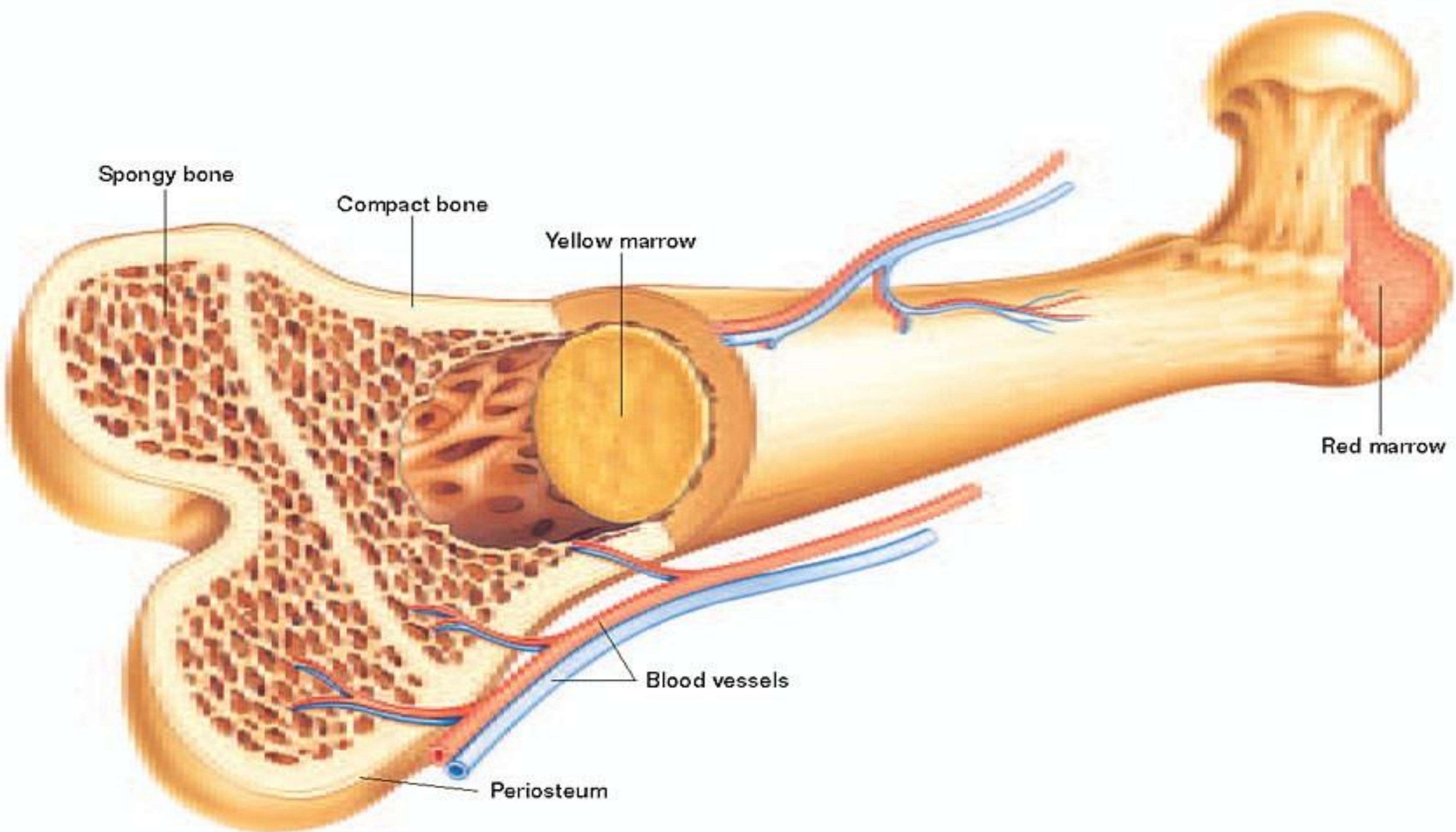
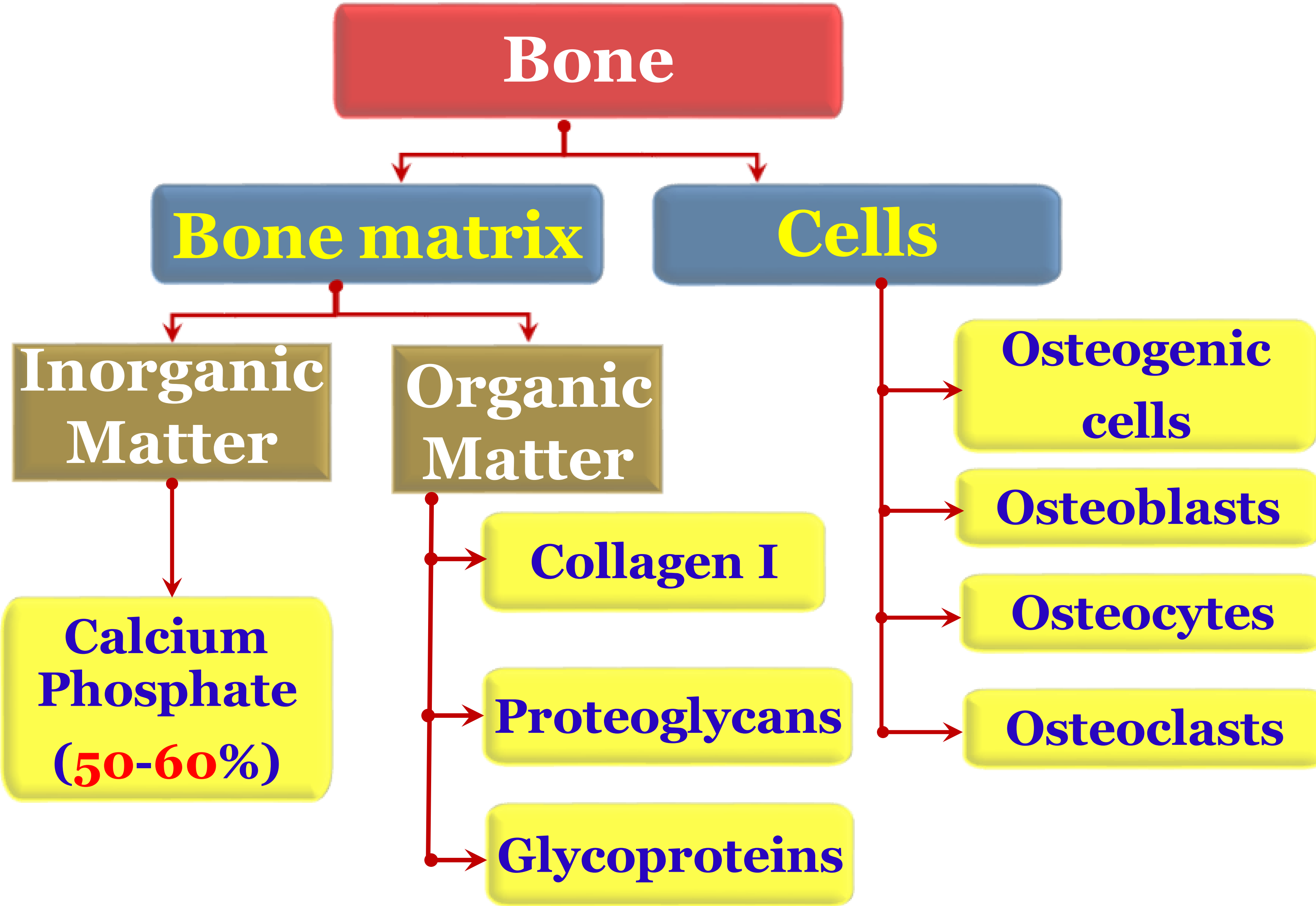
Bone


Spongy bone
Compact bone
Yellow marrow
Red marrow
Blood vessels
Periosteum


Bone
Bone matrix
Cells
Inorganic Matter
Organic Matter
Calcium Phosphate (50-60%)
Collagen I
Proteoglycans
Glycoproteins
Osteogenic cells
Osteoblasts
Osteocytes
Osteoclasts

Bone matrix: [extracellular matrix]

- Bone matrix has inorganic and organic components:-

- **Inorganic Components:**
  - It constitutes about 50% of the dry weight of bone.
  - It is composed mainly of calcium salts (ca hydroxyapatite) and phosphate.

- **Organic Components:**
  - It constitutes about 50% of the dry weight of bone.
  - it is composed of:
    - Collagen fibers type I in the form of collagen fibers.
    - Ground substance which contains:-

a. Glycosaminoglycans [chondroitin sulphate & Keratan Sulphate].

b. Proteoglycans.

c. Glycoproteins.

d. The matrix is stained acidophilic (collagen) in Hx &E sections and it is PAS +ve.

- ***Types of bone tissue:***

(I) Macroscopic types:

  - Gross observation of bone tissue reveals two types.

1. Spongy (cancellous) bone: which consists of irregular bone trabeculae that branch and unit with one another enclosing spaces filled with bone marrow.

2. Compact bone: appears as solid very dense mass of bone tissue without cavities.

(II) Microscopic types:

- Two types are detected:

1. primary bone: [immature or woven bone]
   - It is the first bone formed during fetal development and during bone repair.
   - It has abundant osteocytes and irregular bundles of collagen.
   - Its mineral content (ca salts) is much less than that of secondary bone.

2. secondary bone: [mature or lamellar bone]
   - It is found in adult.

   Collagen fibers are regularly arranged in concentric lamellae which are parallel to each other around a vascular canal (Haversian canal).

   Osteocytes in their lacunae are dispersed between or within lamellae.

   The matrix of secondary bone is more calcified so it is stronger than primary bone.

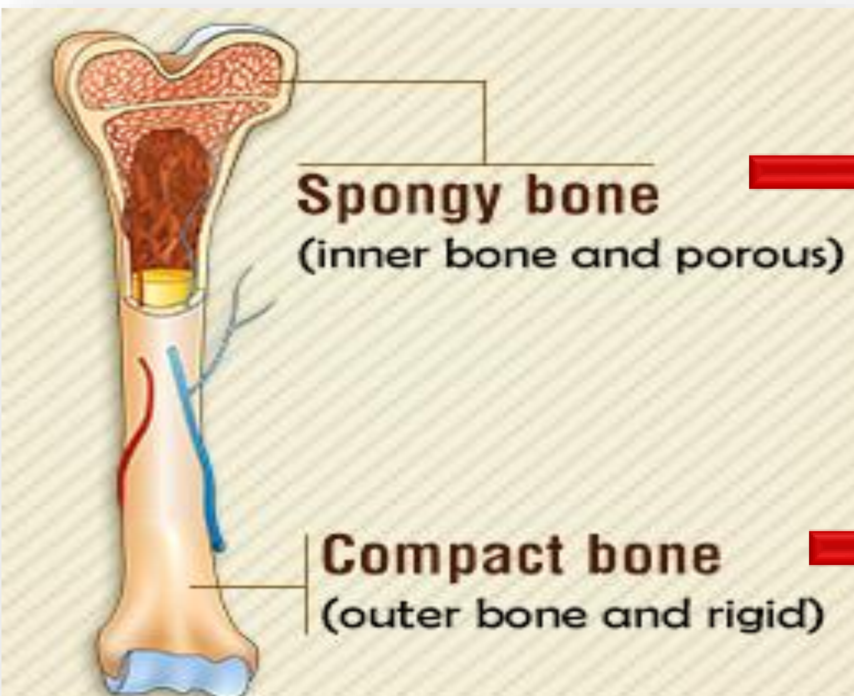
Types of Bone

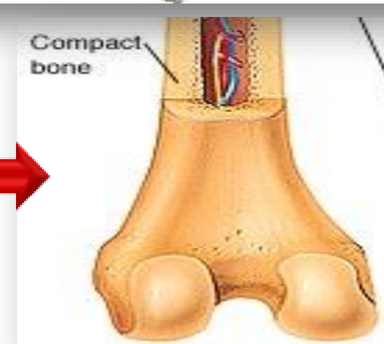
Compact

Solid very dense mass of bone tissue without cavities.

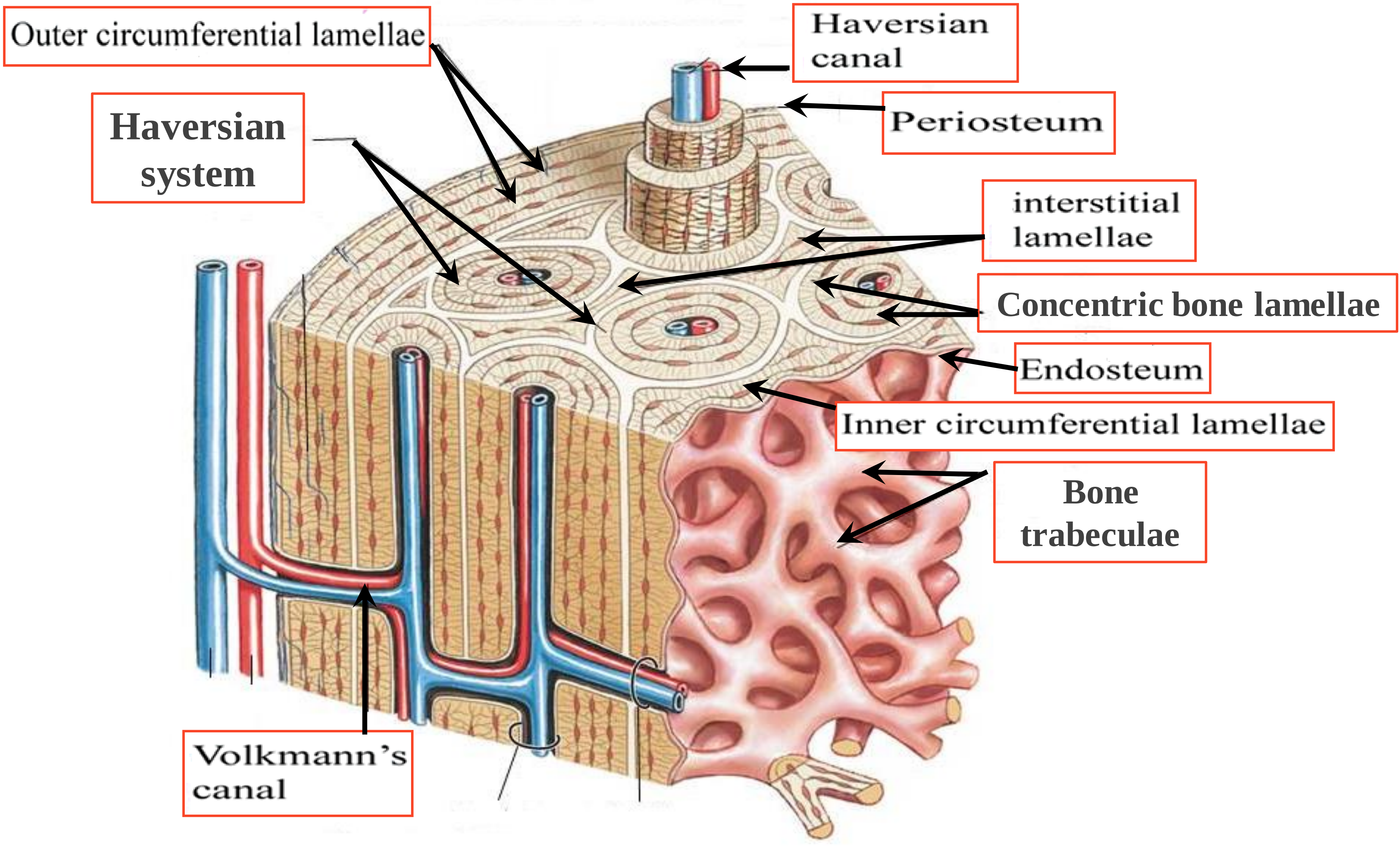
Cancelous (Spongy)

Irregular bone trabeculae that enclosing numerous cavities filled with bone marrow.





Compact Bone



Compact or decalcified compact bone

- Compact bone is composed of four lamellae arranged in the diaphysis of long bones.

i-Outer circumferential lamellae: They are just beneath the periosteum and they contain Sharpy's fibers.

ii- Haversian system (osteon):

-Each Haversian system is composed of concentric lamellae of regularly arranged collagenous fibers concentric around a vascular canal known as Haversian canal.

-Each Haversian canal is lined with endosteum (osteoblasts & osteogic cells).

-Haversian canals contain blood vessels and nerves as well as associated C.T. **The outer boundary of each osteon** is a more collagen-rich layer called **the cement line.**

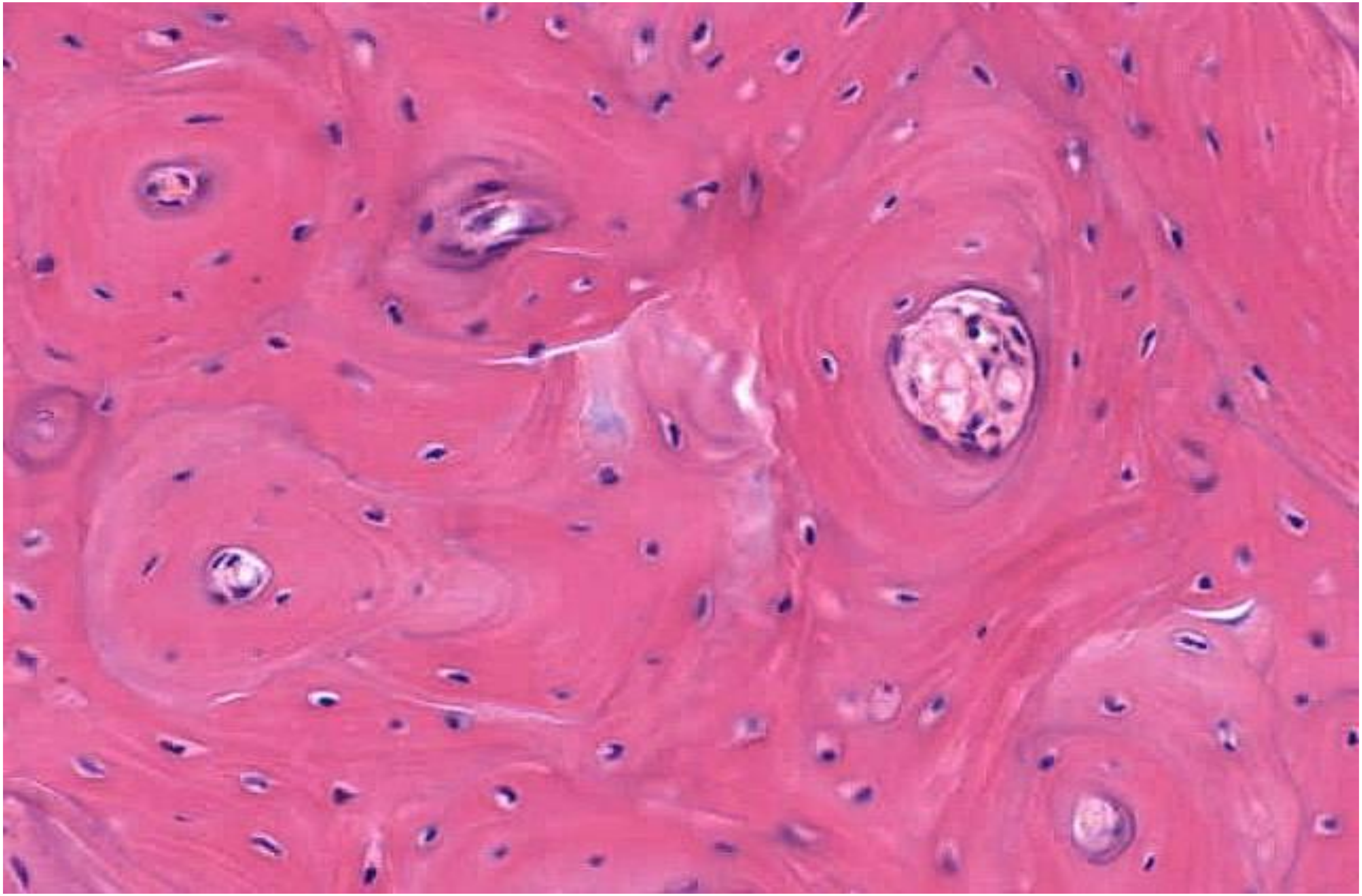
-Haversian canal run parallel to the long axis of the bone and connected with each other, with periosteum and with endosteum by transverse or oblique canals known as **Volkmann's canals**.

-Volkmann's canals are also lined with endosteum and contain blood vessel, nerves and C.T.

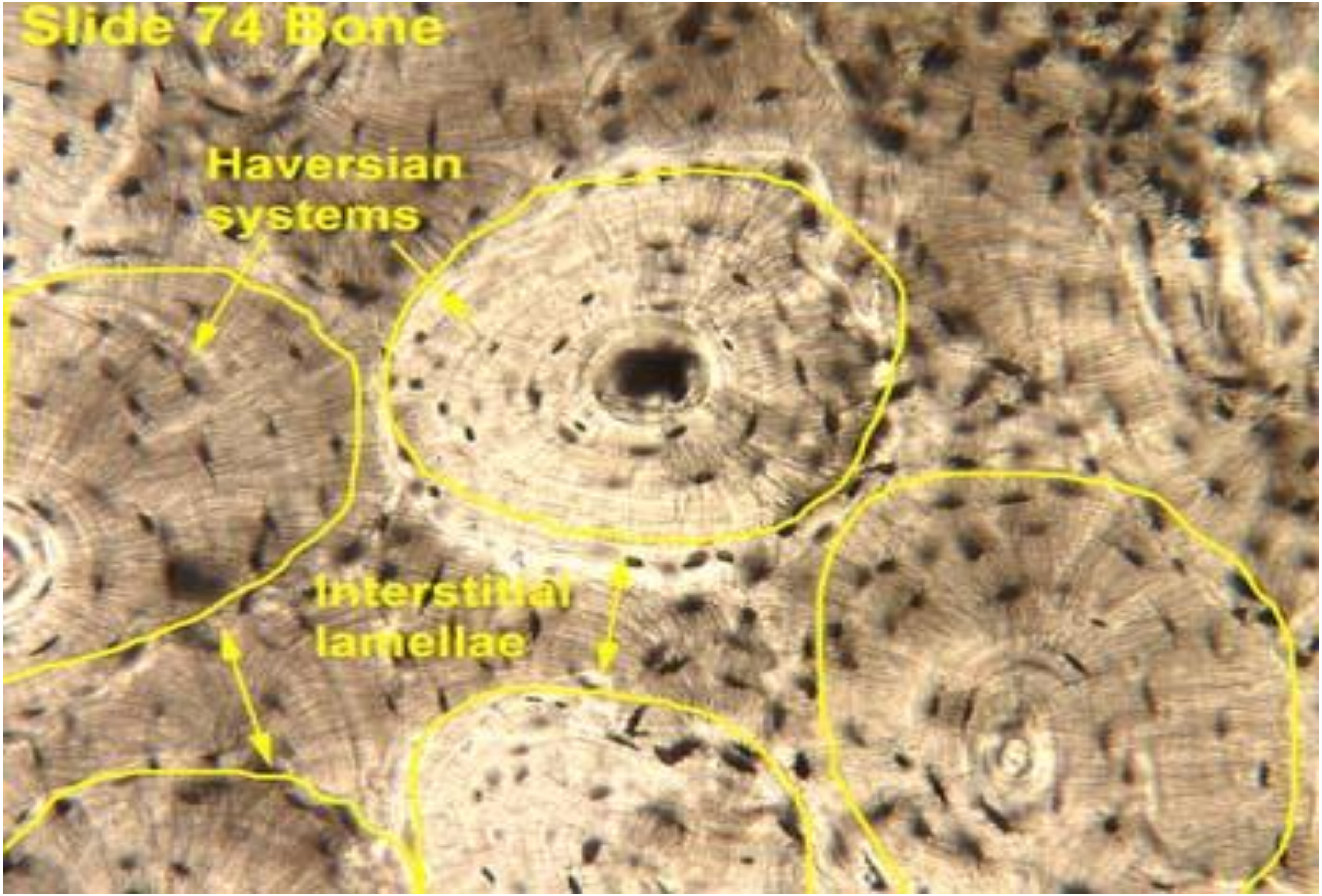
iii-Inner circumferential lamellae: They are located immediately beneath the endosteum and completely encircle the marrow cavity and have less lamellae than the outer circumferential lamellae.

iv- Interstitial lamellae: They are the lamellae of bone present between Haversian systems

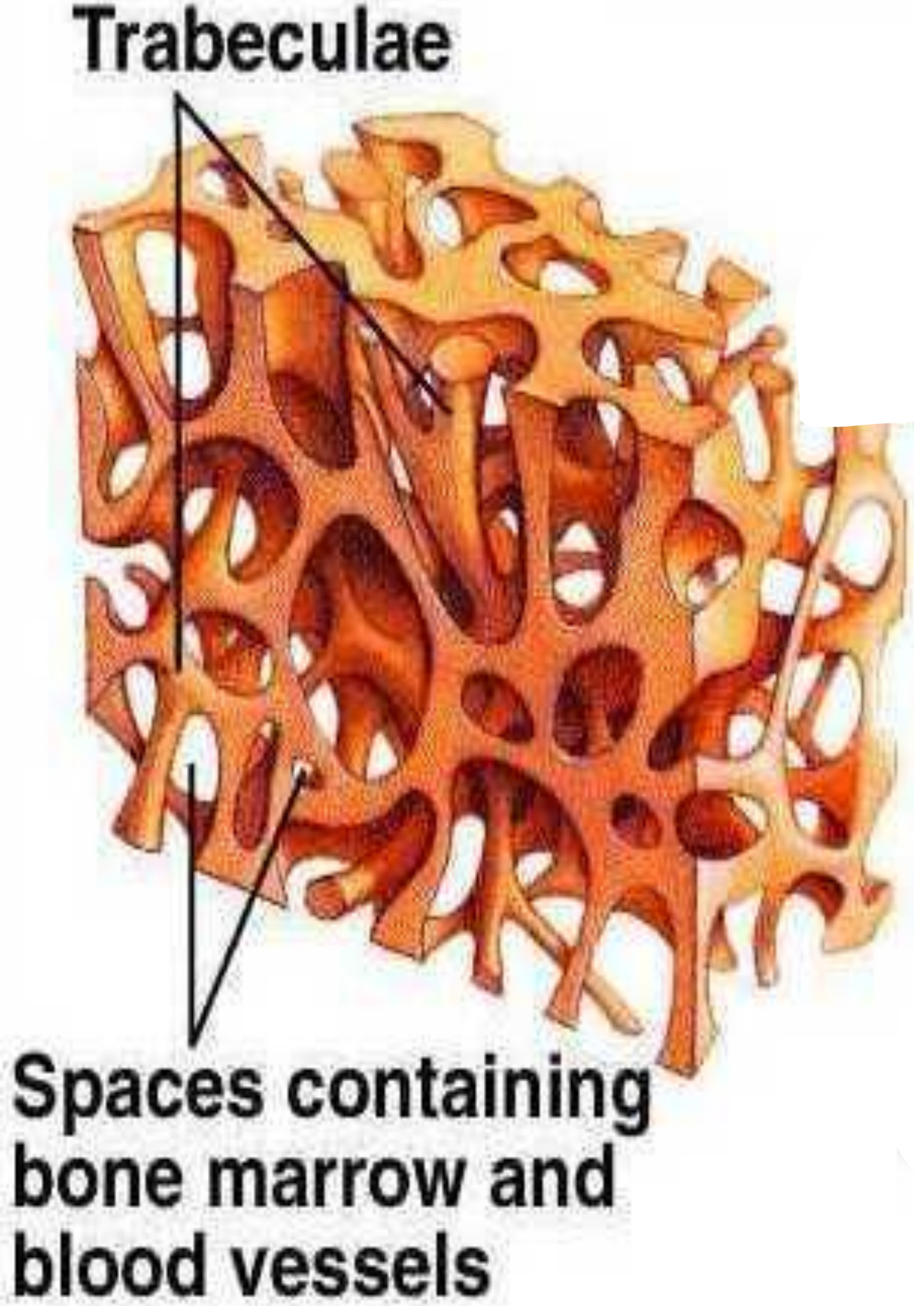
Compact Bone



Compact Bone



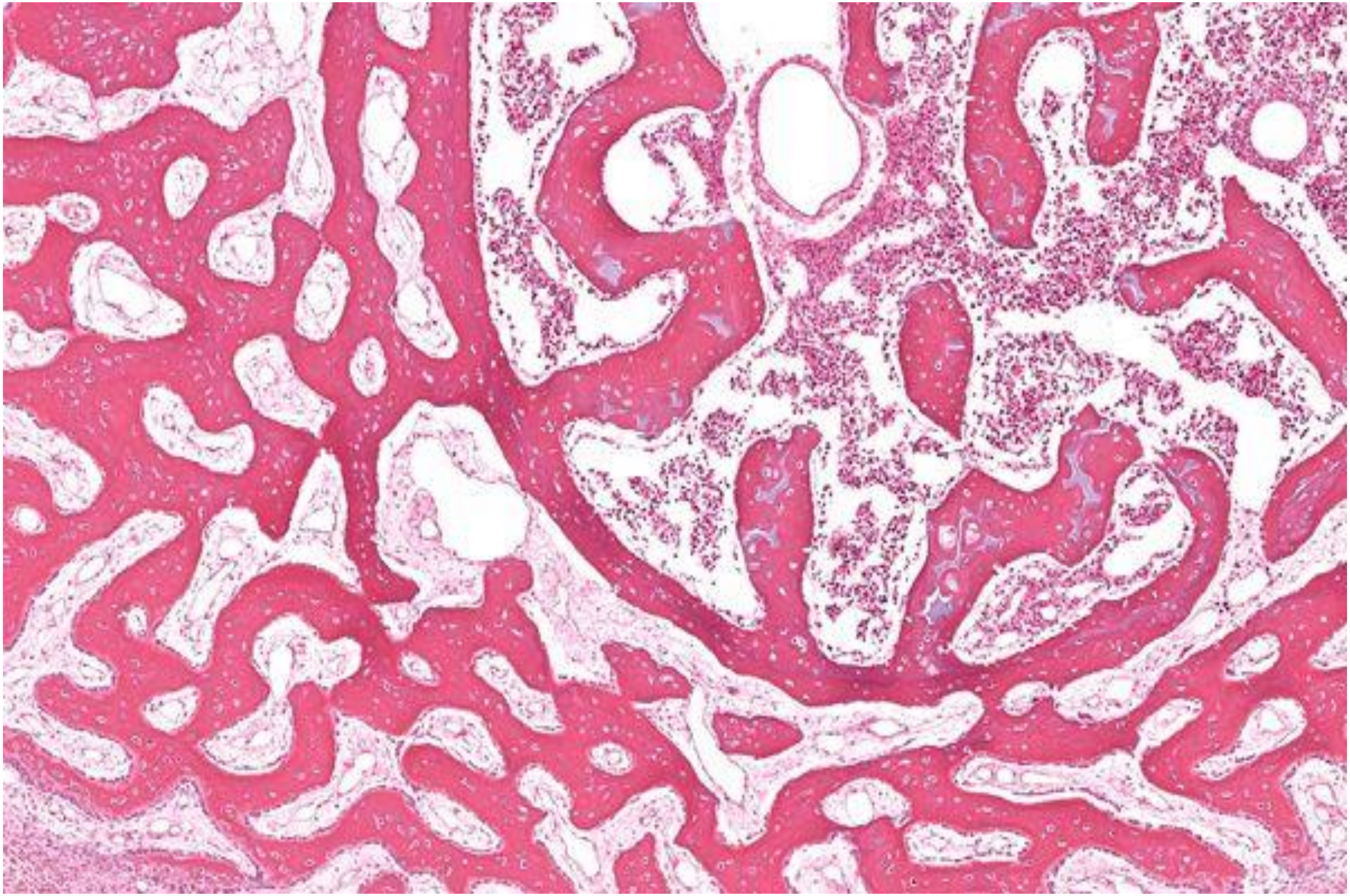
Cancellous Bone



cancellous bone

- They are present in flat bones as skull, sternum, ribs and ends of long bones .It is made up of branching trabeculae of spongy bone which are composed of irregularly arranged lamellae, but they do not have Haversian systems.
- Their bone cells are nourished by diffusion of tissue fluid through the canaliculi from the bone marrow cavities. The bone marrow cavities appear as irregular cavities in between bone trabeculae of spongy bone containing blood cells.

Cancellous Bone

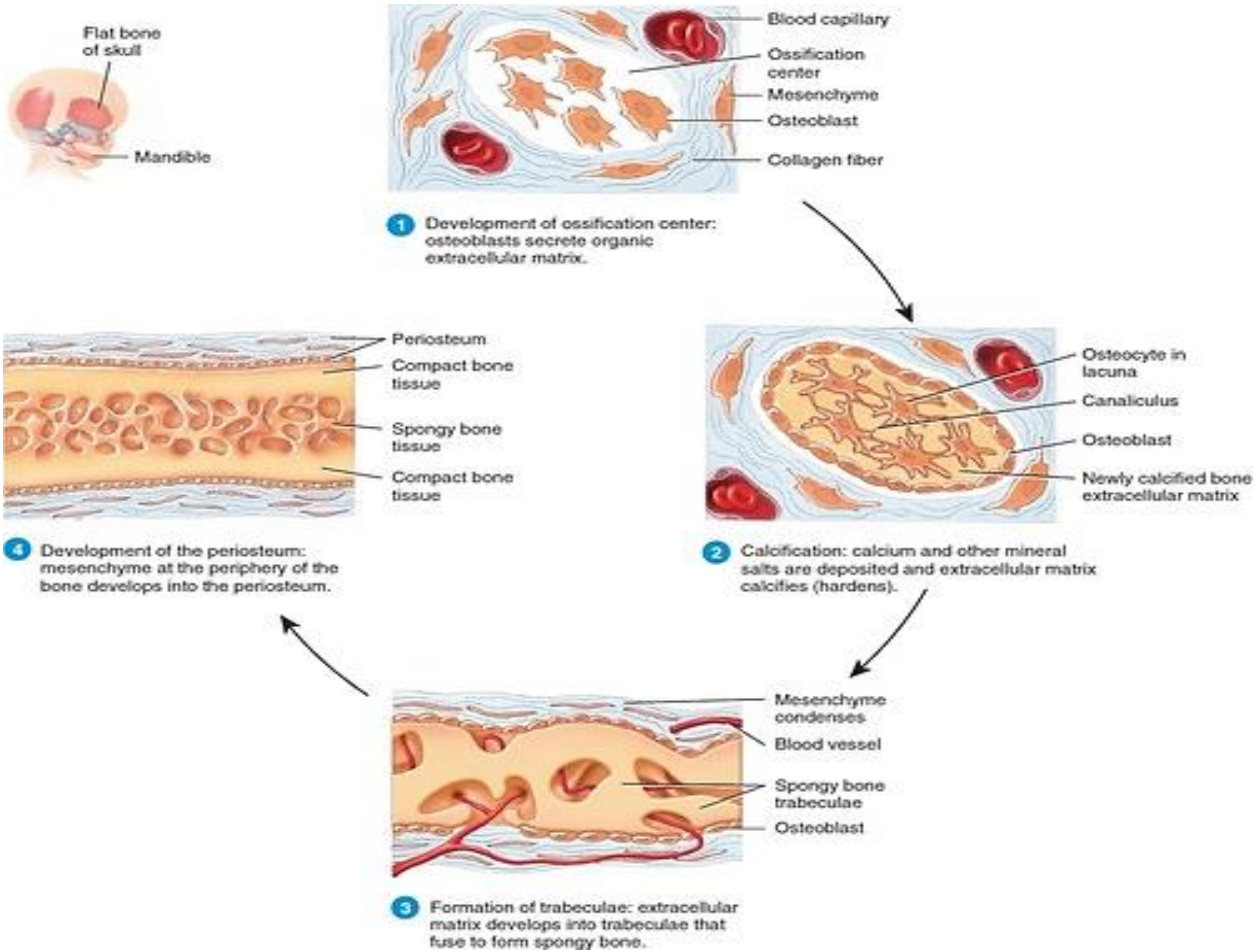


OSTEOGENESIS

I) Intramembranous ossification:

- By which most flat bones begin to form, is so called because it takes place within condensations ("membranes") of embryonic mesenchymal tissue. The frontal and parietal bones of the skull—as well as parts of the occipital and temporal bones and the mandible and maxilla—are produced initially by intramembranous ossification.

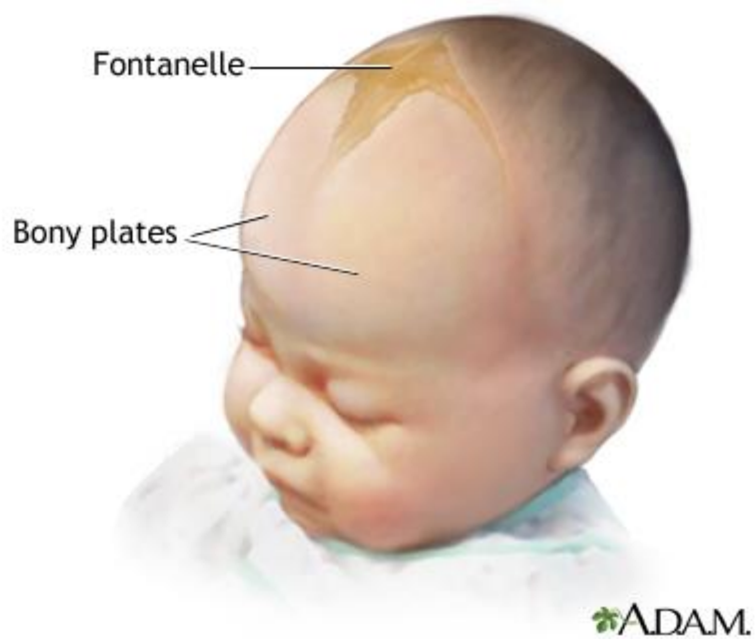
- Within the condensed layer of mesenchyme, the starting points for bone formation are called **ossification centers**. In these areas mesenchymal cells differentiate into osteoprogenitor cells which proliferate and form incomplete layers of osteoblasts around a network of developing capillaries.


Flat bone
of skull
Mandible
Blood capillary
Ossification
center
Mesenchyme
Osteoblast
Collagen fiber
1 Development of ossification center:
osteoblasts secrete organic
extracellular matrix.
Osteocyte in
lacuna
Canaliculus
Osteoblast
Newly calcified bone
extracellular matrix
2 Calcification: calcium and other mineral
salts are deposited and extracellular matrix
calcifies (hardens).
Mesenchyme
condenses
Blood vessel
Spongy bone
trabeculae
Osteoblast
3 Formation of trabeculae: extracellular
matrix develops into trabeculae that
fuse to form spongy bone.
Periosteum
Compact bone
tissue
Spongy bone
tissue
Compact bone
tissue
4 Development of the periosteum:
mesenchyme at the periphery of the
bone develops into the periosteum.

- From their surfaces facing away from these blood vessels, the polarized osteoblasts secrete the osteoid components that calcify and form trabeculae of woven bone.
- Differentiating osteocytes now enclosed within matrix lacunae retain intercellular contacts via their thin cytoplasmic processes within matrix canaliculi. Continued matrix secretion, calcification, and trabecular growth lead slowly to the fusion of neighboring ossification centers and gradually produce layers of compact bone that broadly enclose a region of cancellous bone with marrow and larger blood vessels.

- **In cranial flat bones**, bone formation predominates over bone resorption at both the internal and external surfaces. Thus, two layers of compact bone (internal and external plates) arise, while the central portion (diploë) maintains its cancellous, spongy nature.

- **The fontanelles** or “soft spots” on the heads of newborn infants are areas in the skull that correspond to parts of the connective tissue that are not yet ossified. Regions of the connective tissue that do not undergo ossification give rise to the endosteum and the periosteum of the new bone

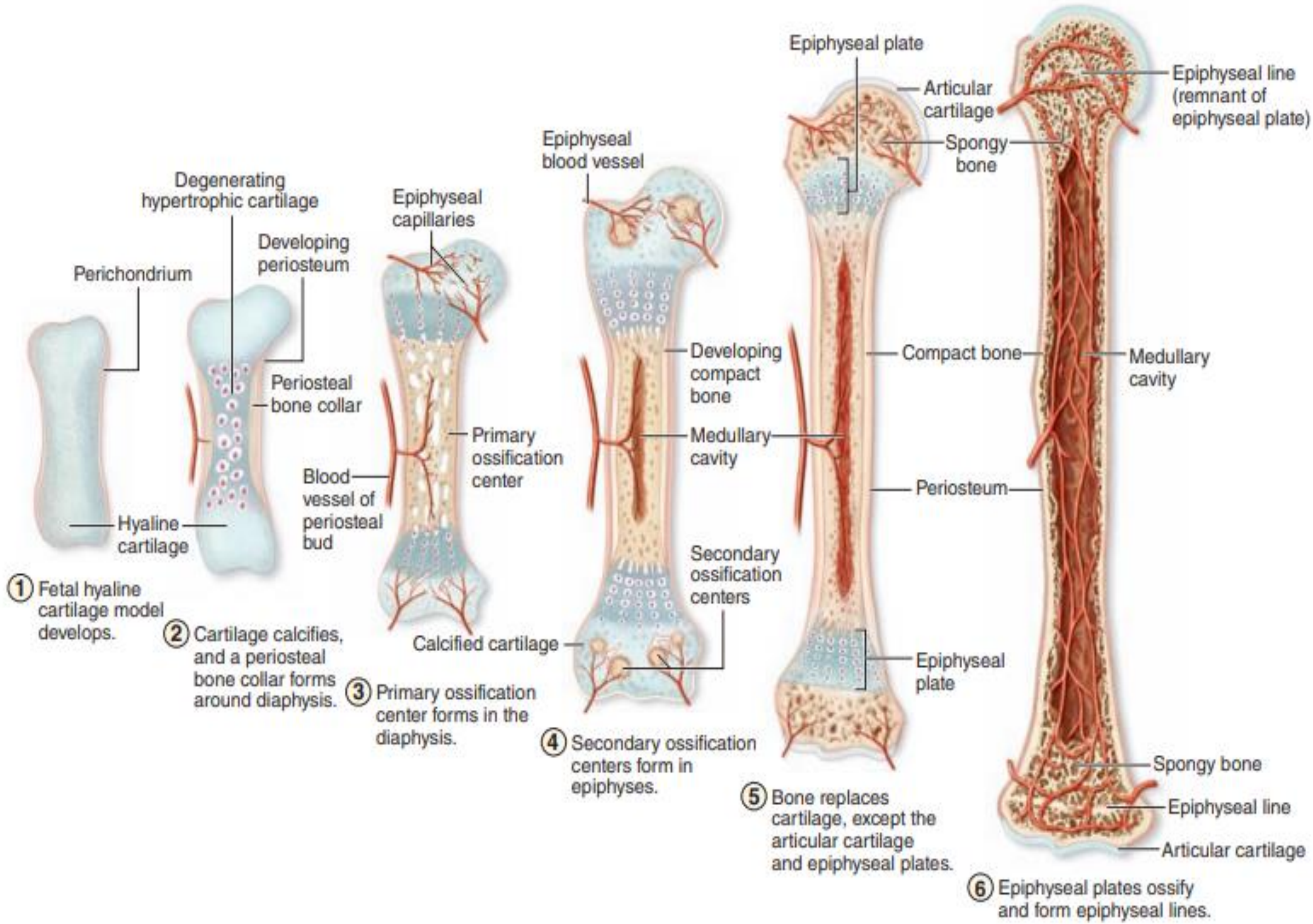


II) Endochondral Ossification

- Ossification takes place within a piece of hyaline cartilage whose shape resembles a small version, or model, of the bone to be formed. This type of ossification is principally responsible for initiating most bones of the body and is especially well studied in developing long bones.

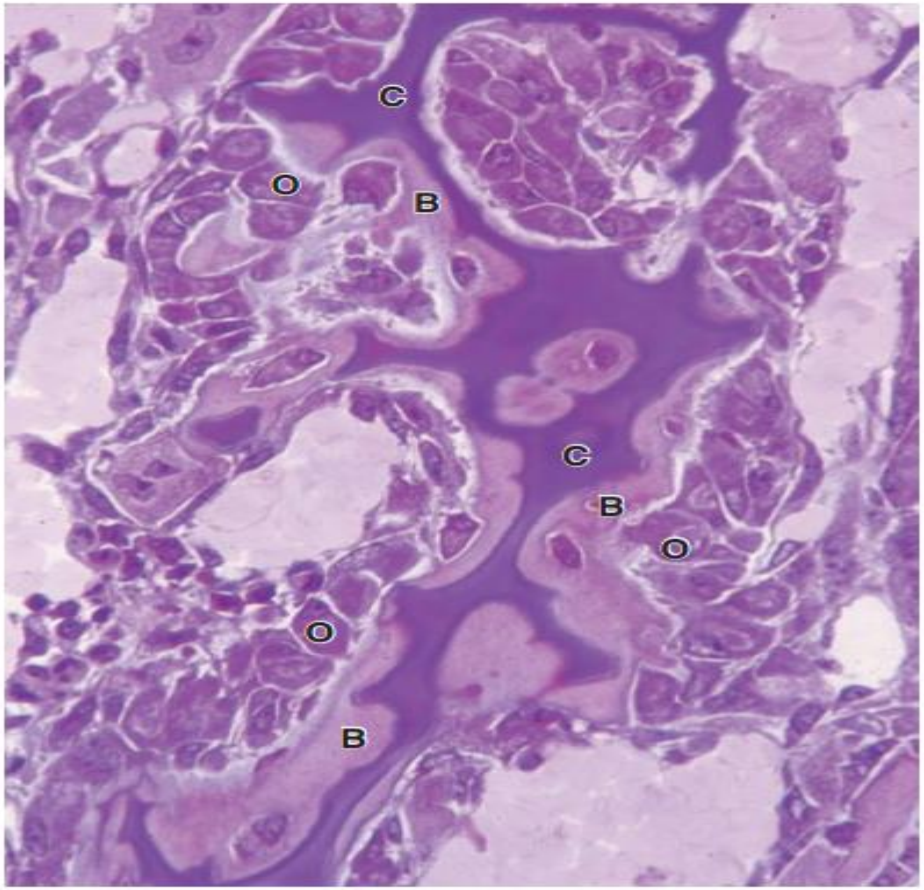
- The first bone tissue appears as a collar surrounding the diaphysis of the cartilage model. This bone collar is produced by activity of osteoblasts that form within the surrounding perichondrium. The collar inhibits diffusion of oxygen and nutrients into the underlying cartilage, promoting degenerative changes there.

- The chondrocytes begin to produce alkaline phosphatase and swell up (hypertrophy), enlarging their lacunae. These changes both compress the matrix into narrow trabeculae and lead to calcification in these structures. Death of the chondrocytes creates a structure consisting of calcified cartilage remnants which become covered by a layer of osteoblasts


Perichondrium
Hyaline cartilage
Degenerating hypertrophic cartilage
Developing periosteum
Periosteal bone collar
Epiphyseal capillaries
Primary ossification center
Blood vessel of periosteal bud
Calcified cartilage
Epiphyseal blood vessel
Developing compact bone
Medullary cavity
Secondary ossification centers
Epiphyseal plate
Articular cartilage
Spongy bone
Compact bone
Periosteum
Epiphyseal plate
Epiphyseal line (remnant of epiphyseal plate)
Medullary cavity
Spongy bone
Epiphyseal line
Articular cartilage
① Fetal hyaline cartilage model develops.
② Cartilage calcifies, and a periosteal bone collar forms around diaphysis.
③ Primary ossification center forms in the diaphysis.
④ Secondary ossification centers form in epiphyses.
⑤ Bone replaces cartilage, except the articular cartilage and epiphyseal plates.
⑥ Epiphyseal plates ossify and form epiphyseal lines.

- Next, osteoblasts adhere to the remnants of calcified cartilage matrix and produce woven bone. The calcified cartilage at this stage appears basophilic, and the new bone is more acidophilic. Blood vessels from the perichondrium (now the periosteum) penetrate through the bone collar, bringing osteoprogenitor cells to the central region.
- This process in the diaphysis forms **the primary ossification center**, beginning in many bones as early as the first trimester.

calcified cartilage matrix **(C)** are basophilic and devoid of chondrocytes. This material becomes enclosed by more lightly stained osteoid and woven bone **(B)**. The new bone is produced by active osteoblasts **(O)**

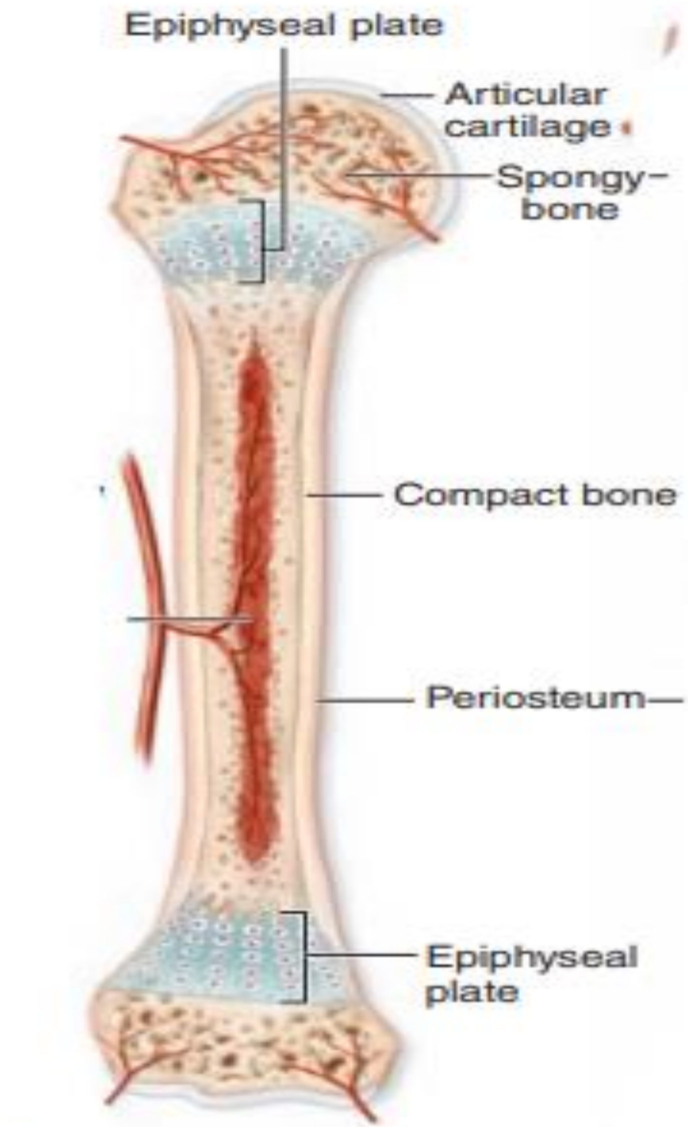


- **Secondary ossification centers** appear later at the epiphyses of the cartilage model and develop in a similar manner. During their expansion and remodeling, the primary and secondary ossification centers produce cavities that are gradually filled with bone marrow and trabeculae of bone.

- With the primary and secondary ossification centers, two regions of cartilage remain:

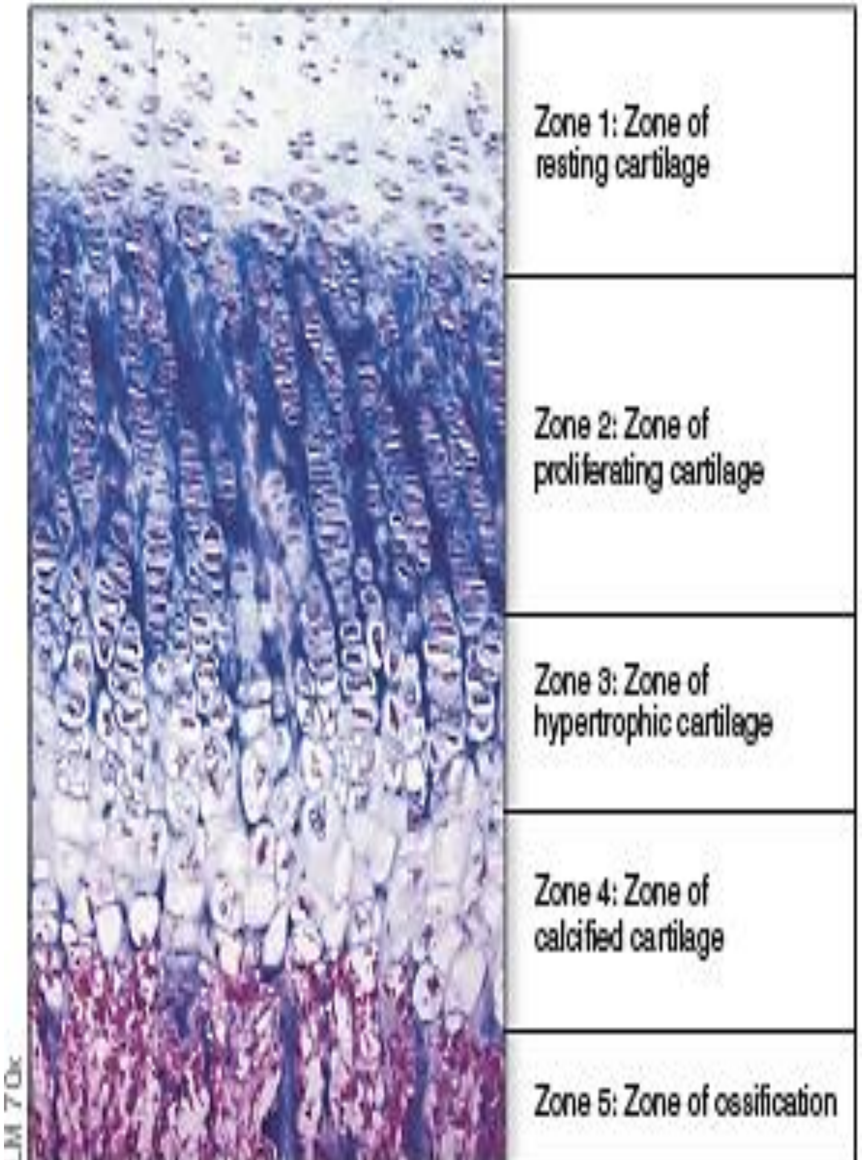
■ **The layer of articular cartilage** within joints , which usually persists through adult life and does not contribute to bone growth.

■ **The epiphyseal cartilage** (also called epiphyseal plate or growth plate), which connects each epiphysis to the diaphysis. The epiphyseal cartilage is responsible for the growth in length of the bone and disappears at adulthood. (“epiphyseal closure”) occurs at different times with different bones and is complete in all bones by about age 20.



(5) Bone replaces cartilage, except the articular cartilage and epiphyseal plates.

In forensics or through x-ray examination of the growing skeleton, it is possible to determine the "bone age" of a young person, noting which epiphyses are open and which are closed. Once the epiphyses have closed, additional growth in length of bones is no longer possible although bone widening may still occur.



(a) Epiphyseal plate

(b) X-ray of a hand

An epiphyseal growth plate shows distinct regions of cellular activity and is often discussed in terms of five zones starting from the thin region of normal cartilage:

1. The resting zone consists of hyaline cartilage with typical chondrocytes.

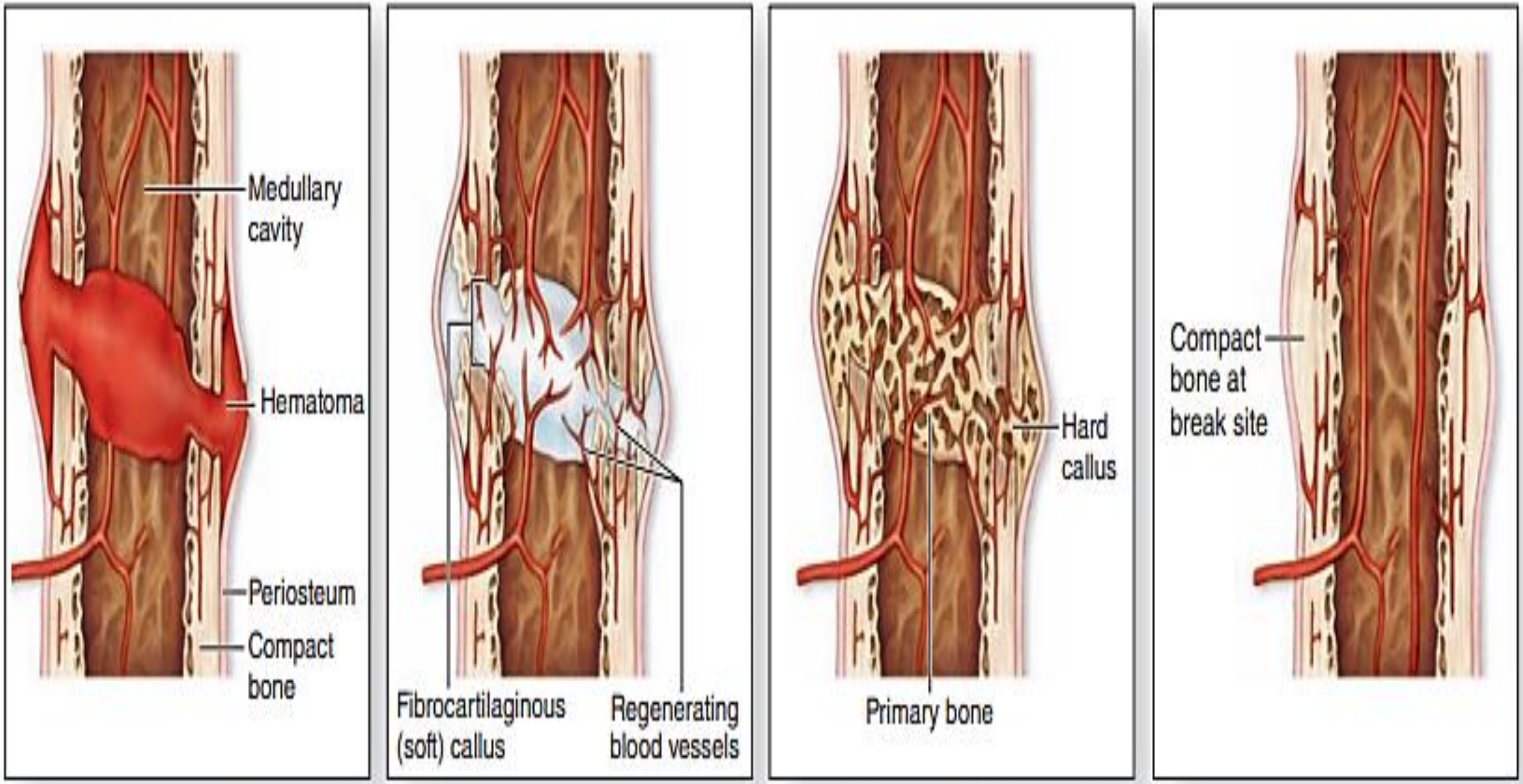
2. the proliferative zone, chondrocytes begin to divide rapidly and form columns of stacked cells parallel to the long axis of the bone.

3. The hypertrophic cartilage zone contains swollen, degenerative chondrocytes whose cytoplasm has accumulated glycogen. This hypertrophy compresses the matrix into thin septa between the chondrocytes.

4. the calcified cartilage zone, loss of the chondrocytes by apoptosis is accompanied by calcification of the septa of cartilage matrix by the formation of hydroxyapatite crystals.

5. the ossification zone, Capillaries and osteoprogenitor cells from the periosteum invade the cavities left by the chondrocytes. Osteoblasts settle in a layer over the septa of calcified cartilage matrix and secrete osteoid over these structures, forming woven bone.

features of bone fracture repair



(a) A fracture hematoma forms.
(b) A fibrocartilaginous (soft) callus forms.
(c) A hard (bony) callus forms.
(d) The bone is remodeled.

- **Bone fractures** are repaired by a developmental process involving fibrocartilage formation and osteogenic activity of bone cells:

(a) Blood vessels torn within the fracture release blood that clots to produce a large fracture hematoma.

(b) This is gradually removed by macrophages and replaced by a soft fibrocartilage-like mass of **procallus** tissue rich in collagen and fibroblasts. If broken, the periosteum reestablishes continuity over this tissue.

(c) This soft procallus is invaded by regrowing blood vessels and osteoblasts. In the next few weeks the fibrocartilage is gradually replaced by trabeculae of woven bone (process that resembles a combination of endochondral and intramembranous ossification) forming **a hard callus** throughout the original area of fracture.

(d) The woven bone is then remodeled as **compact and cancellous** bone in continuity with the adjacent uninjured areas and fully functional vasculature is reestablished.

THANK YOU