Development and growth of bone

Bone can be formed in two ways by direct mineralization of matrix secreted by osteoblasts or by deposition of bone matrix on a preexisting cartilage matrix. In both processes, the bone tissue that appears first is primary or woven. Primary bone is a temporary tissue where replaced by the secondary bone. There are two types of developments:

1-Intramembranous ossification

Most flat bones of the skull and the mandible and maxilla are formed by this process. Also this process contributes to the growth of short bones and the thickening of long bones.

This type of ossification take place within mesenchyme. In specific areas, these sites where bone is then formed, some mesencymal cells aggregate into clusters and differentiated into osteoblasts. These osteoblasts begin to produce bone matrix as bars or trabeculae. These osteoblasts present as a layer on the surface of developing bone. This matrix is not calcified so called osteoid. Later the matrix undergo calcification where the mineral salts (calcium phosphate crystals) are deposit in osteoid. The calcified matrix is surround the osteoblasts which then become osteocytes which found within lacunae in this matrix. These areas of developing bone are known spicules. The fusion of these spicules forming a network of trabeculae. The resulting bone is spongy bone (Figure 1).

The spaces between the trabeculae are occupied by primitive mesenchymal tissue that develops into bone marrow, also these regions

penetrated by blood vessels. The connective tissue surrounding the developing bone mass condenses and differentiate into the periosteum (Figure 2).

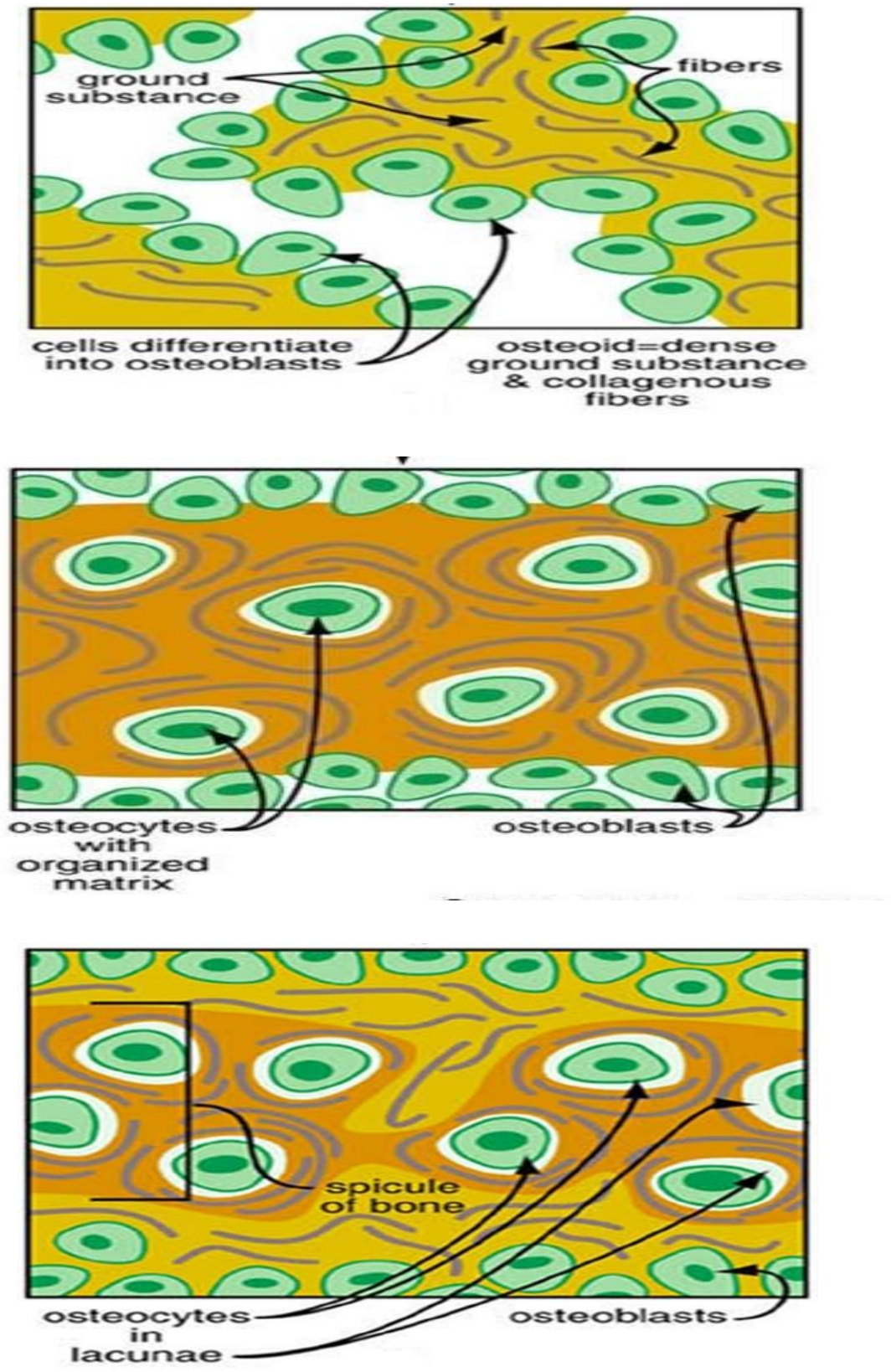

Figure (1): The intramembranous ossification.

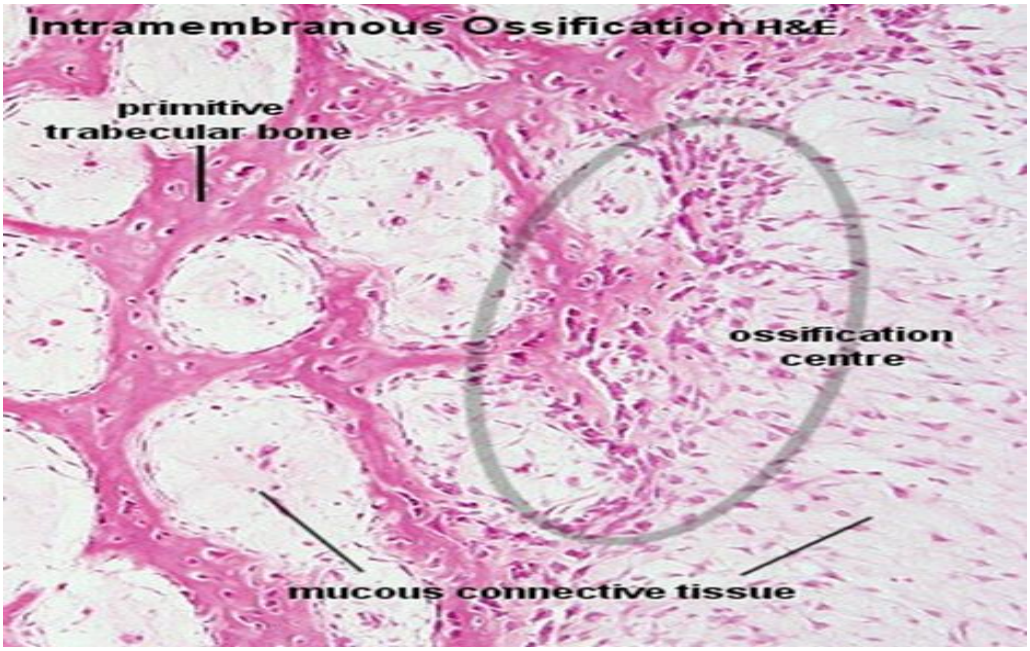

Figure (2): The tissue formed by intramembranous ossification.

2-Endochondral ossification

This type of ossification occurs within a cartilage model (template) whose shape resemble a shape of bone to be formed. This type is responsible for the formation of short and long bones.

This process include both removal of the cartilage model and deposition of bone matrix. The bone formation is initiated within **bond-shaped area** of perichondrium surrounding the center of the cartilage model that called diaphysis.

In perichondrium, the chondrogenic cells become osteoprogenitor cells that differentiated into osteoblasts that secrete bone matrix forming the periosteal bone collar or ring which surrounded the surface of the middle of the diaphyseal region of the cartilage. The perichondrium surround this area becomes periosteum. The result of these changes a thin layer of bone is formed around the cartilage model (Figure 3).

Within the forming of bone collar, changes occur in the cartilage itself. In the center of diaphysis, the chondrocytes hypertrophy and then degenerate and die due to new bone collar prevents the diffusion of nutrients into the chondrocytes within the matrix. This lead that chondrocytes resorb their surrounding matrix causing enlarged lacunae. The matrix between these lacunae becomes reduced in amount and become thin septa. The cartilage matrix undergo calcification where the calcium deposits in this matrix and become calcified matrix (Figure 4).

The **periosteal or osteogenic bud** consisting of osteoprogenitor cells and blood vessels migrate from the periosteum through holes made by osteoclasts in the bone collar. These buds penetrate the calcified cartilage matrix forming cavities called primary marrow cavities. These spaces contain blood vessels and osteoprogenitor cells which proliferate and differentiate into osteoblasts that form a continues layer on the surface of calcified cartilage matrix remnants. These cells start to synthesis bone matrix. At first the matrix is deposited as osteoid and then becomes calcified bone. The calcified cartilage can be distinguished as basophilic, whereas the bone tissue formed is acidophilic. When the spongy bone matrix develops, the cartilage matrix is removed by continued resorption of calcified cartilage through the activity of osteoclasts. The deposition of bone in the center of diaphysis is called **primary ossification center.**

The zone of endochondral ossification extends toward both ends of the cartilage that called epiphysis by process similar to that take place in the primary ossification center, except that bone collar is not formed. The osteoprogenitor cells invade the cartilage of epiphysis, differentiate into osteoblasts which begin secreting bone matrix. This process is called **secondary ossification center.**

In the secondary ossification center, cartilage remains in two regions: the **articular cartilage**, which persists throughout adult life and does not contribute to bone growth in length, and the **epiphyseal cartilage**, also called **epiphyseal plate**, which connects the two epiphyses to the diaphysis. The epiphyseal plate is responsible for increase in the length of the bone due to continued endochondral bone formation at each end of these bones (Figure 5).

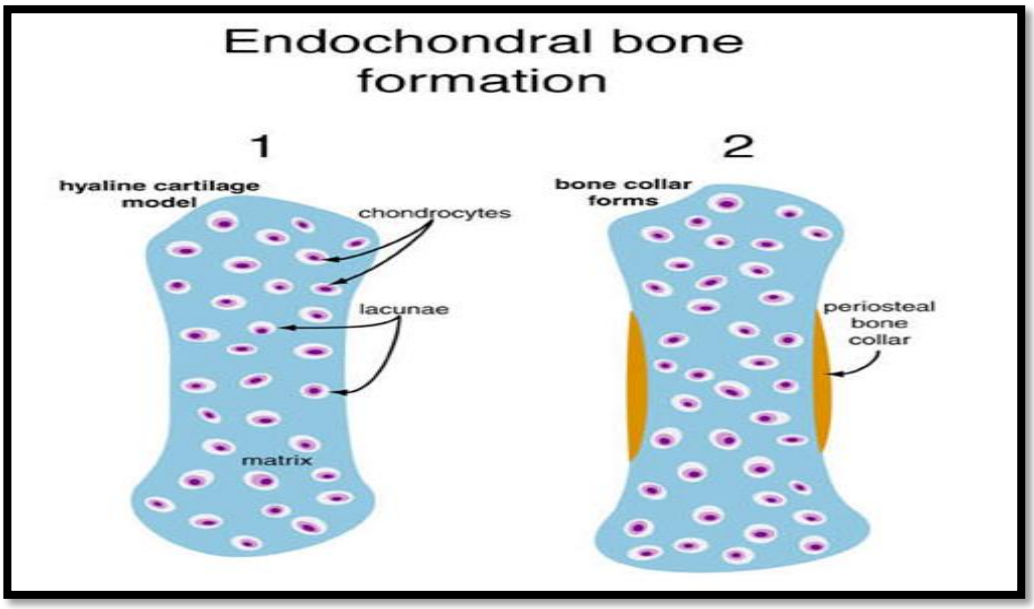

Figure (3): The formation of bone collar

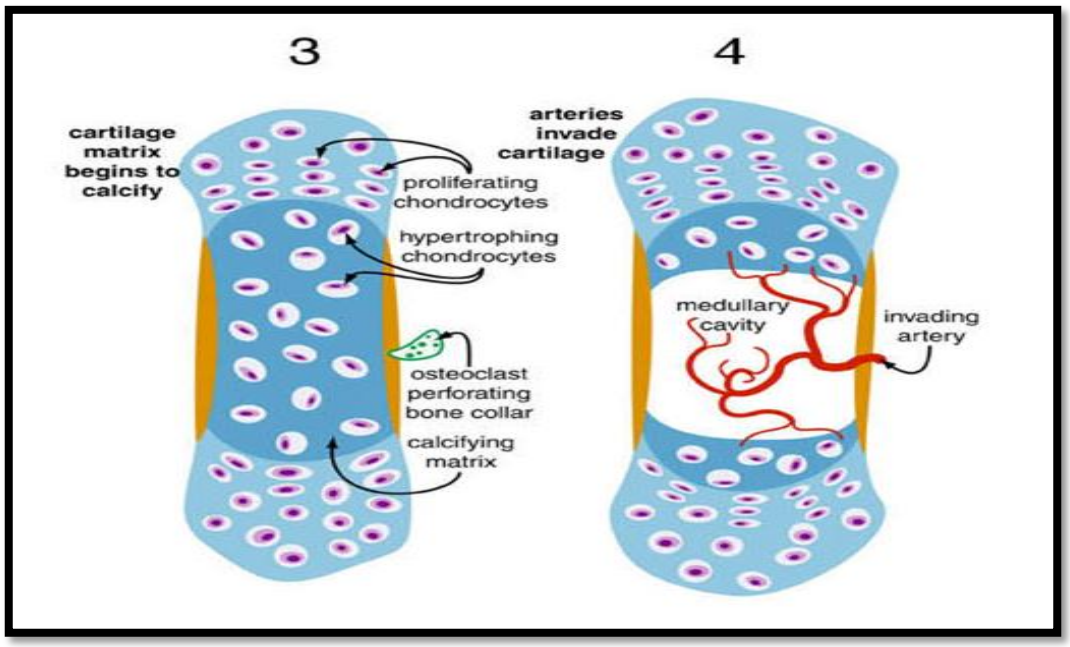

Figure (4): The cartilage undergo calcification.

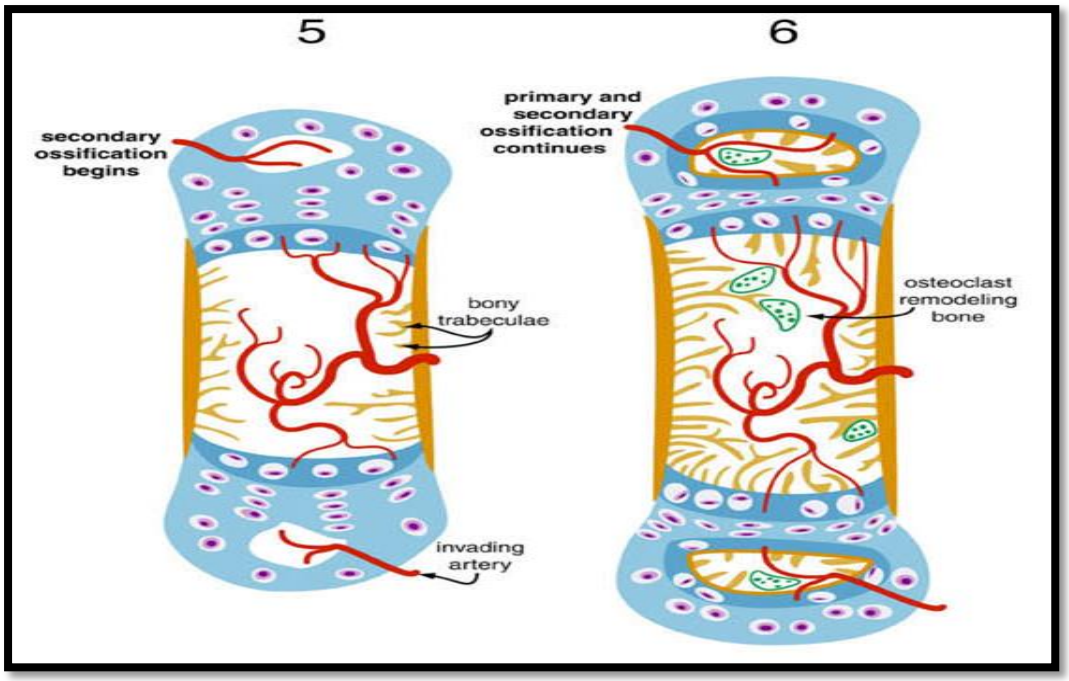

Figure (5): Secondary ossification center

The **epiphyseal plate** (epiphyseal cartilage) is responsible for maintaining the growth process. The epiphyseal cartilage is divided into five zones (Figure 7):

1-Resting zone

Consisting of hyaline cartilage without morphological changes in the cells.

2- Proliferation zone

This is active zone where chondrocytes undergo division and produce cells arranged into rows or columns parallel with the long axis of the cartilage. Each row consist of a number of flattened cells and separated by a small amount of matrix.

3- Hypertrophy zone

The cartilage cells enlarge and becoming cuboidal in shape, and the lacunae enlarge. The matrix is reduced to thin septa between the chondrocytes due to resorption it by these cells.

4- Calcification zone

In this zone the death of chondrocytes, the matrix surrounding the enlarged lacunae become calcified by the deposition of minerals within it and appear deeply basophilic in staining.

5- Ossification zone

The bone tissue appears. The osteoprogenitor cells and blood vessels from the periosteum invade the spaces or cavities left by the chondrocytes. The osteoprogenitor cells differentiate into osteoblasts, which are distributed in a continuous layer over the septa of calcified cartilage matrix. The osteoblasts begin to deposit bone matrix.

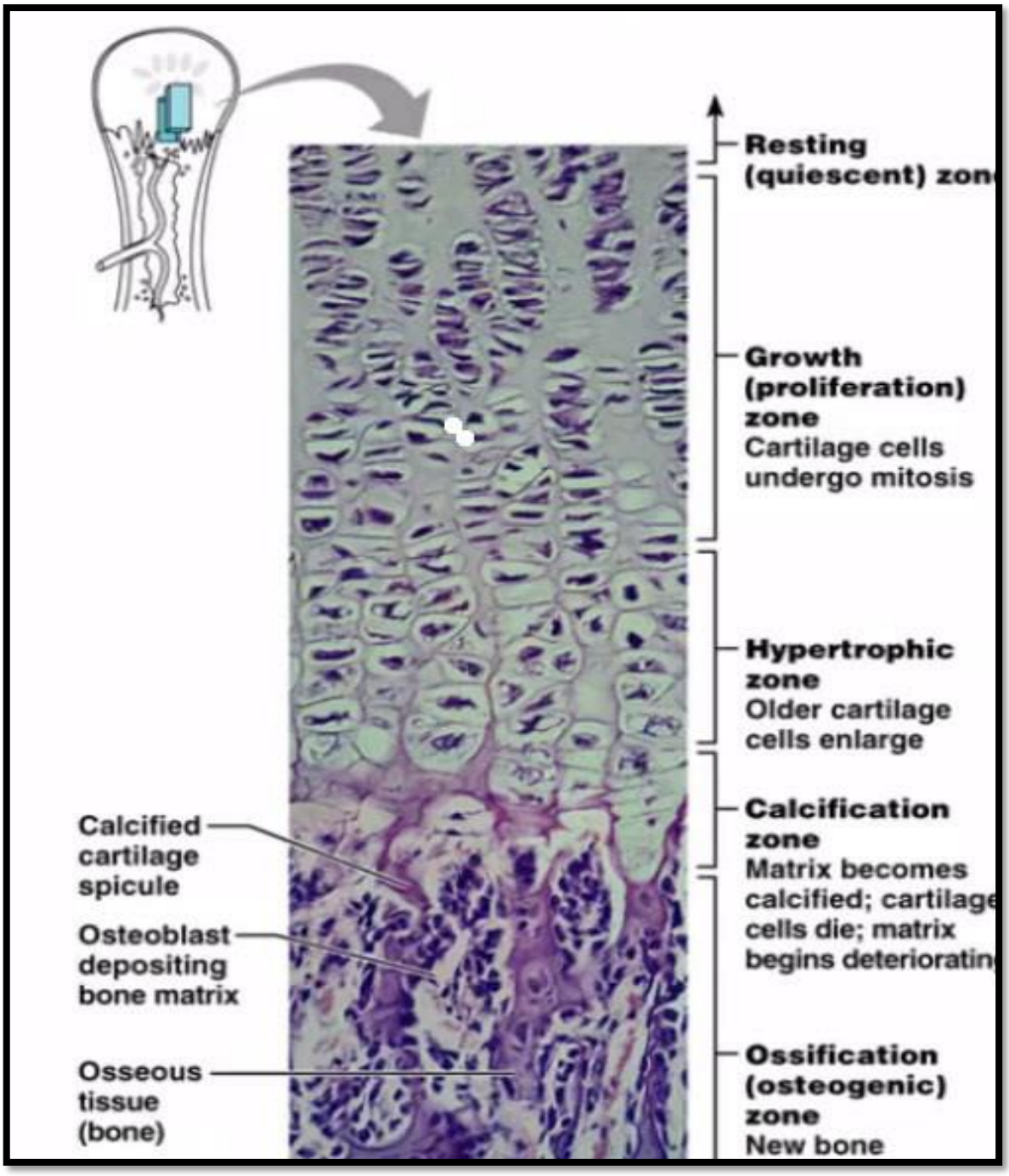

Figure (7): The zones of epiphyseal plate.