Bone

Lec1

collage of pharmacy

1st stage

Histology

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Bone functions

Bone is a modified type of connective tissue in which the matrix is hard.

Functions:

1- Locomotion.

2- Protection of vital organs.

3- Metabolic function: by acting as a reservoir for calcium, phosphate and other minerals.

Components of Bone
I- Bone matrix

1- Water:

-Constitutes about 25% of the bone weight.

- permits exchange of minerals between blood and matrix.

2- Inorganic components:

-Constitutes about 45% of the bone weight.

- it is mainly in the form of :

✓ *calcium phosphate (in the form of hydroxyapatite crystals) & calcium carbonate.*

✓ *few other ions e.g. sodium, magnesium and ferrous.*

-It is responsible for the hardness of bone.

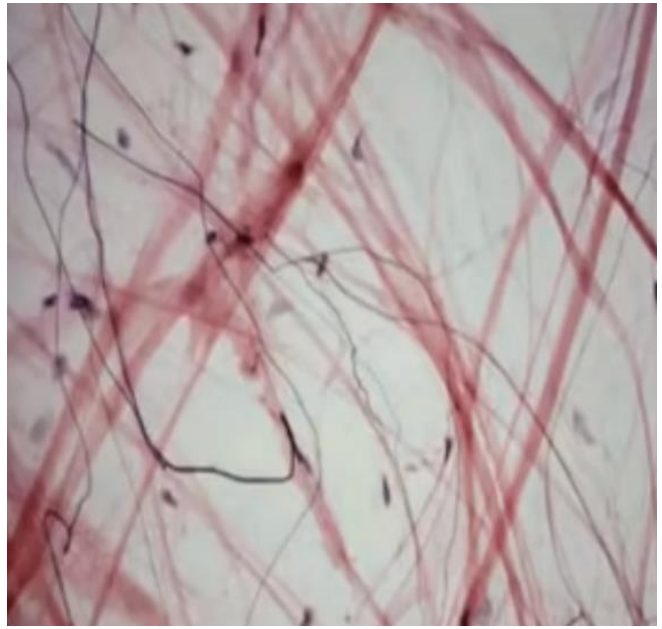
Components of Bone
I- Bone matrix

3- organic component:

- it constitutes about 30% of the bone weight.

- it include:

- *ground substances: formed of:*
  - *proteoglycans.*
  - *adhesive glycoproteins e.g. osteonectin which anchors to the collagenic matrix.*
- *type I collagen fibers: responsible for the eosinophilic staining of bone matrix.*



Components of bone
II- Bone coverings

1- Periosteum:

- It covers the external surfaces of bone.

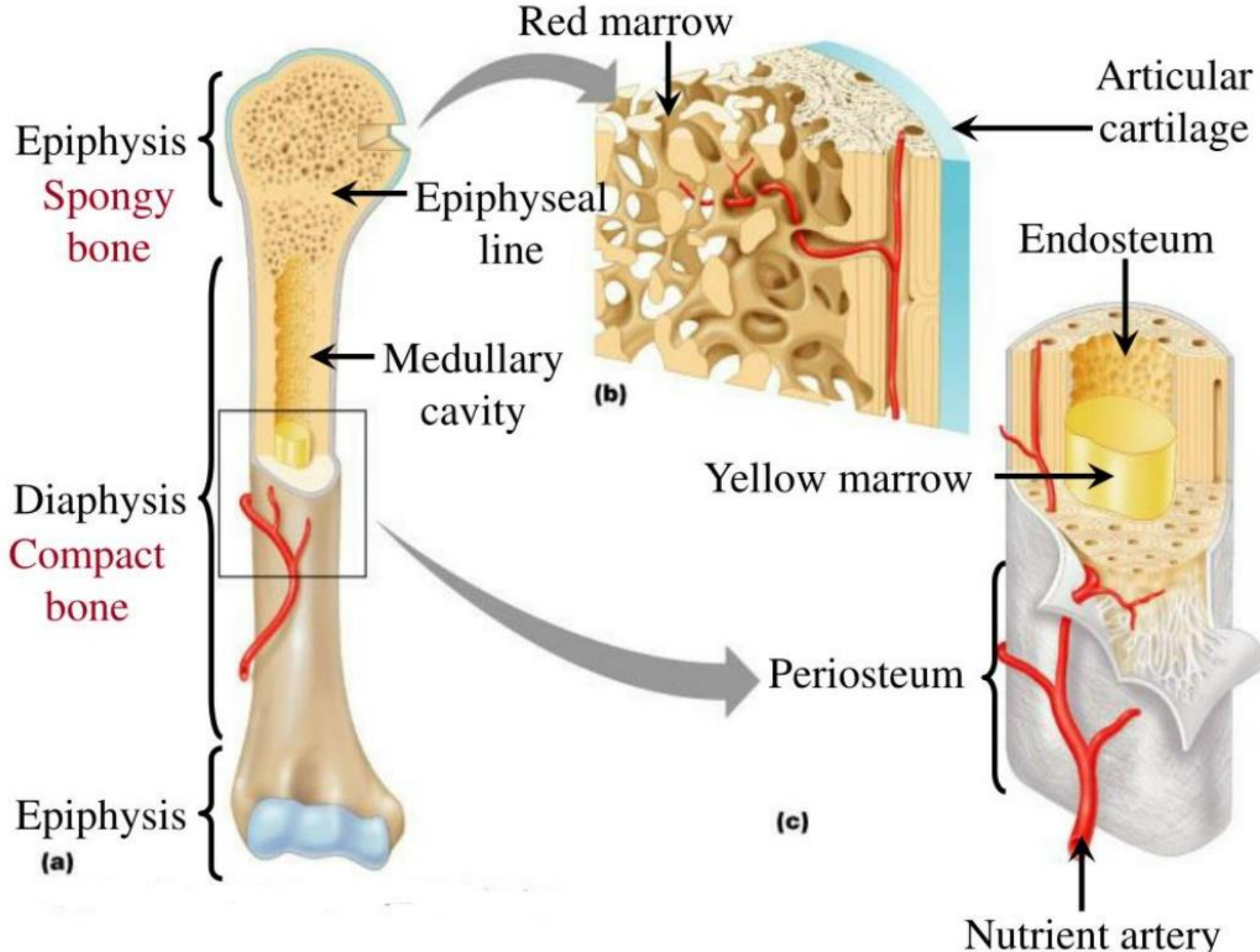
- It is like the perichondrium, formed of two layers:

- *The outer fibrous layer: formed of dense connective tissue with few blood vessels.*
- *The inner vesicular and cellular layer: containing the osteogenic cells (osteoprogenitor cells & osteoblast) which form new bone during growth and repair.*

2- Endosteum:

-It lines the bone marrow cavities.

-It is formed of cellular layer of osteogenic cells and blood vessels.


Red marrow
Articular cartilage
Epiphysis
Spongy bone
Epiphyseal line
Endosteum
Medullary cavity
(b)
Yellow marrow
Diaphysis
Compact bone
Periosteum
Epiphysis
(a)
(c)
Nutrient artery

Components of bone
III- Bone cells

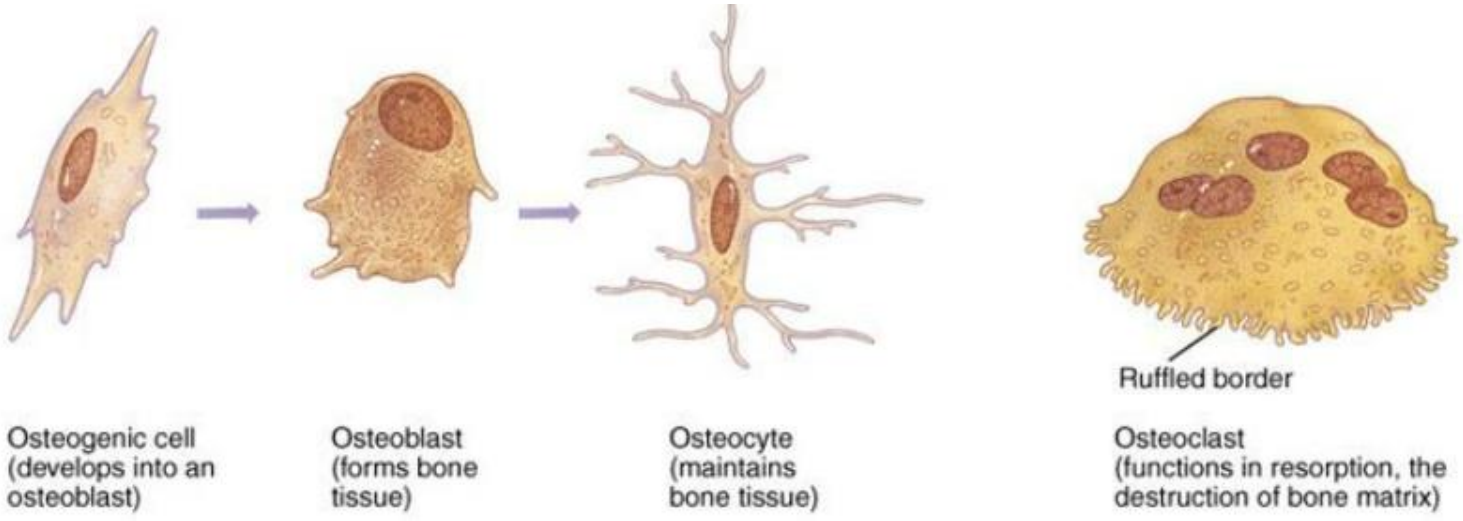
- *There are four types of bone cells*

1- Osteoprogenitors cells

2- Osteoblasts

3- Osteocytes

4- Osteoclasts.



1- Osteoprogenitor cells

It is the mother cells of the bone.

- *Origin: from undifferentiated mesenchymal cells.*
- *Function: whenever there is bone formation, the osteoprogenitor cells proliferate and differentiate to osteoblasts.*
- *Sites:*
  - *Cellular layer of the periosteum.*
  - *Endosteum.*
  - *Lining of Haversian canals.*
- *L.M. picture:*
  - *Shape: small & spindle.*
  - *Nucleus: oval.*
  - *Cytoplasm: pale basophilic.*
- *E.M. Picture: few organelles, mainly polysome.*

2- Osteoblasts

It is the forming cells.

- *Origin: from osteoprogenitor cells.*
- *Sites: in the same sites of osteoprogenitor cells*
- *Function: bone formation by:*

1- secretion of the osteoid which is uncalcified organic components of the bone matrix.

2- secretion of alkaline phosphatase enzyme which is responsible for deposition of calcium salts from the blood into the bone matrix (bone mineralization).

3- the osteoblast is entrapped by the calcified matrix in a lacuna and becomes an osteocyte.

- *L.M. Picture:*

- *Shape: cuboidal or columnar arranged in one row (resembling the simple epithelium), attached to each other by short processes.*
- *Nucleus: eccentric & pale.*
- *cytoplasm: deep basophilic with a juxtanuclear negative Golgi image.*

- *E.M. Picture: it shows the ultrastructure feature of proteins synthesizing cells (constitutive secretion).*

3- osteocytes

It is the unit bone cells.

- *Origin: from osteoblasts, when entrapped within the lacunae (cavities).*
- *Sites: inside the lacunae within the bone matrix.*
- *Function: maintenance of the bone matrix.*
- *L.M. Picture:*

• *Shape: flattened cells with many processes.*

• *Nucleus: deeply stained.*

• *Cytoplasm: pale basophilic.*

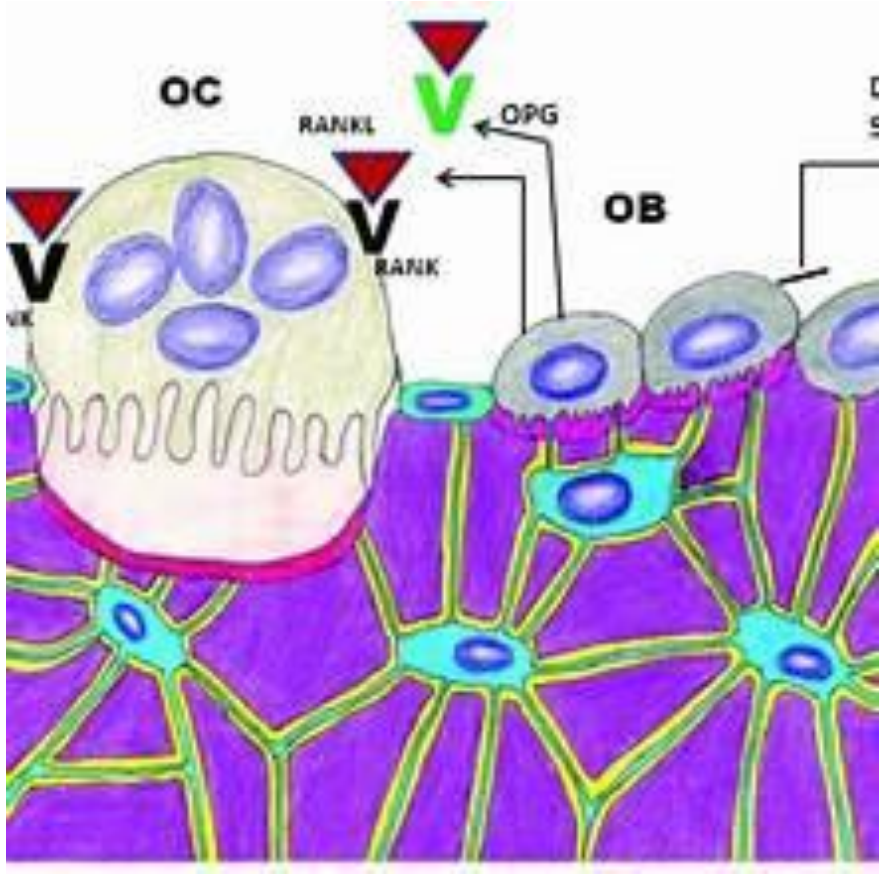
- *E.M. Picture:*

• *Nucleus: more heterochromatinic than that of osteoblasts.*

• *cytoplasm: moderate amounts of organelles.*

3- osteocytes

- *they are present within lacunae.*
- *their processes are present within minute spaces in the bone matrix called canaliculi.*
- *the lacunae and canaliculi communicate with each other.*
- *the processes of neighboring osteocytes are connected via gap junction.*



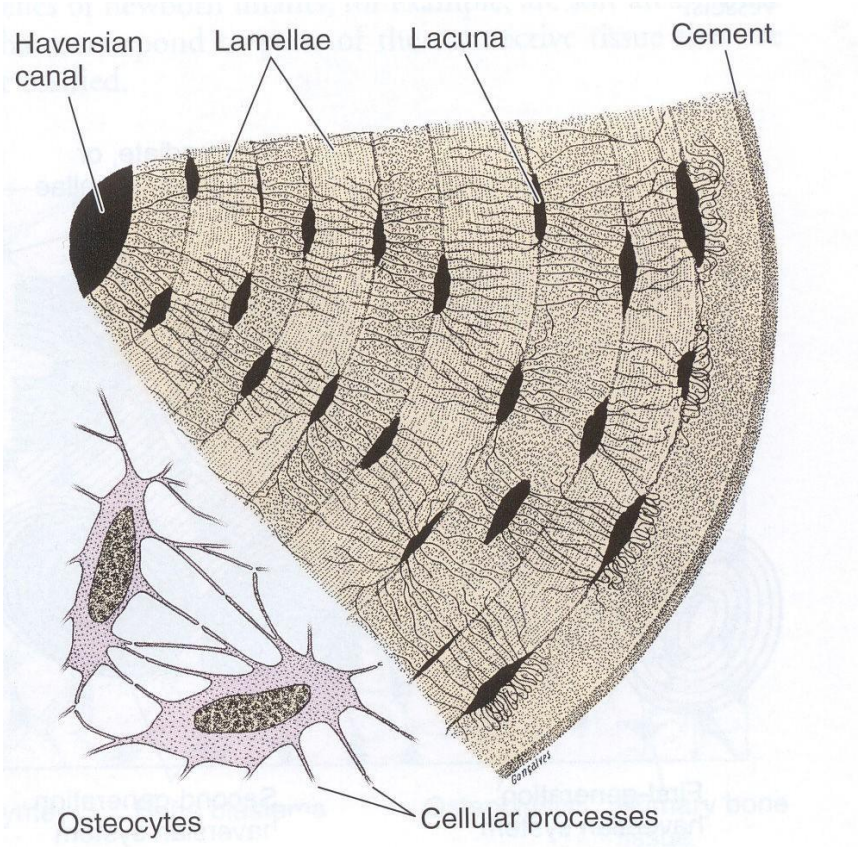
3- osteocytes

How do the osteocytes get their nutrition?

1- Small amount of extracellular fluid in the lacunae and canaliculi surrounding the cells and their processes. this fluid carries the nutrients and metabolites from nearest blood vessels to the cells.

2- Gap junctions present between the processes of the osteocytes allowing transport of ions and small molecules.

Note: Nutrition of the osteocytes can not occur by diffusion through calcified matrix.



4- Osteoclasts

The bone eating cells.

- Origin: from the blood monocyte (mononuclear phagocyte system), migrate to the bone, fuse together and differentiate into osteoclasts (motile cells).
- Sites: present within shallow depression in bone matrix called *the resorption pays* or *Howship's lacunae* *(formed by the osteoclasts activity).*
- Function: bone resorption during osteogenesis.
- L.M. Picture:

- size: Giant.
- Shape: irregular outline.
- Nucleus: multinucleated (may contain up to 50 dense nuclei).
- cytoplasm: deeply eosinophilic and vacuolated.

4- Osteoclasts

○ E.M. Picture:

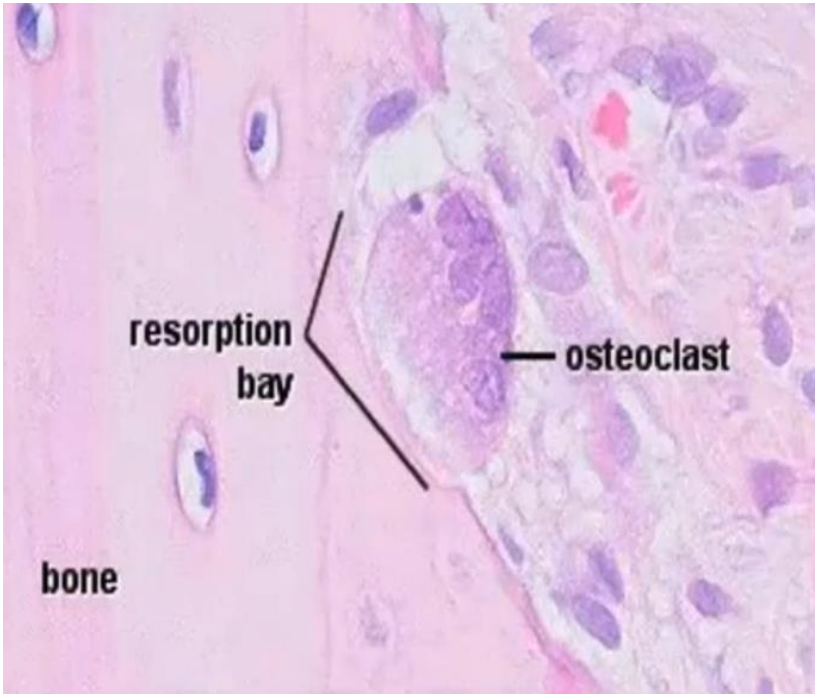
- It has two surfaces: a *smooth surface* and a *ruffled surface towards the aera of bone resorption, with many irregular projections separated by narrow clefts.*
- *cytoplasm contains:*

-*Many mitochondria*

- *well, developed Golgi apparatus.*

- *large number of lysosomes, vesicles, and vacuoles.*

Note: the cell has a polarity.



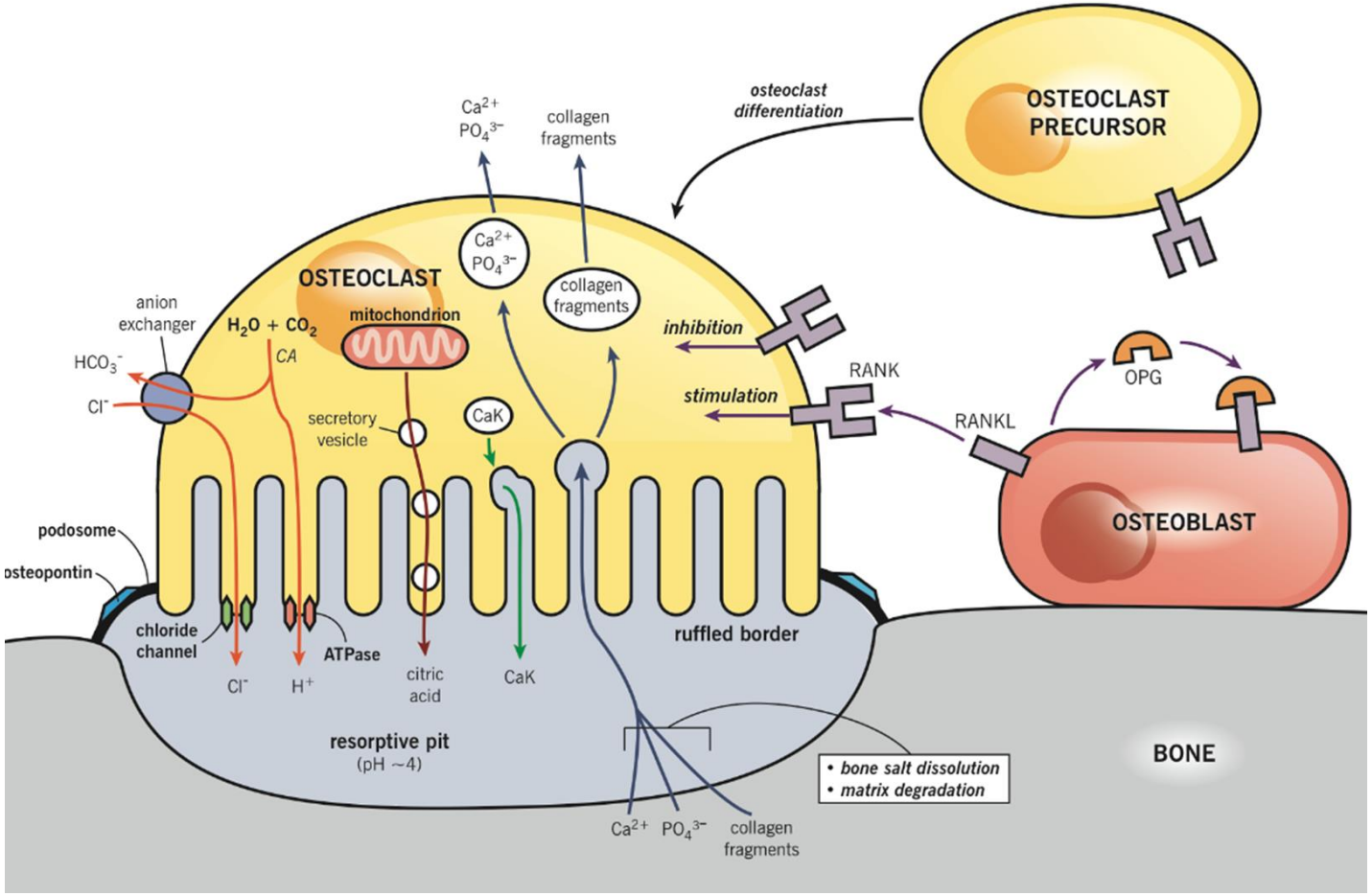
Polarity of osteoclasts

1- Ruffled border: face the resorption aera.

2- Smooth surface: away from aera of resorption.

3- Mitochondria: under ruffled border.

4- Nuclei: toward smooth surface.



Types of bone
1- primary bone or woven bone

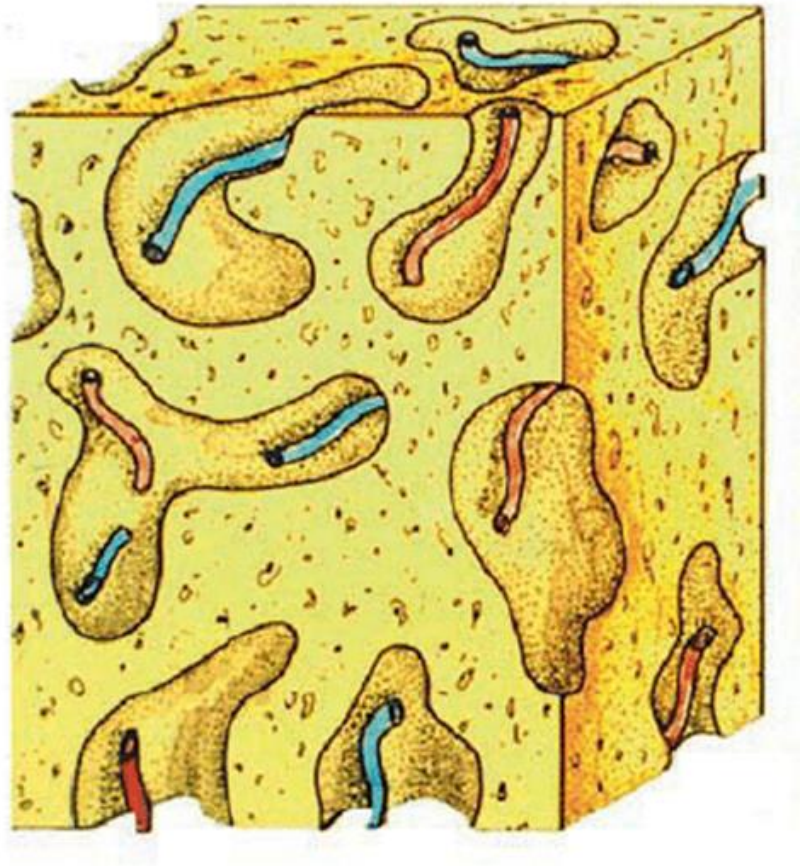
It is the first bone to be deposited during the bone development, growth, and repair.

1- It is immature weak bone due to low calcium content.

2- Irregular arrangement of collagen fibers.

3- Osteocytes are numerous and irregularly arranged.

4- Temporary and is replaced later by the secondary bone.



Types of bone
2- secondary or lamellar bone

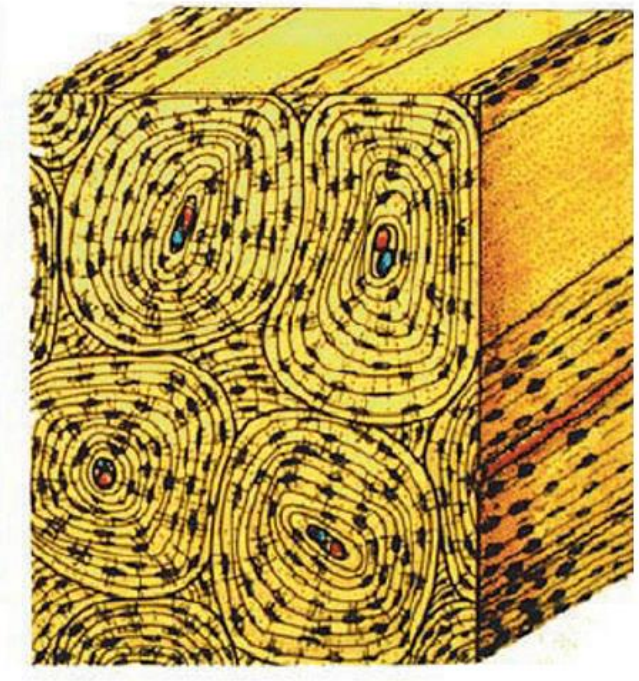
It is characterized by:

1- it is mature strong bone with high calcium content.

2- regular arrangement of collagen fiber in the form of multiple layers lamellae (the histological unit of bone) where collagen fibers in each lamella are organized parallel to each other.

3- osteocytes are less abundant, regularly aligned inside their lacunae along the lamellae.

4- it is either compact (lamellar) or cancellous (spongy) bone.



I- Compact bone

Sites:

1- the diaphysis (shaft) of long bones.

2- the outer and inner tables of flat bones.

Structure:

1- bone covering: the external surface is covered by the periosteum, while its single medullary cavity in long bone is lined by the endosteum.

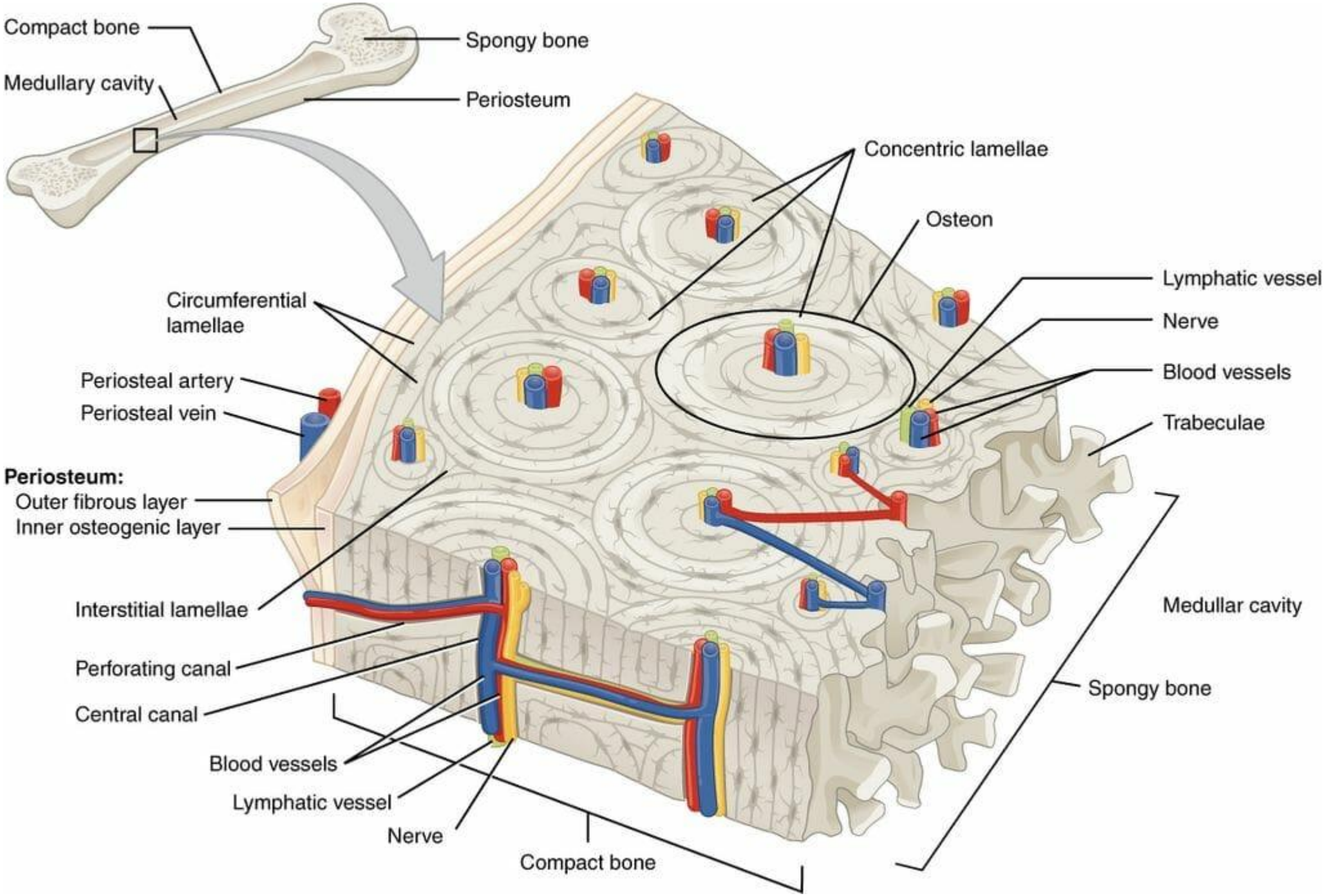
Note: at the site of attachment of the periosteum to the tendon, the collagen fibers are thickened forming the Sharpley's fibers that penetrate deep into the bone substance to be fixed to the external circumferential lamellae and interstitial lamellae.

2- the bone tissue: the bone lamellae are regularly arranged in three patterns.

- circumferential lamellae.

- Haversian system (osteons).

- interstitial lamellae.

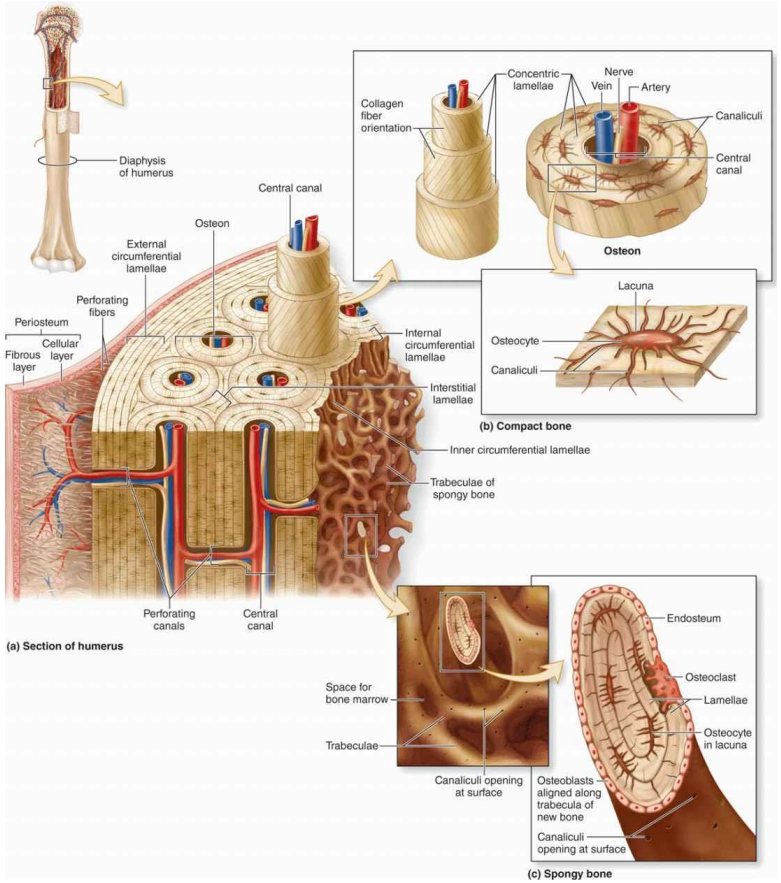

Compact bone
Spongy bone
Medullary cavity
Periosteum
Concentric lamellae
Osteon
Lymphatic vessel
Nerve
Blood vessels
Trabeculae
Circumferential lamellae
Periosteal artery
Periosteal vein
Periosteum:
Outer fibrous layer
Inner osteogenic layer
Interstitial lamellae
Perforating canal
Central canal
Blood vessels
Lymphatic vessel
Nerve
Compact bone
Medullar cavity
Spongy bone

Circumferential lamellae

there are 2-3 parallel bone lamellae that encircle the whole circumference of the bone shaft.

1- the external (outer) circumferential lamellae : lie just beneath the periosteum.

2- the inner circumferential lamellae: surrounded the central medullary cavity just beneath the endosteum.

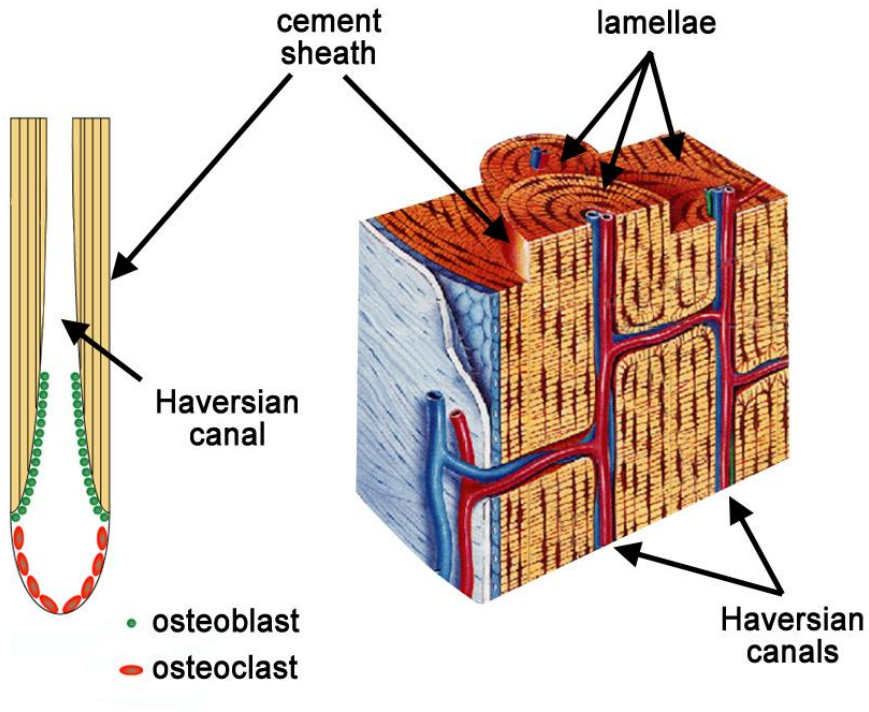


The Haversian system (osteons)

It is the characteristic structural unit in the compact bone.

Each osteon is formed of:

- ❑ *a cylinder of 4-20 concentric bone lamellae that are telescoped inside each other.*
- ❑ *the lamellae are concentrically arranged around a central Haversian canal that runs parallel to the long axis of the bone.*
- ❑ *the Haversian canal is lined by osteogenic cells and contains loose connective tissue rich with blood vessels and nerve.*



The Haversian system (osteons)

Volkmann's canals:

- *they are transverse or oblique bony canals that connect the blood vessels of Haversian canal with each other and with the blood vessels of periosteum and the endosteum.*
- *they differ from Haversian canals in:*

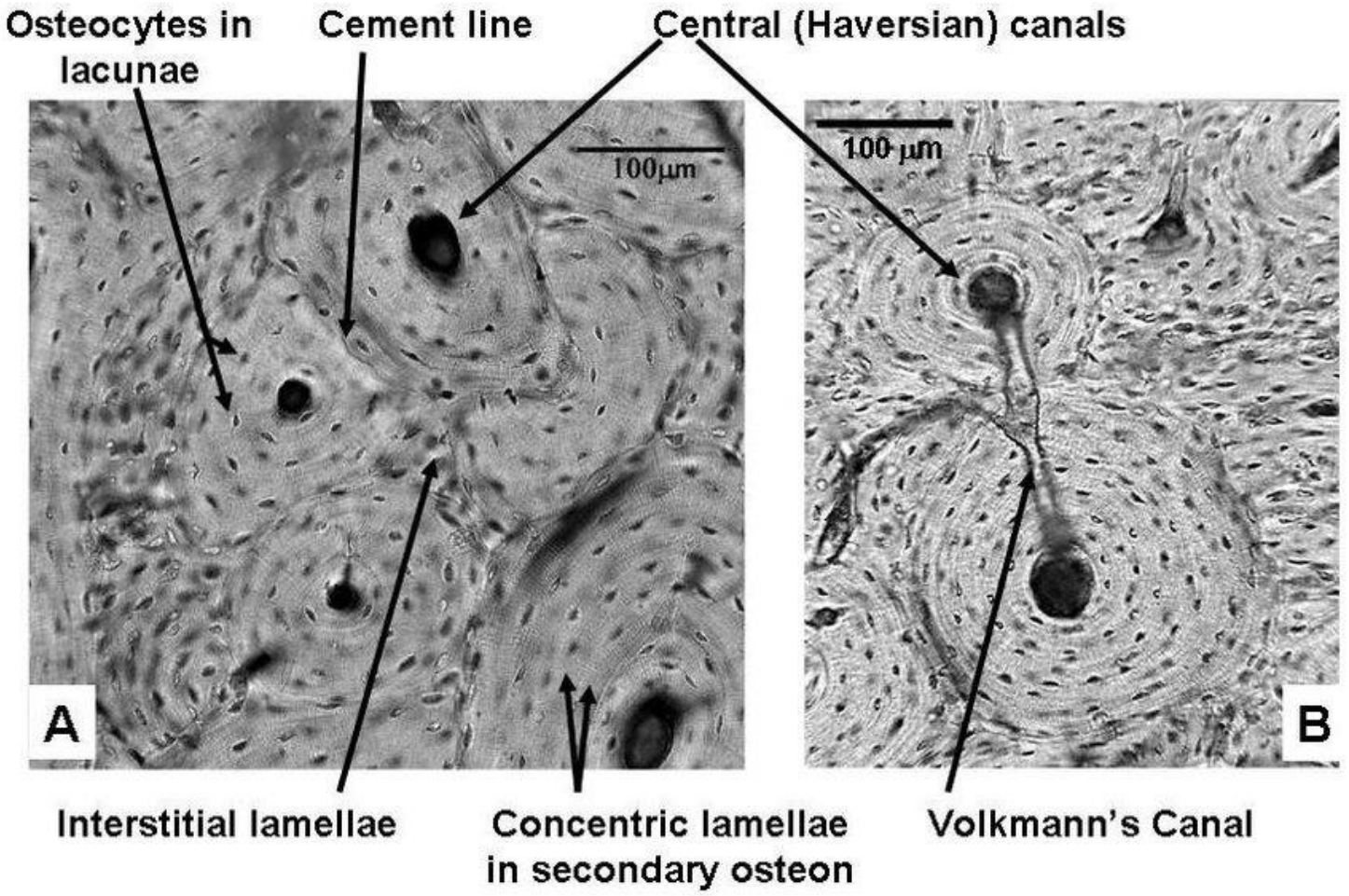
1- they are not surrounded by concentric bone lamellae; instead, they perforate the lamellae.

2- they extend in an oblique or transverse direction and not in a longitudinal direction as the Haversian canals.

- *function of Haversian and Volkmann canals: they represent the vascular channels that transport nutritive substances throughout the compact bone.*

The interstitial lamellae

- *These are irregular groups of parallel bone lamellae filling the space between the Haversian system.*
- *they represent the lamellae that are left behind from the old osteons during the process of continuous remodeling bone.*



II- Cancellous bone

❑ *Site :*

1- the epiphysis of long bone (the outer surface is covered by a thin layer of compact bone).

2- the aera between the outer and inner tables of flat bone.

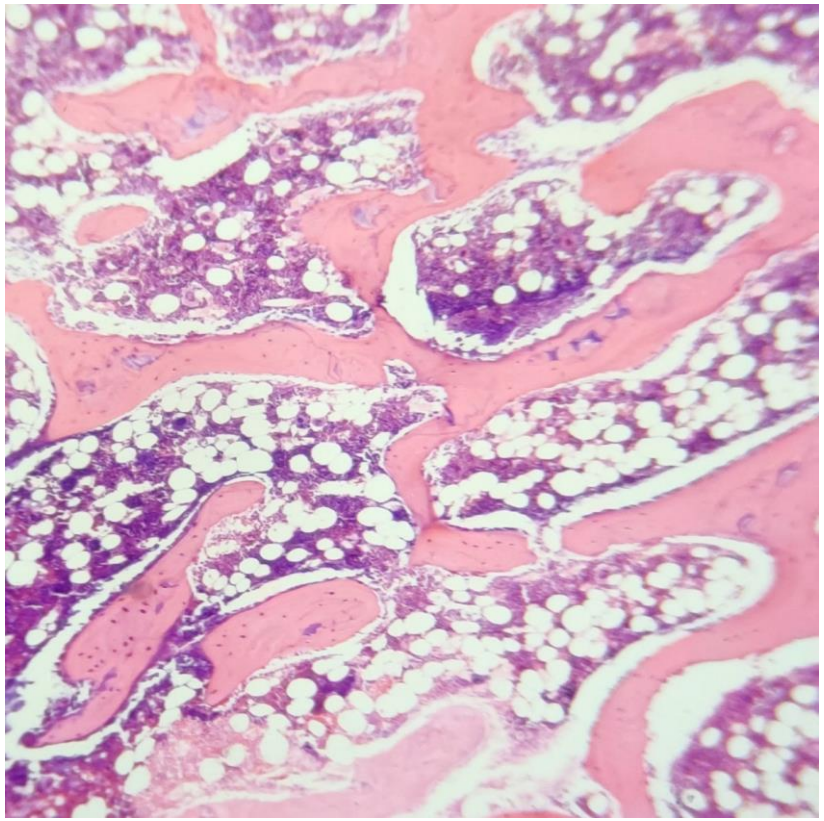
❑ *Components of cancellous bone:*

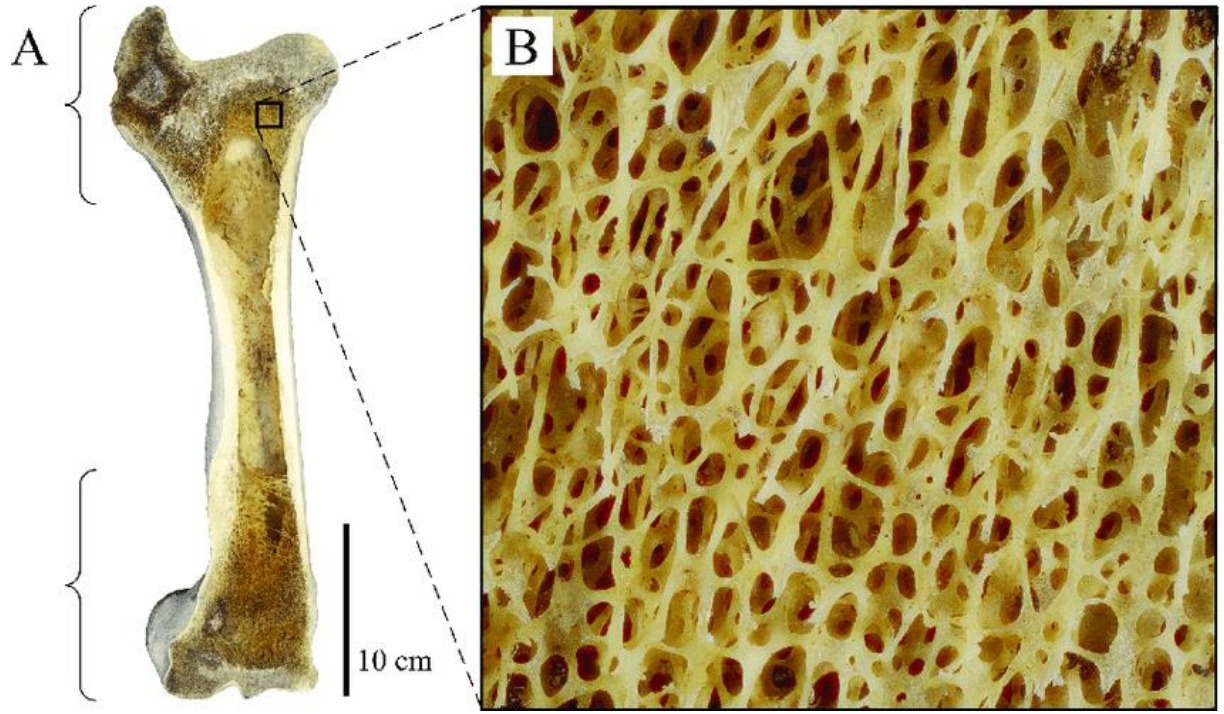
1- the bone trabeculae:

- *thin interconnected bone trabeculae.*
- *each trabecula is made up of bone trabeculae not arranged as osteons.*
- *primitive Haversian system might be present.*

2- the bone marrow cavity:

- *these are numerous cavities of separating the bone trabeculae and responsible for nourishment of the bone tissue.*
- *they are lined by endosteum.*
- *they are filled with myeloid tissue (active red bone marrow)*

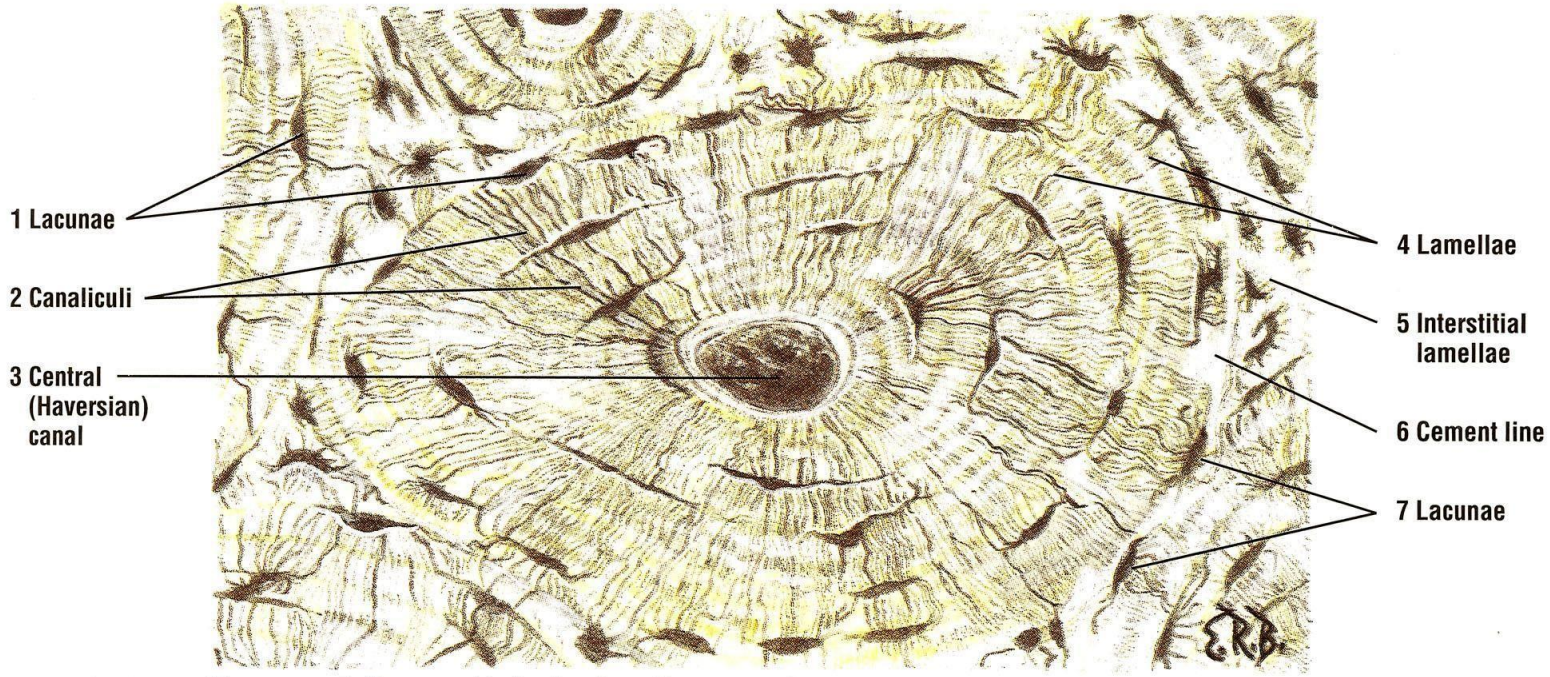



A
B
10 cm

Method of studying the bone

1- Ground compact bone:

- *bone is grinned by a special machine to produce very thin slices.*
- *these sections of compact bone are unstained.*

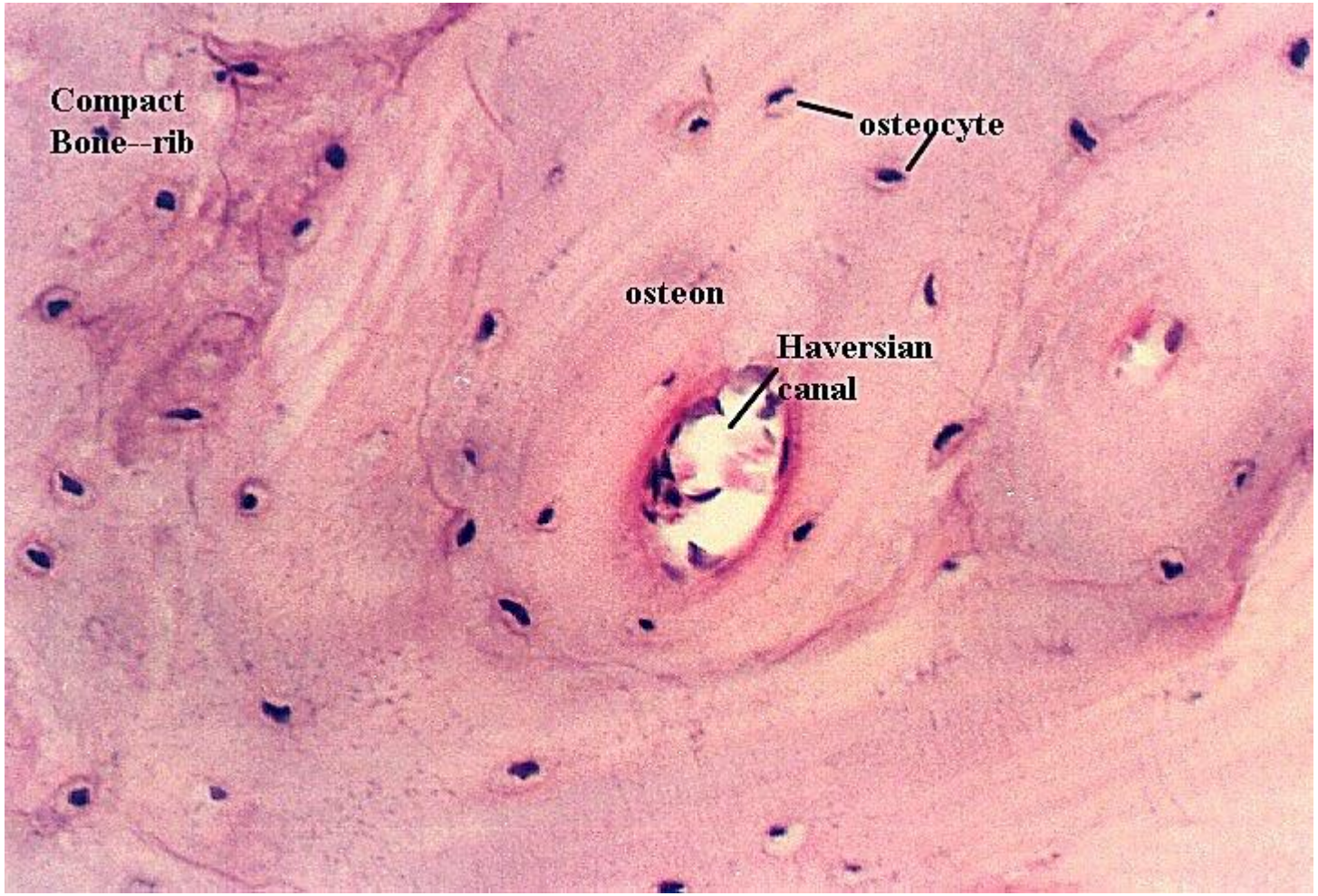


Compact Bone, Dried: An Osteon (transverse section). High magnification.

Method of studying the bone

2- decalcified bone:

- *the calcium salts are removed from bone using a strong acid solution or a chelating agents, thus the sections become soft easy to be processed and stained with H and E.*
- *this method is used to study the compact and cancellous.*



Histogenesis of bone (osteogenesis)

Notes for osteogenesis:

1- osteogenesis means vascularization.

2- for the matrix of the bone to be secreted, it needs a surface to be laid upon it.

3- this surface may by a mesenchymal tissue or a piece of cartilage.

4- the bone secreted at the beginning of ossification is immature; woven or primary bone resemble spongy bone, which will be replaced with mature secondary lamellar bone by remodeling.

5- not all ossification occurs intrauterine; in some aeras it occurs after birth (e.g. fontanelles) up to the age of puberty.

Histogenesis of bone (osteogenesis)

Bone can be formed by either of two ways:

1- Intramembranous ossification:

- *in which osteoblasts secret bone matrix within a membrane of mesenchymal tissue.*

2- endochondral ossification:

- *in which the matrix of preexisting hyaline cartilaginous model is eroded and replaced by bone matrix.*

Note: during osteogenesis of all types of bone, aeras of Woven bone, aeras of resorption, and aeras of lamellar bone usually appear side by side.

1- intramembranous ossification

❑ *It occurs during:*

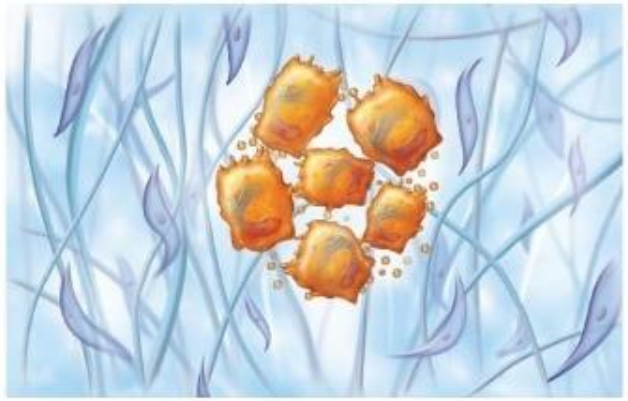
- *embryonic life: results in formation of flat bones.*
- *postnatal life: results in increase in width of long bones.*

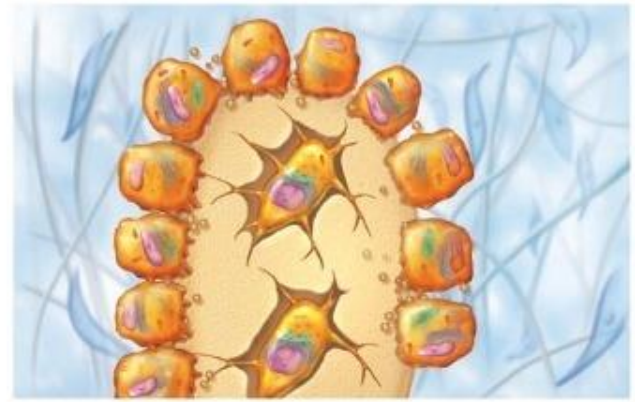
❑ *steps of intramembranous ossification:*

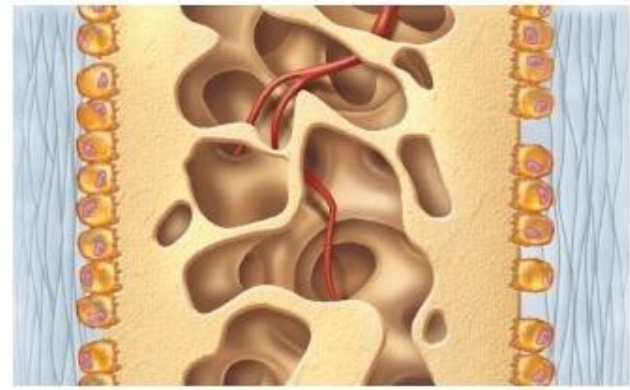
- *development of one or more ossification centers: by condensation of mesenchymal connective tissue in the aera of developing bone with increased vascularity to provide enough mineral needed for bone formation.*
- *in response to specific growth factors and enough oxygen tension: mesenchymal cells proliferative and differentiate into osteoprogenitor cells.*
- *osteoprogenitor cells proliferate and differentiate into osteoblasts secreting bone matrix, then the osteoblasts transform into osteocytes.*
- *trabeculae of developing bones are formed and fuse together giving the spongy bone with bone marrow cavities in between.*

Intramembranous Ossification

Know the steps

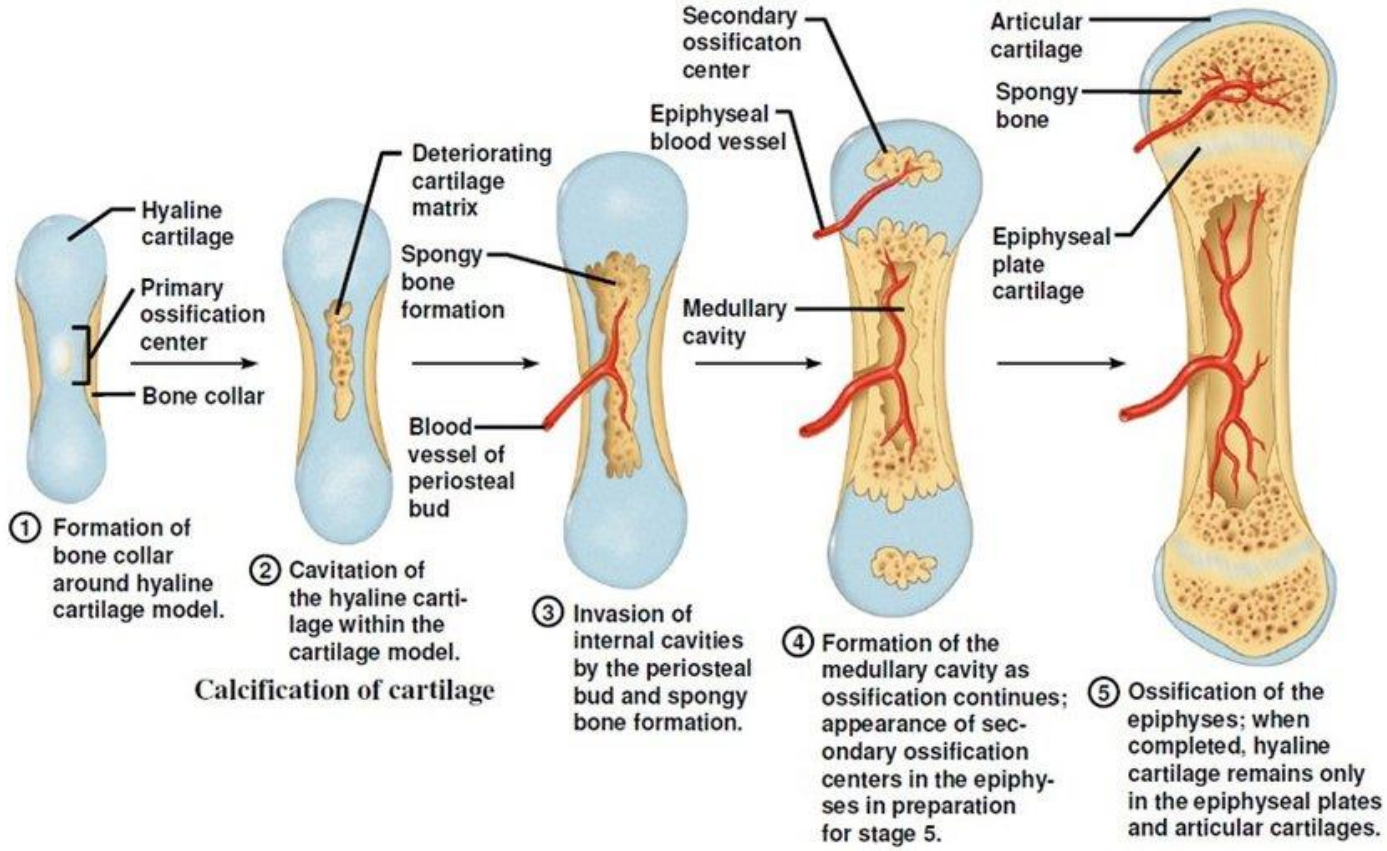






2- Endochondral ossification (intracartilaginous)

- *during embryonic life, many parts of the skeletons are laid down first as hyaline cartilage, which gradually replaced by bones results in the formation of long bones.*
- *later in the fetal and early postnatal life, these cartilaginous models become gradually replaced by bone tissue except in two places; the epiphyseal plate and the articular cartilage.*



Growth of bone

❑ *During postnatal life, bone formation occurs from:*

1- growth of the bone: which includes increase in the length, increase in the width, and bone remodeling.

2- repair of bone fractures.

1- increase in the length of long bone

It occurs in the epiphyseal plate by endochondral ossification:

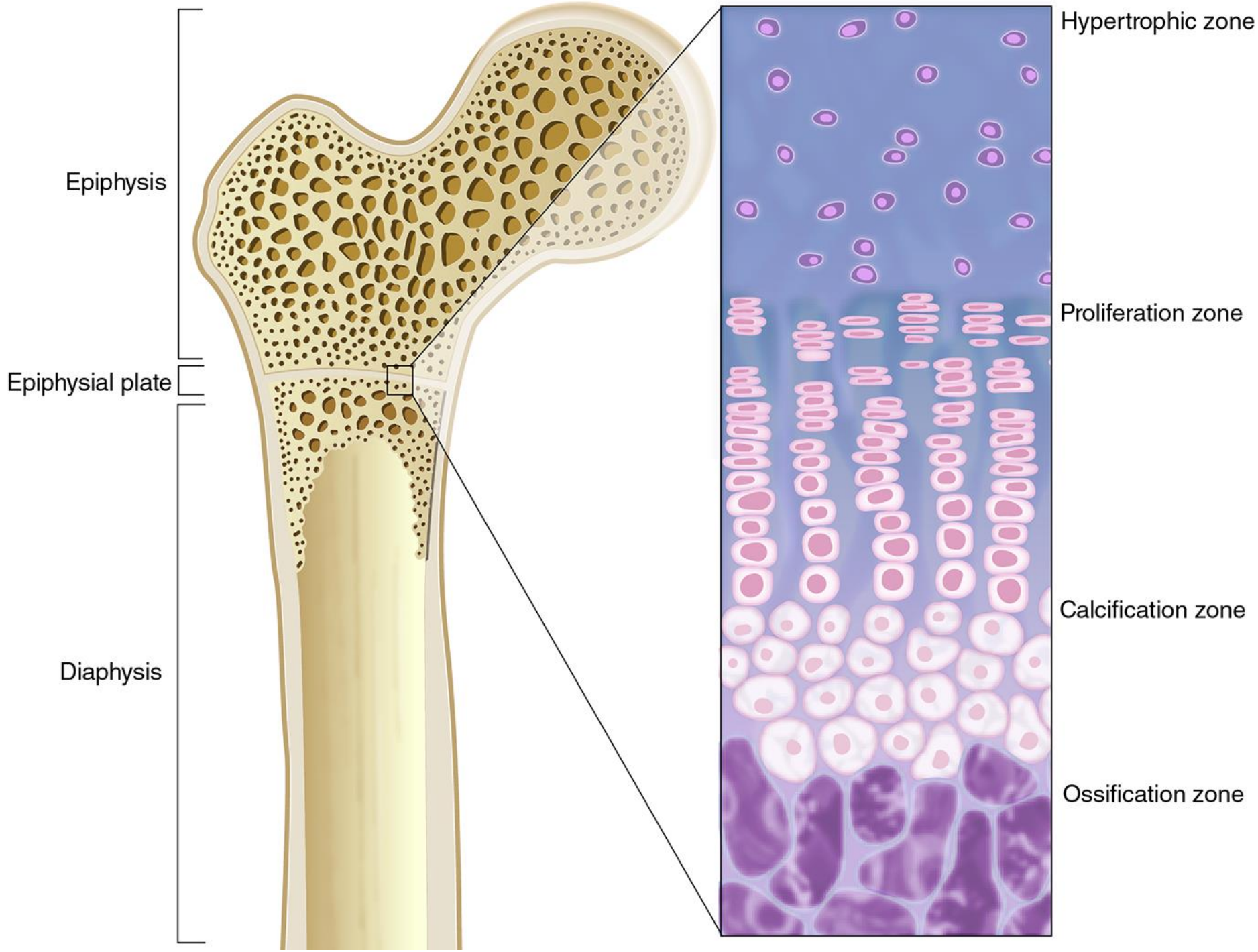
- *steps of endochondral bone formation: the following zones are seen starting from epiphyseal side of cartilage.*

1- zone of resting cartilage: chondrocytes don't show any sign of activity. It acts as a reserve.

2- zone of proliferation and arrangement: in response to growth hormone, chondrocytes proliferate by interstitial forming longitudinal rows resembling stacks of cions.

3- zone of hypertrophy: chondrocytes accumulate large amount of glycogen become enlarged and pale and the matrix is compressed into thin septa between the chondrocytes.

4- zone of calcification: the hypertrophied chondrocytes start to release alkaline phosphatase → calcification of the cartilage matrix. The insoluble calcium salts in the matrix interfere with the diffusion of sufficient nutrients to the chondrocytes → degradation and death the chondrocytes → leaving empty cavities.


Epiphysis
Epiphysial plate
Diaphysis
Hypertrophic zone
Proliferation zone
Calcification zone
Ossification zone

1- increase in the length of long bone

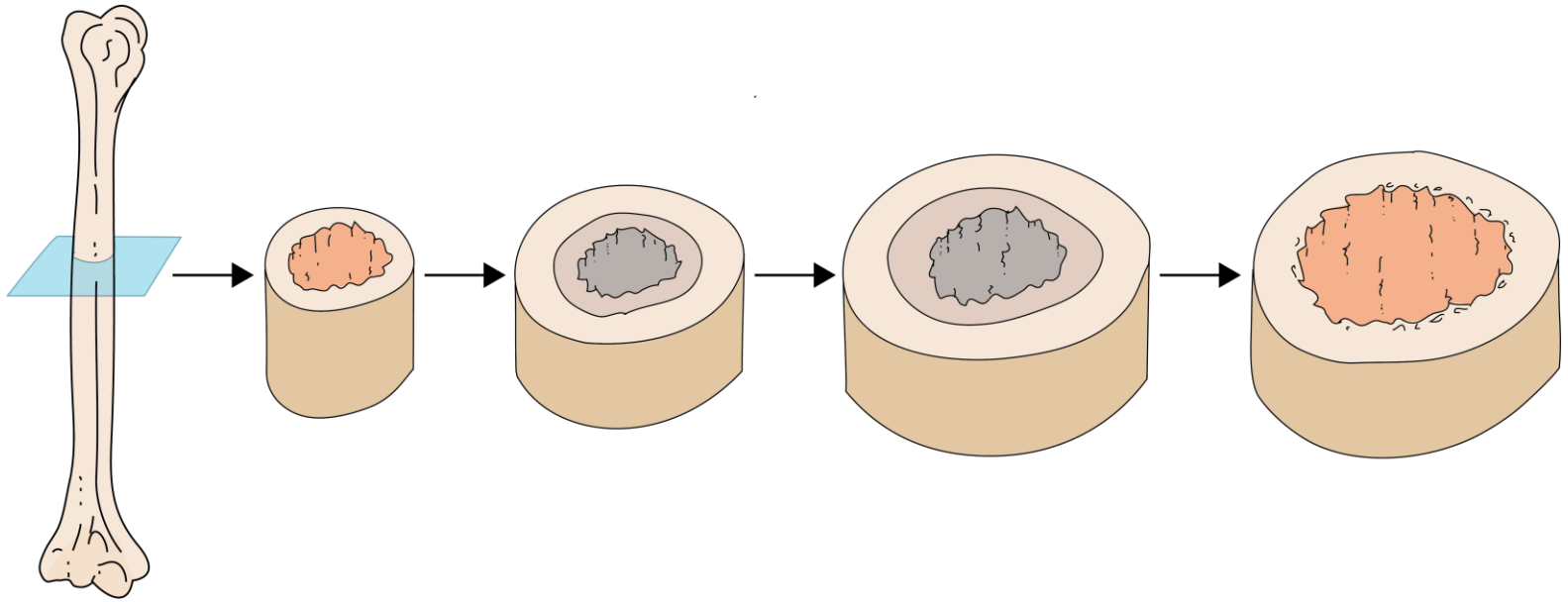
- *Because the rate of the proliferation and destruction are nearly equal, the thickness of the epiphyseal plate dose not change. Instead, it is displaced away from the middle of diaphysis, resulting in growth in the length of the bone.*
- *Growth of long bones stops at adulthood when the epiphyseal plates are eliminated (closure of the epiphysis). Once the epiphysis is closed, increase in the length of bone becomes impossible.*
- *different bones have different time of closure of their epiphysis.*

II- Increase in the width of long bone

- *It occurs by two parallel mechanisms.*

1- Subperiosteal bone formation: by osteoblasts from outside, it occurs by oppositional intramembranous ossification.

2- Bone resorption by osteoclasts: at the endosteum from inside, to enlarge the narrow cavity.



Bone remodeling

- *It is a continuous process that occurs throughout life.*
- *It involves bone resorption and bone formation.*
- *During childhood: bone formation exceeds bone resorption.*
- *In adults: bone formation is balanced by bone resorption.*

Bone remodeling

❑ *Bone remodeling is important for the following:*

- *replacement of immature bone woven by mature lamellar bone.*
- *renewal of bone; resorption of old osteons and formation of new one.*
- *maintenance of plasm calcium homeostasis.*
- *maintenance of bone shape to adapt mechanical stresses (weight & posture).*
- *repair of fraction.*

Repair of bone fracture

❑ *Bone has an excellent capacity for repair because:*

1- it contains osteoprogenitor cells in the periosteum and endosteum.

2- it has an excellent blood supply.

Phases of fracture healing

1- clotting formation:

- *when bone is fractured → the blood vessels are disrupted → hemorrhage and bone cells adjoining the fracture site die.*
- *a blood clot is formed to stop the hemorrhage.*

Phases of fracture healing

2- soft callus formation:

- *the blood clot is removed by macrophages and adjacent bone matrix is resorbed by osteoclasts.*
- *the periosteum and endosteum at the site of fracture show enhanced activity of their osteoprogenitors cells, which under this conditions of low oxygen tension, form a soft callus of fibro-cartilage like tissue that surrounds the fracture and penetrates between its ends.*

Phases of fracture healing

3- Callus ossification (hard callus):

- *primary bone formation is initiated by:*

1- intramembranous ossification: through the osteoprogenitor cells in the periosteum.

2- intracartilaginous ossification.

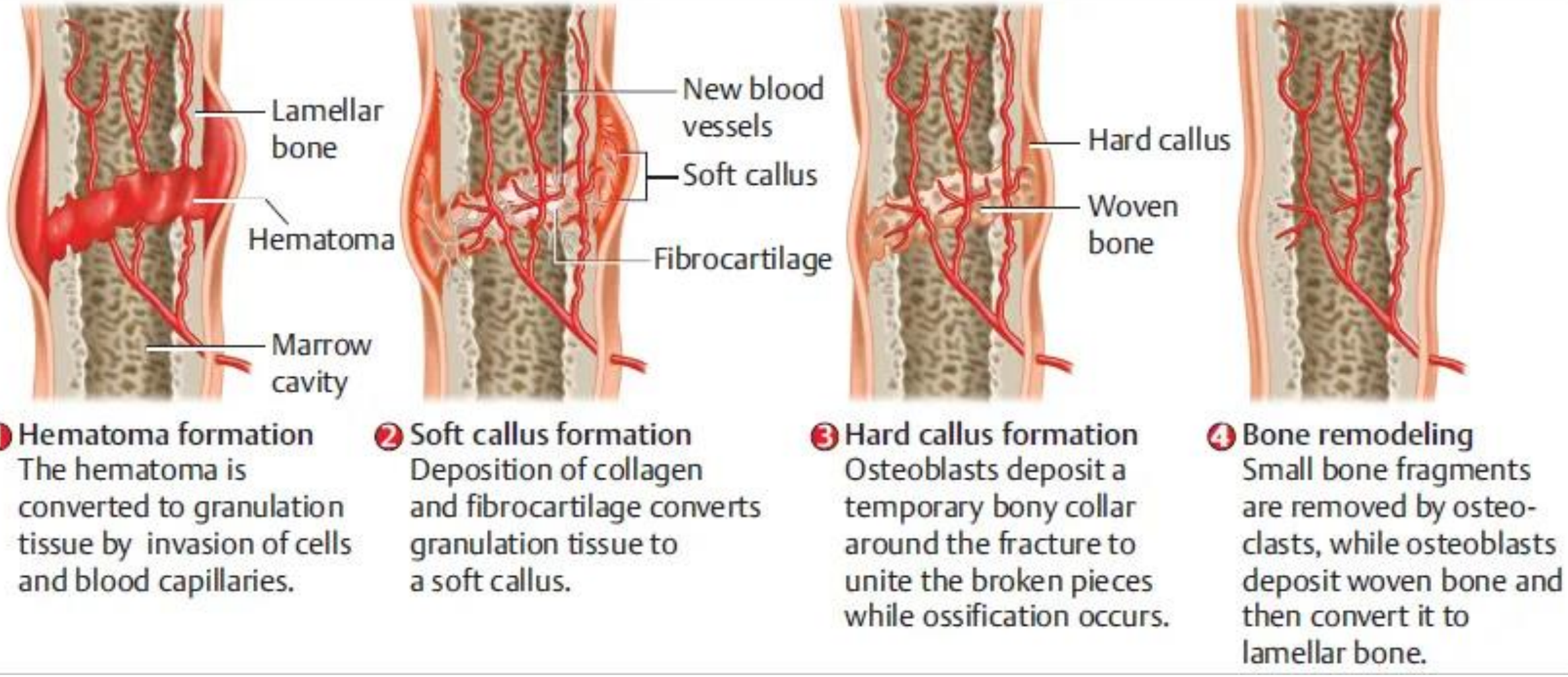
- *thus, histological examination of a repairing fractured bone reveals areas of cartilage together with areas of intramembranous and endochondral ossification.*

- *as repair proceeds, a hard bone callus is formed. It is made of irregular bone trabeculae of primary bone that unite the extremities of the fractured bone.*

Phases of fracture healing

4- Bone remodeling:

- *the primary bone of the callus is gradually resorbed and replaced by secondary bone.*
- *further remodeling restores the original bone structure and contour.*



1 Hematoma formation
The hematoma is converted to granulation tissue by invasion of cells and blood capillaries.

2 Soft callus formation
Deposition of collagen and fibrocartilage converts granulation tissue to a soft callus.

3 Hard callus formation
Osteoblasts deposit a temporary bony collar around the fracture to unite the broken pieces while ossification occurs.

4 Bone remodeling
Small bone fragments are removed by osteoclasts, while osteoblasts deposit woven bone and then convert it to lamellar bone.

Thank You!