lattice of trabeculae of cancellous bone. (Courtesy of DW Fawcett.) **B:** Section of cancellous (spongy) bone with its characteristic random disposition of collagen fibers. Picrosirius-polarized light (PSP) stain. Low magnification.

According to shape ;

❶ **Long bones :** The bulbous ends called *Epiphyses* are composed of spongy bone covered by a thin layer of compact bone
The cylindrical part _ *Diaphysis* is composed of compact bone with a small component of spongy bone on its inner surface around the bone marrow cavity .
❷ **Short bones :** Have a core of spongy bone completely surrounded by compact bone .
❸ **Flat bones :** Form the calvarias have two layers of compact bones called plates (table), separated by a layer of spongy bone called the diloe.

According to development rate

❶ **Primary** ,immature ,woven bone: Is the first bone tissue to appear in embryonic development and in repair processes .It is temporary, is replaced in adults by secondary bone tissue except in few places in the body (near the structures of the flat bones of the skull, in tooth socket).
- They have irregular array of collagen fibers .
- They are a lower mineral content & higher proportion of osteocytes than in secondary bone T.

❷ **Sesondary bone tissue :**
- It is found in adults.
- collagen fibers arranged in lamellae , which are paralled to each other or concentrically organized around a vascular canal.
- The concentric lamellae of bone surrounding a canal containing blood vessels ,nerve & loose connective tissue is called **Haversian system ,or Osteon**
- Lacunae containing osteocytes are found between or within the lamellae .
- Surrounding each haversian systems is cementing substance Which consists of mineralized with few collagen

In long bone , the lamellae exhibit a typical organization consisting of Havesian systems , outer circumferential lamellae , inner circumferential & interstitial lamella .
Haversian system ,is long .bifurcated cylinder parallel to the axis of the diaphysis .It communicate with the marrow cavity ,the periosteum, and one another through transverse or oblique Volkmann's canals . Each system is formed by successive deposits of lamella ,starting inward from the periphery ,so the most recently formed lamella is the one closest to the central canal.

Histogenesis

Bone can be formed in two ways :

❶ **Intramembranous Ossification** : By which direct meneralization of matrix secreted by Ostoblasts. is the source of most of the flat bones ,it takes place within Mesenchymal tissue . The frontal & partial bones of the skull-as well as parts of the occipital , temporal bones , the mandible & maxilla are formed by this way .

The starting point for ossification is called *A primary ossification center.* The process begin when

1) Group of mesenchymal cells differentiate into osteoblasts.
2) Osteoblasts produce bone matrix & calcification follows ,resulting in the encapsulation of some osteoblast which then become osteocytes
3) These islands of developing bone form wall that delineate elongated cavities containing capillaries, bone marrow cells & undifferentiated cells .
4) Several such groups arise almost simultaneously at the ossification center .
5) Fusion of the walls gives the bone a spongy structure .
6) The connective tissue that remain among the bone walls is penetrated by growing blood vessels & additional undifferentiated mesenchmal cells .
7) The ossification centers of a bone grow radially & finally fuse together , replacing the original connective tissue .
8) The fontanelles of newborn infants, for example , are soft areas in the skull that are not yet ossified .

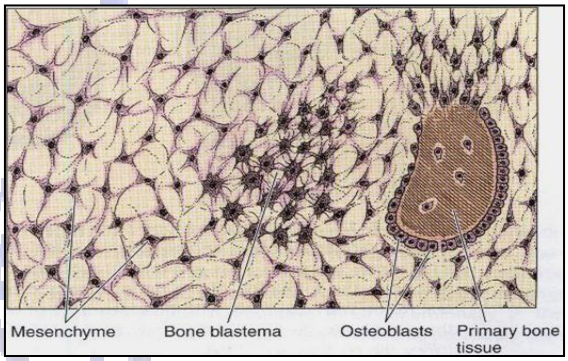


Fig. 8.9 : The beginning of intramembranous ossification. Mesenchymal cells round up and form a blastema, from which osteoblasts differentiate, producing primary bone tissue.

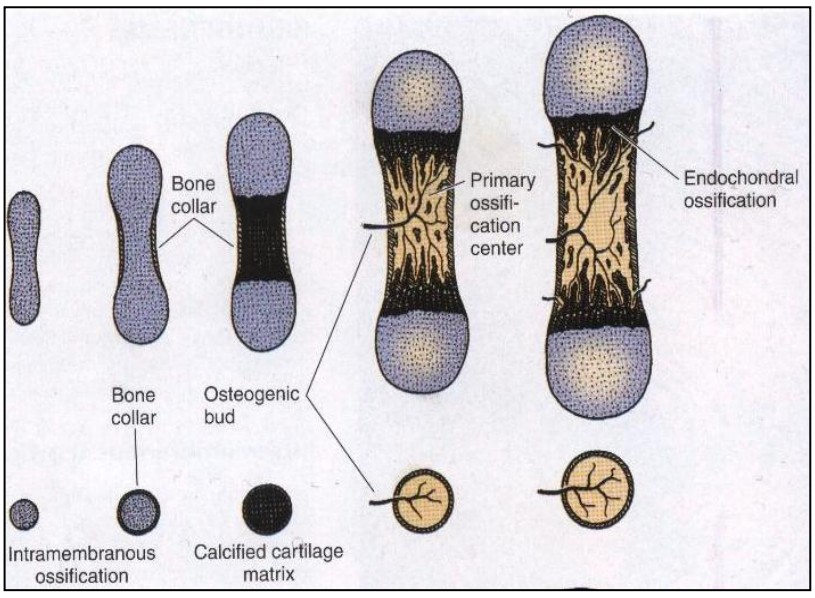
❷ Endochodrale Ossification :

- It takes place within a piece of Hyaline cartilage .
- These type of ossification is principally responsible for the formation of short and long bones .
- *Endochondral Ossification of long bone consists of the following sequence of events.*

❶ The (bone collar) which is produced by intramembranous ossifications within the local perichondrium represent the first bone tissue appear.

❷ the local cartilage undergoes a degenerative in process of programmed cell death with cell enlargement (hypertrophy) and matrix calcification .

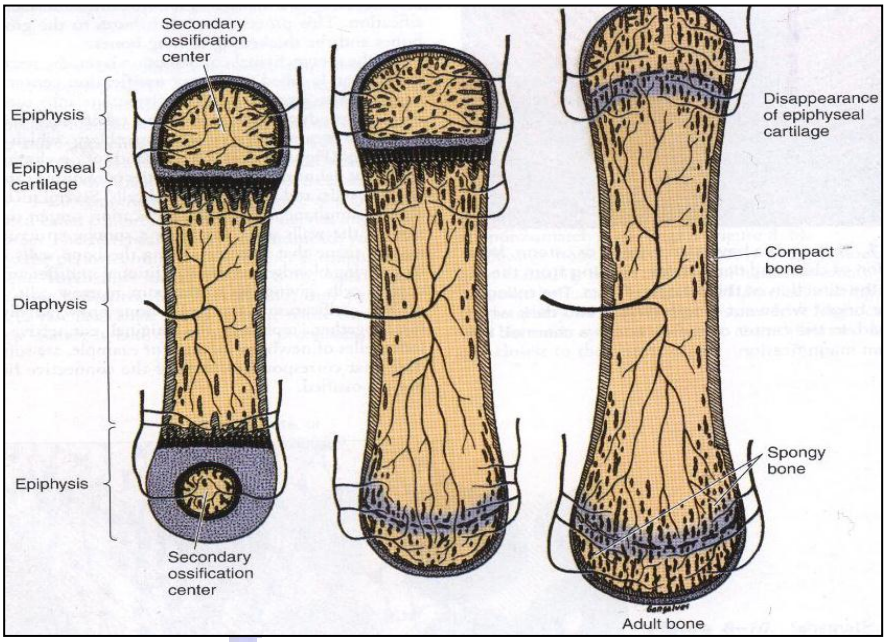
❸ This process begins at the central portion of the cartilage model (diaphysis) ,which previously perforate by osteoclasts . The blood vessels penetrate the perforation region bringing osteoprogenitor cells to this region.



❹ Osteoblasts adhere to be calcified cartilage matrix and produce continuous layers of primary bone that surround the cartilaginous matrix remnants, so the primary Ossification center is produced

Then **the secondary ossification center**, appear at the swellings in the extremities of the cartilage model(epiphyses) . During their expansion and remodeling the primary & secondary oss. Centers produced cavities that gradually filled with bone marrow .

Epiphyseal cartilage (epiphyseal plate) ,which connects the two epiphyses to the diaphysis .*It is responsible for* the growth in length of bone and Disappears in adults.



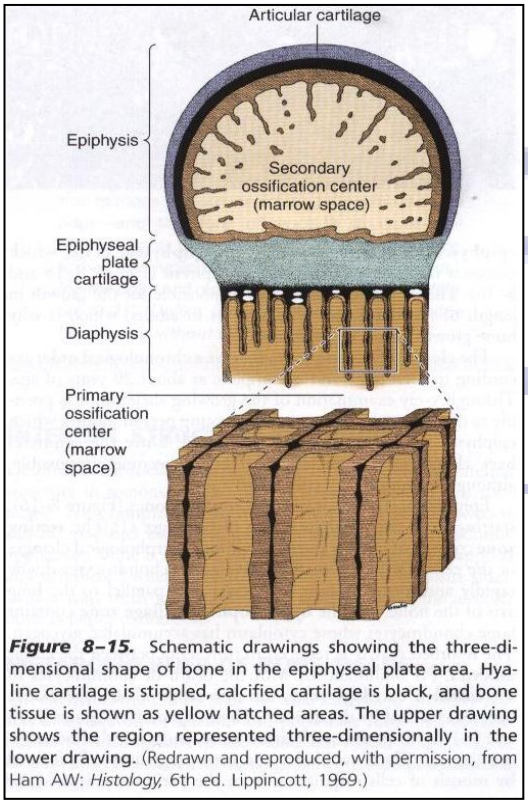
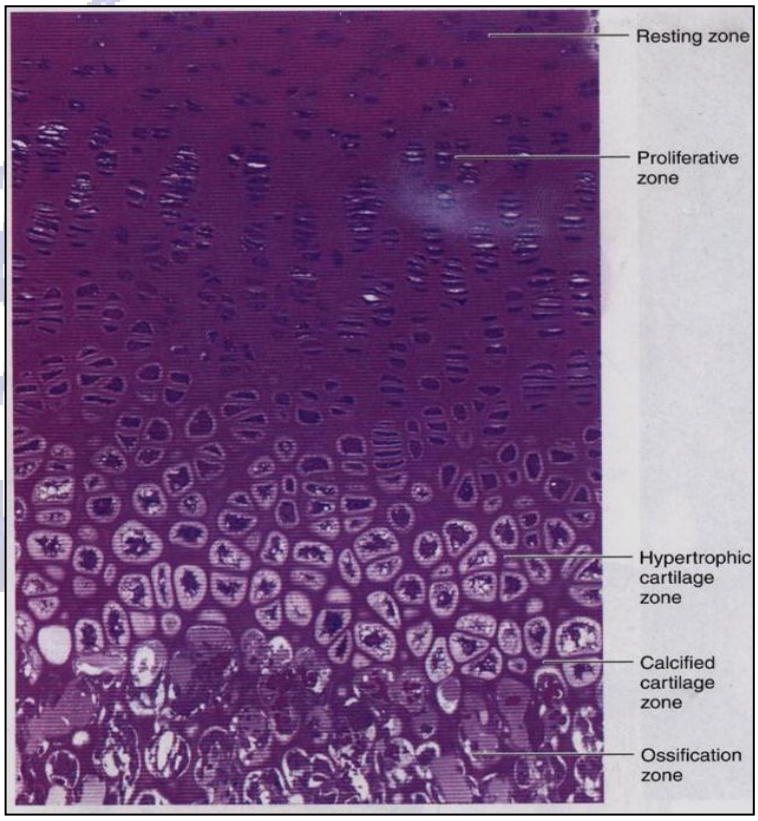


Figure 8–15. Schematic drawings showing the three-dimensional shape of bone in the epiphyseal plate area. Hyaline cartilage is stippled, calcified cartilage is black, and bone tissue is shown as yellow hatched areas. The upper drawing shows the region represented three-dimensionally in the lower drawing. (Redrawn and reproduced, with permission, from Ham AW: *Histology,* 6th ed. Lippincott, 1969.)



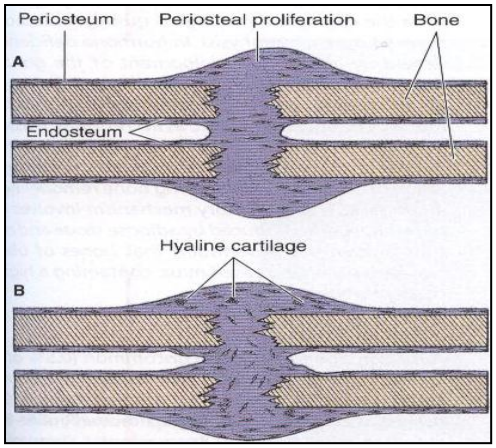
Bone growth and remodlingbone

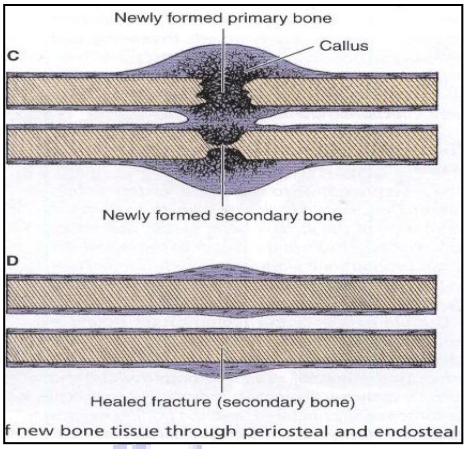
Bone growth is associated with partial resorption of preformed tissue and the simultaneous laying down of new bone .This process permits the shape of the new bone to be maintained ,while it grows .bone remodeling in young children can be 200 times faster than the rate in the adult .Bone responds to the growth of the brain and forms a skull of adequate size .

Medicale aplication (Fractur repair)

❶ Bone matrix is destroyed .
❷ Bone cells adjoining the fracture die .
❸ The damaged blood vessels produce a localized hemorrhage and form a blood clot.
❹ During repair ,the blood clot ,cells and damaged bone matrix are removed by macrophages

❺ The periosteum and endosteum around the fracture respond with intense proliferation producing a tissue that surrounds the fracture and penetrates between the extremities of fractured bone .
❻ Primary bone is formed by endochondral and intramembranous ossification .
❼ The extremities of the fractured bone ,forming a **Bone callus** .
❽ The primary bone tissue of the callus is gradually resorbed and replaced by secondary tissue, remodeling the bone and restarting its original structure





Internal Structure Of Bones

Despite its hardness,bone is capable of changes in its internal structure in response to the various sresses it is subjected ,for ex. The positions of the teeth in the jaw bone can be modified by lateral pressures produced by Orthodontic appliances.

Metabolic Role Of The Bone

The skeleton contains 99% of the total calcium of the body .The concentration ions in the blood &tissue is stable because of continuous interchange between blood calcium & bone calcium .

Bone calcium mobilized by two mechanisms .

The first is the simple transfer of ions from hydroxypatite crystals to interstitial fluid then pass into the blood .It takes place in spongy bone .
The second mechanism ,depend on the action of hormones on bone .
❶ Parathyroid hormone promotes Osteoclastic resorption of the bone matrix with liberation of calcium . This hormone act on osteoblast receptors ,which start the secretion of an Osteoclast-stimulating factor
❷ Another hormone, Calcitonin , which is synthesized mainly by the parafollicular cell of the thyroid gland , Inhibits matrix resorption.

Medical aplication

Decalcification of bone ,due to nutritional deficiency of calcium .Decalcification may also be caused by excessive production of **Parathyroid hormone (hyperparathyriodism)**, which results in creased osteoclastic activity ,intense resorption of bone, elevation of blood Ca and PO4 levels,and abnormal deposits of calcium in several organs, mainly the kidney & arterial walls.

Effects of Nutritional Deficiencies on Bone Tissue

- Calcium deficiency in children causes **Rickets** , A disease in which the bone matrix does not calcify normally & the epiphyseal plate distorted by the body weight & muscular activity .

- **Osteopetrosis** , a disease caused by a defect in osteoclast Function that results in overgrowth ,thickening ,and hardening of bones .
- **Osteoporosis** , is an imbalance in skeletal turnover so that bone resorption exceed bone formation ,frequently found in, immobilized patients and postmenopausal women .

Hormones Acting On Bone Tissue

The anterior lobe of pituitary synthesizes hormone has an effect on growth ,especially on the epiphyseal cartilage .Lack of growth hormone during the grow thing years causes Pituitary Dwarfism ; an excessive growth of the long bones , resulting in Gigantism . The sex hormones , both male (androgens) & female (astrogens),have a complex effect on bones . They influence the time of appearance and development of ossification centers and accelerate the closure of epiphyses

Bone tumors

Bone tumor uncommon (0.5% of all cancer deaths) .The benign (e.g. Osteoblastoma, osteoclastoma) , while malignant (e.g. Osteosarcoma) .The lower end of the femur, the upper tibia ,and the upper humerus are the most common locations. The most frequent bone metastases are from breast , lung ,prostate , kidney , & thyroid tumors

Joints

Joints are regions in which bones are capped and surrounded by connective tissues that hold the bones together and determine the type and the degree of movement between them . There are classified as Diarthroses ,in which there is free bone movement , or Synarthroses , in which very limited or no movement occurs .

There are three of Synathroses .

❶ Synostosis ,in which bone are united by bone tissue and no movment takes place eg. Skull bones in adults .
❷ Synchodroses are articulation in which the bones are joined by hyaline cartilage (eg. The epiphyseal plates ,in adult ,synchodrosis unites the first ribe to the sternum) .
❸ Diarthroses are joints that generally unite long bones and have great mobility ,such as the elbow and knee joints.

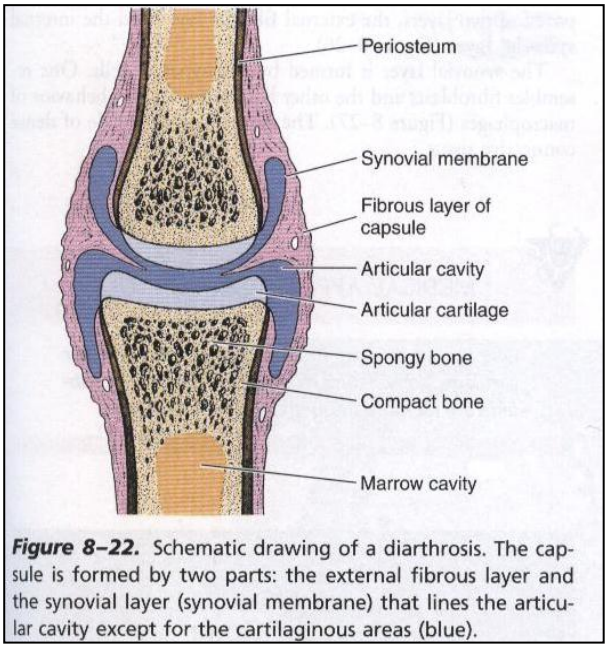


Figure 8–22. Schematic drawing of a diarthrosis. The capsule is formed by two parts: the external fibrous layer and the synovial layer (synovial membrane) that lines the articular cavity except for the cartilaginous areas (blue).