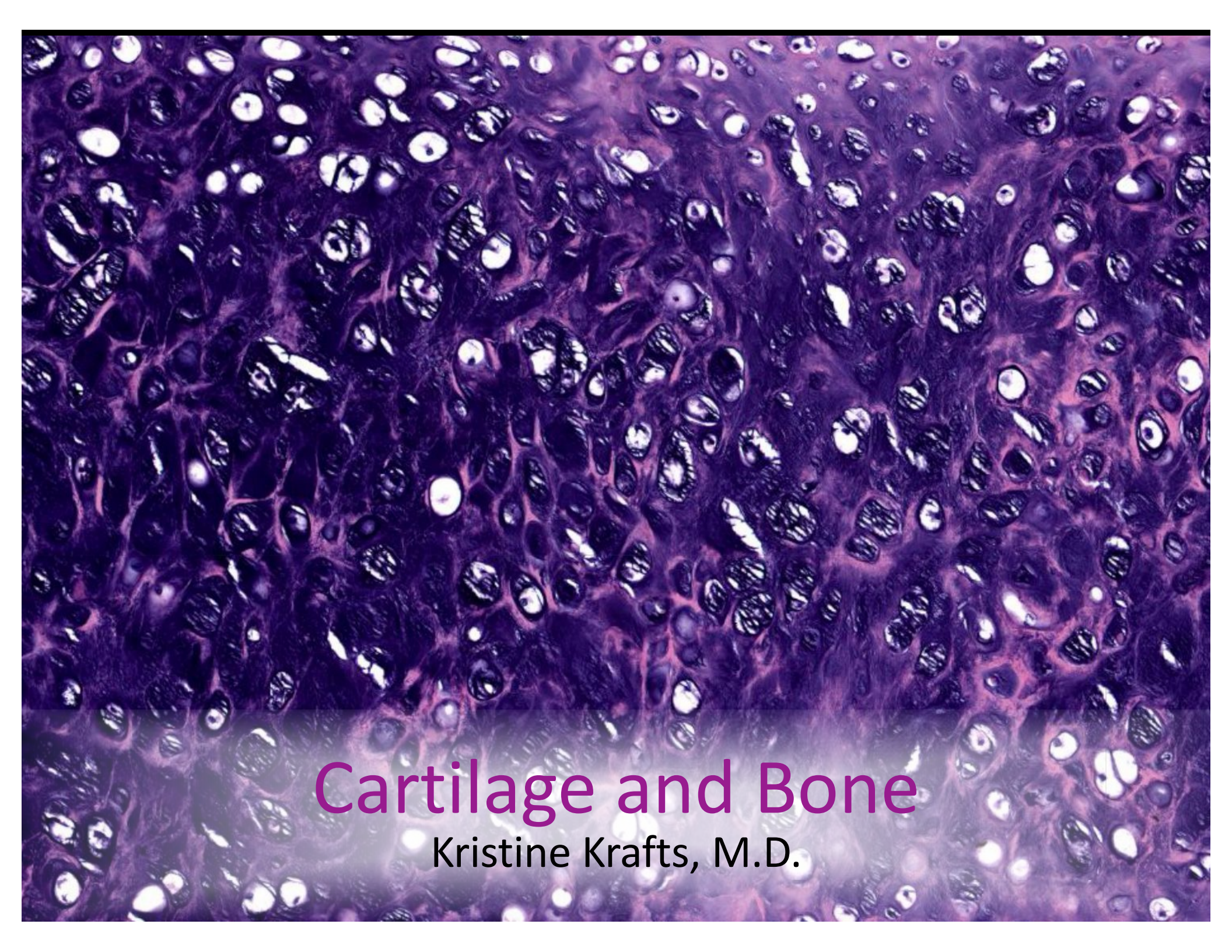


A high-magnification histological image of cartilage tissue, likely stained with hematoxylin and eosin (H&E). The image shows numerous chondrocytes, which are cells responsible for the production and maintenance of the extracellular matrix. These cells are embedded within a dense, dark purple-stained matrix. The chondrocytes themselves are small, round, and have a prominent, dark nucleus. The overall appearance is a dense, cellular network with a granular texture.

Cartilage and Bone

Kristine Krafts, M.D.

Cartilage and Bone Lecture Objectives

- Describe the general functions of cartilage and bone.
- Compare the function and composition of the three types of cartilage.
- Describe the two methods of cartilage formation.
- Describe the cells and extracellular matrix of bone.
- Compare and contrast immature and mature bone.
- Describe the two methods of bone formation.

Cartilage and Bone Lecture Outline

Cartilage

- Function and characteristics of cartilage
- Composition of cartilage
- Three types of cartilage
- Formation of cartilage

Bone

- Function and characteristics of bone
- Composition of bone
- Two (okay, four) types of bone
- Formation of bone

Cartilage and Bone Lecture Outline

Cartilage

- Function and characteristics of cartilage

Functions and Characteristics of Cartilage

- Cartilage is strong and sort of rigid but also flexible. It can withstand force, but it can also bend.
- It's made of cells (chondroblasts and chondrocytes) and extracellular matrix.
- Forms the supporting framework of some organs.
- Lines the surface of articulating bones.
- Forms the template for growth and development of long bones.

Cartilage and Bone Lecture Outline

Cartilage

- Function and characteristics of cartilage
- Composition of cartilage

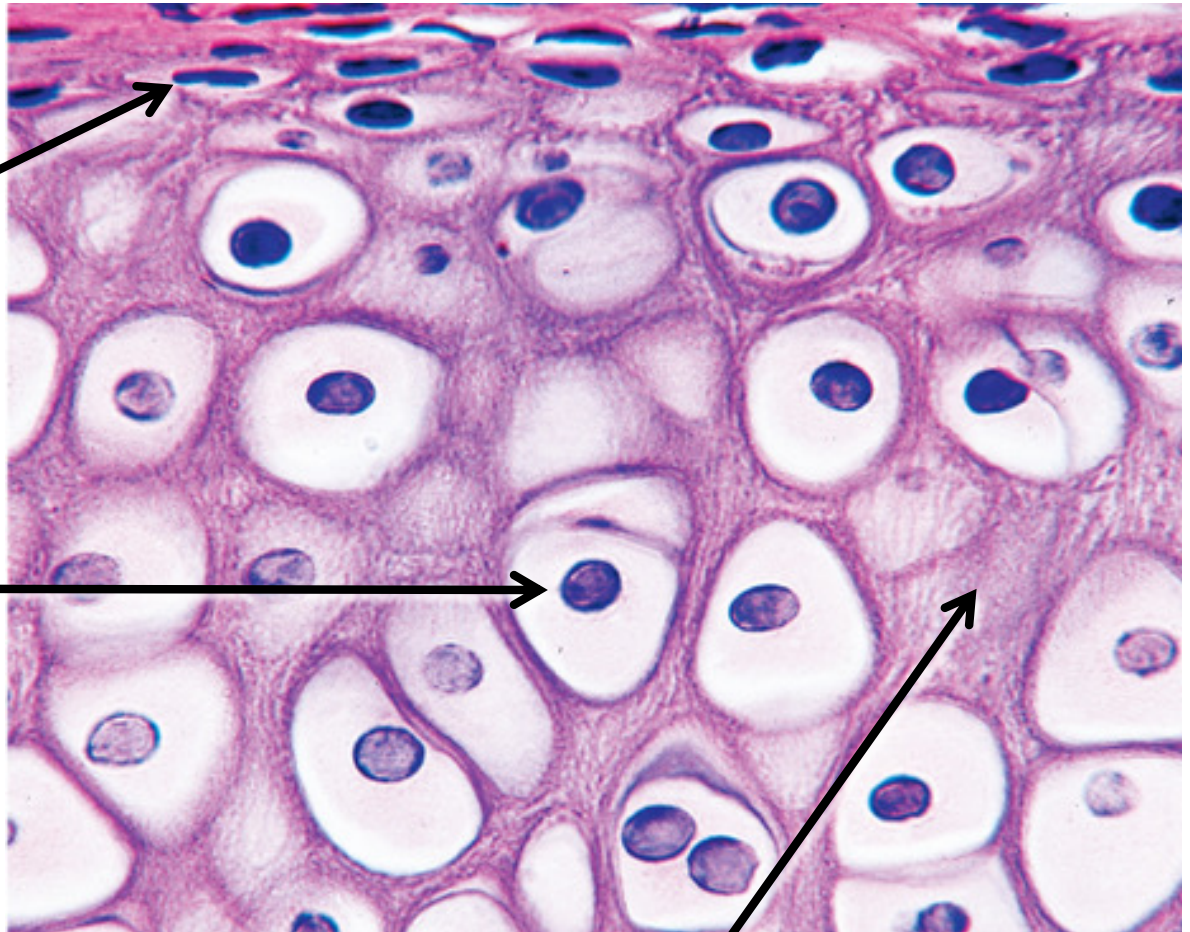
Cartilage Composition

Chondroblasts

Precursor cells that differentiate into chondrocytes.

Chondrocytes

Mature cartilage cells that lie in little artifactual lacunae.



Extracellular matrix:

- Collagen and/or elastic fibers
- Lots of GAGs and proteoglycans

Cartilage is avascular. So what?

- Cartilage itself has no blood vessels or nerves in its extracellular matrix (bone is a different story).
- Nutrients must diffuse from perichondrium through extracellular matrix to chondrocytes.
- This means metabolic activity is low, the width of cartilage is limited, and cartilage heals poorly.

Cartilage and Bone Lecture Outline

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The fibers of the extracellular matrix determine the type of cartilage.

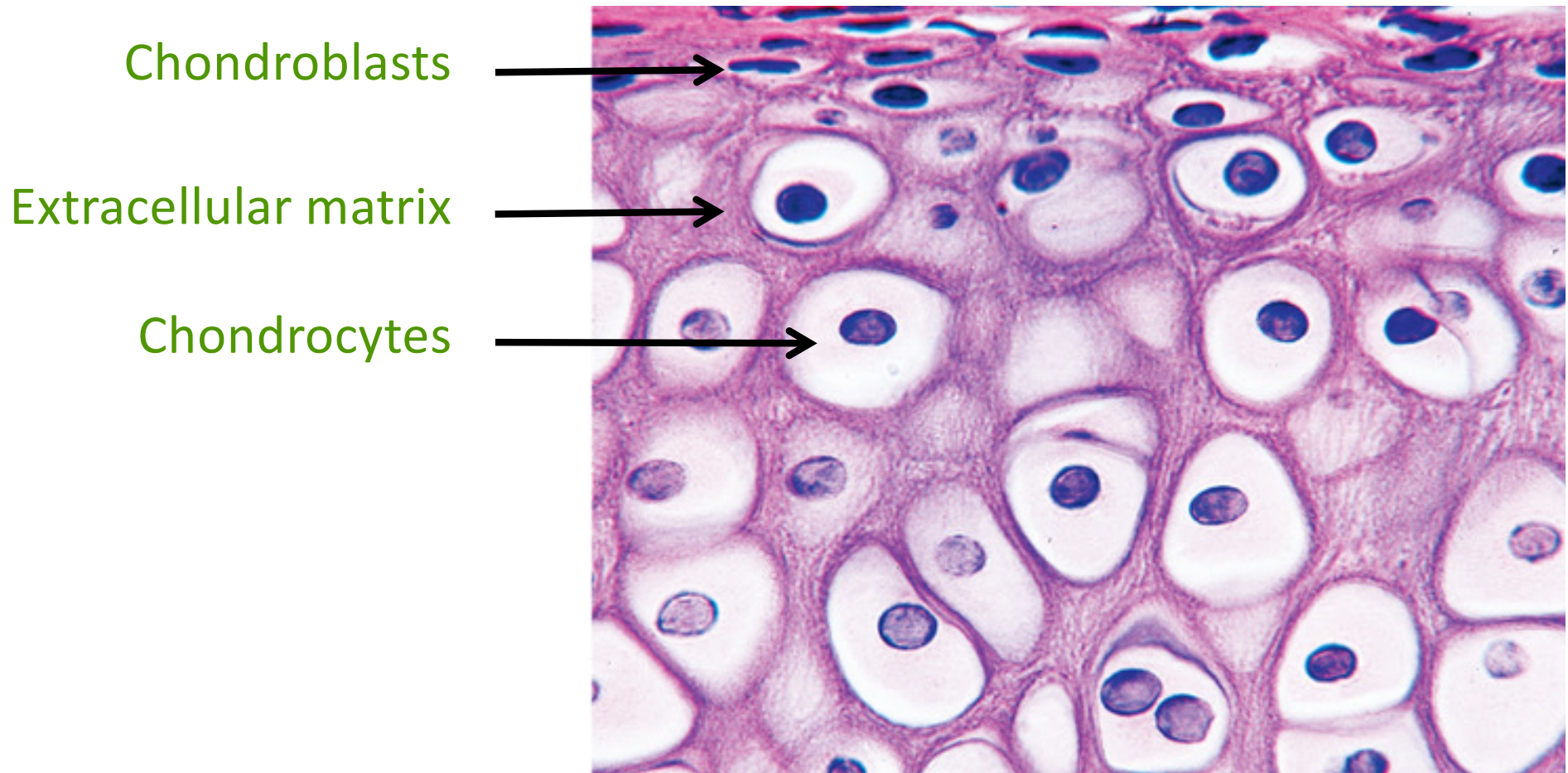
Hyaline cartilage	Type II collagen fibers
Elastic cartilage	Type II collagen fibers and elastic fibers
Fibrocartilage	Type I collagen fibers

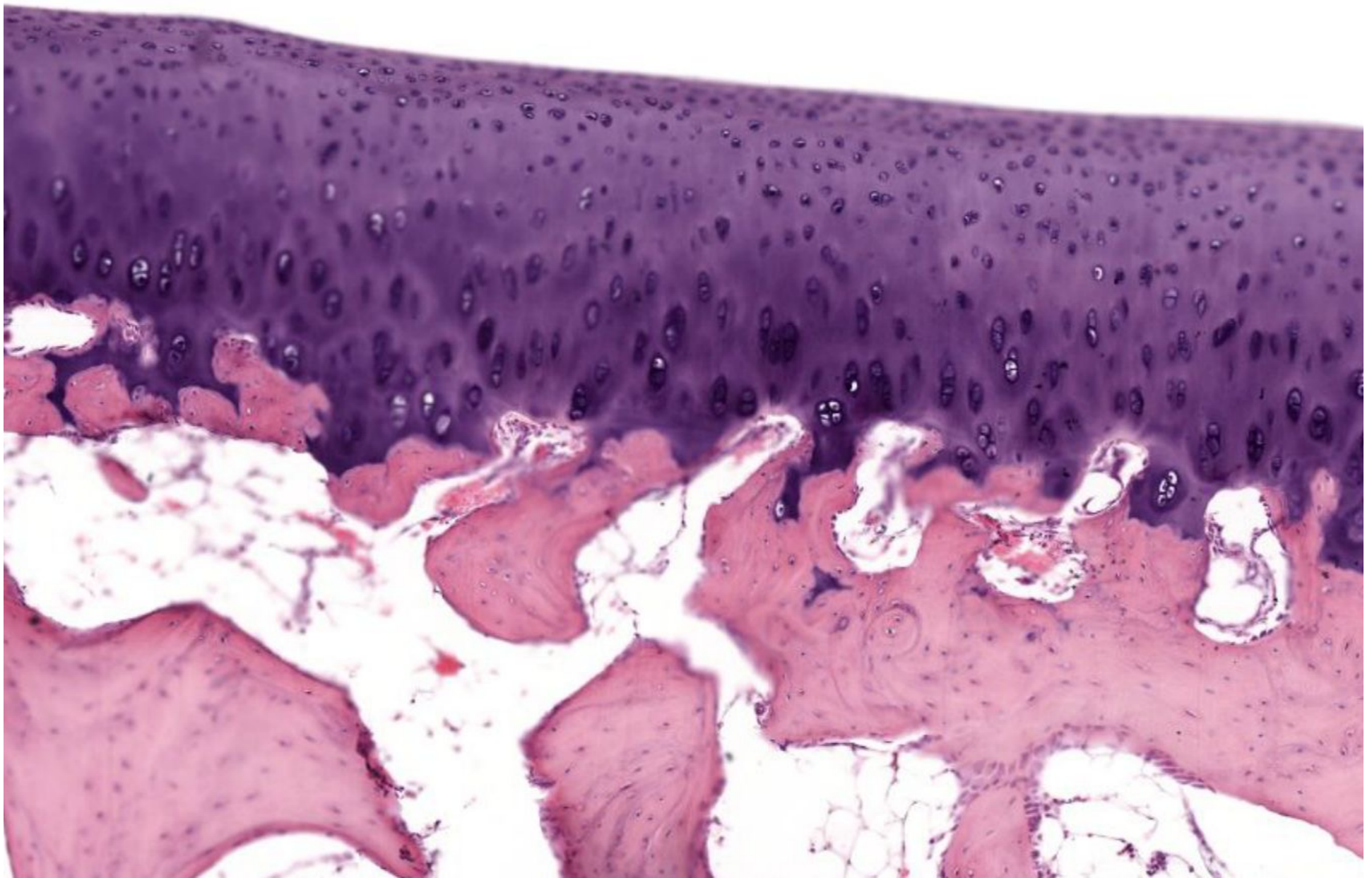
Three Types of Cartilage

Hyaline cartilage

- Most common.
- Articular surfaces of joints, large respiratory passages, and epiphyseal plate.
- Functions: support soft tissue, line joints, aid in growth of long bones.

Hyaline Cartilage: Histologic Features





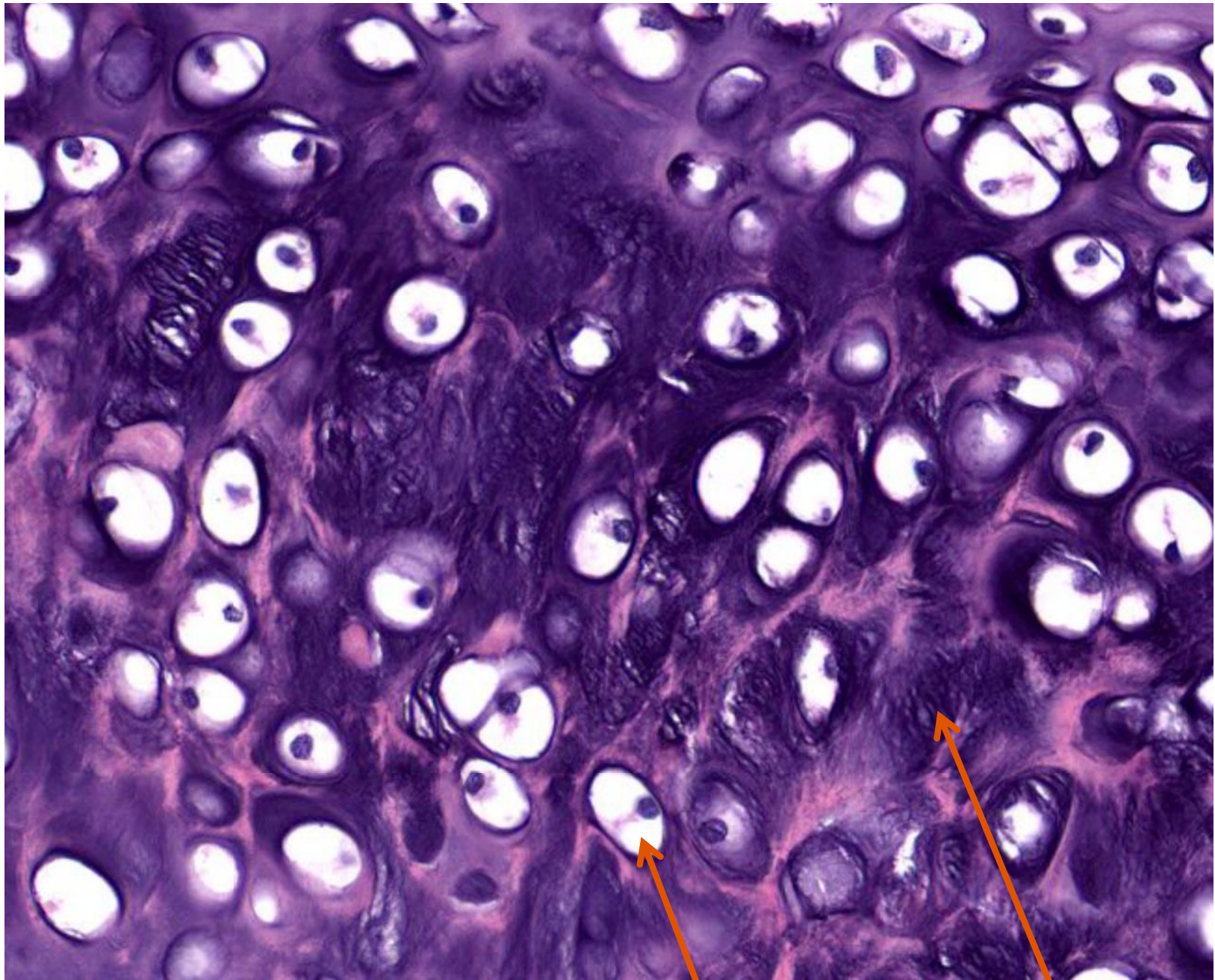
Hyaline articular cartilage

Three Types of Cartilage

Hyaline cartilage

Elastic cartilage

- Located in areas that are pliable and flexible
- External ear, eustachian tube, epiglottis



Elastic cartilage: chondrocytes and matrix

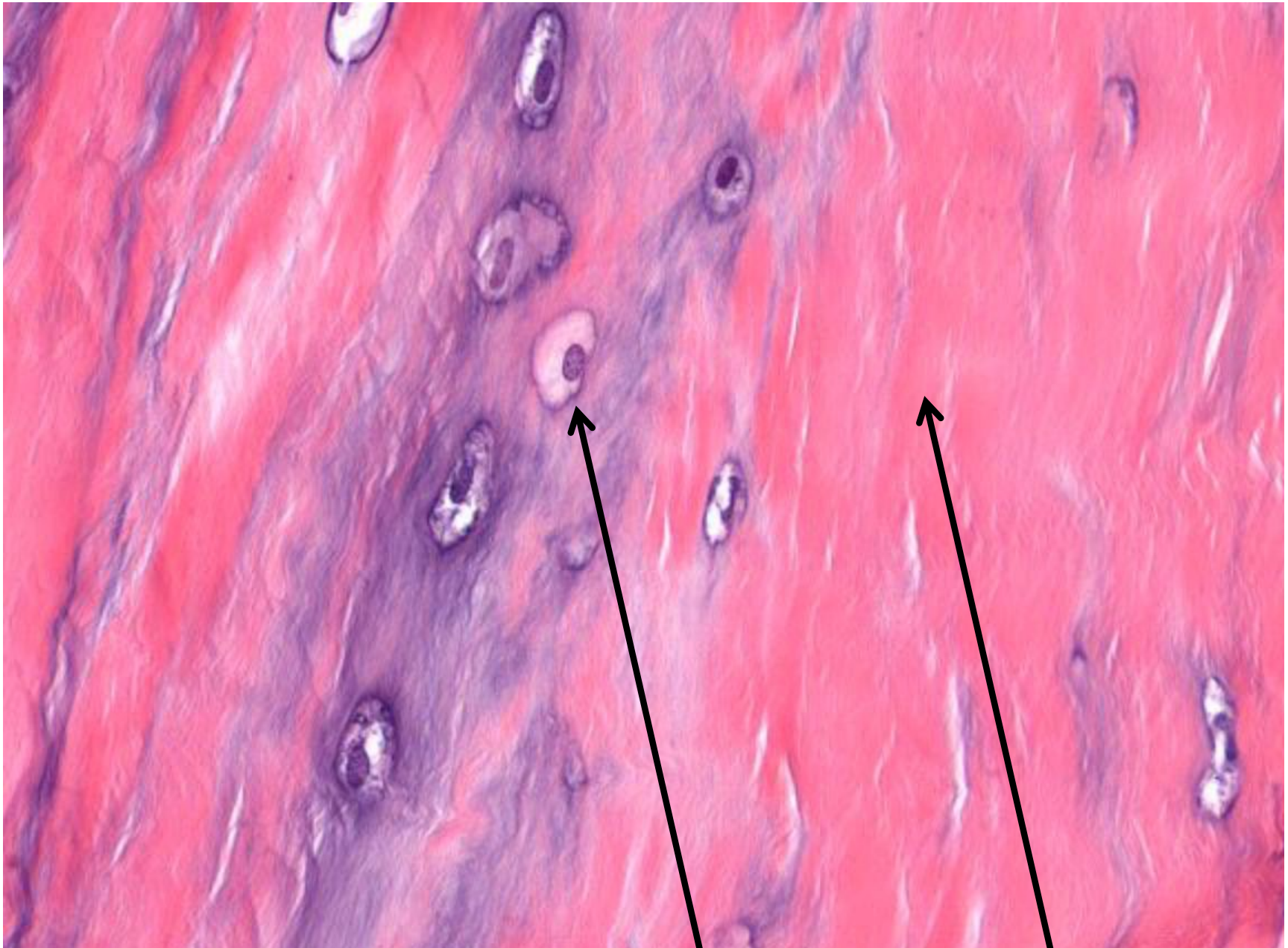
Three Types of Cartilage

Hyaline cartilage

Elastic cartilage

Fibrocartilage

- Located in areas subjected to pulling forces
- Intervertebral discs, pubic symphysis



Fibrocartilage: chondrocytes and matrix

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Two Methods of Cartilage Formation

Interstitial growth

Growth from within cartilage.

Chondrocytes divide and secrete matrix.

Appositional growth

Growth along the outside of cartilage.

Chondroblasts secrete matrix and differentiate into chondrocytes.

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Bone

- Function and characteristics of bone

Functions of Bone

- Supports and protects soft tissues
- Attaches to muscles for movement
- In some places, it houses bone marrow (where blood cells are produced)
- Stores and releases calcium, phosphate and other ions

Characteristics of Bone

- Bone is highly vascularized and very metabolically active.
- Bone remodels (turns over) constantly throughout life. Ideally, bone removal occurs at same rate as bone production.
- Inhibition of bone turnover leads to poor quality, unhealthy bone.

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Composition of Bone

Cells

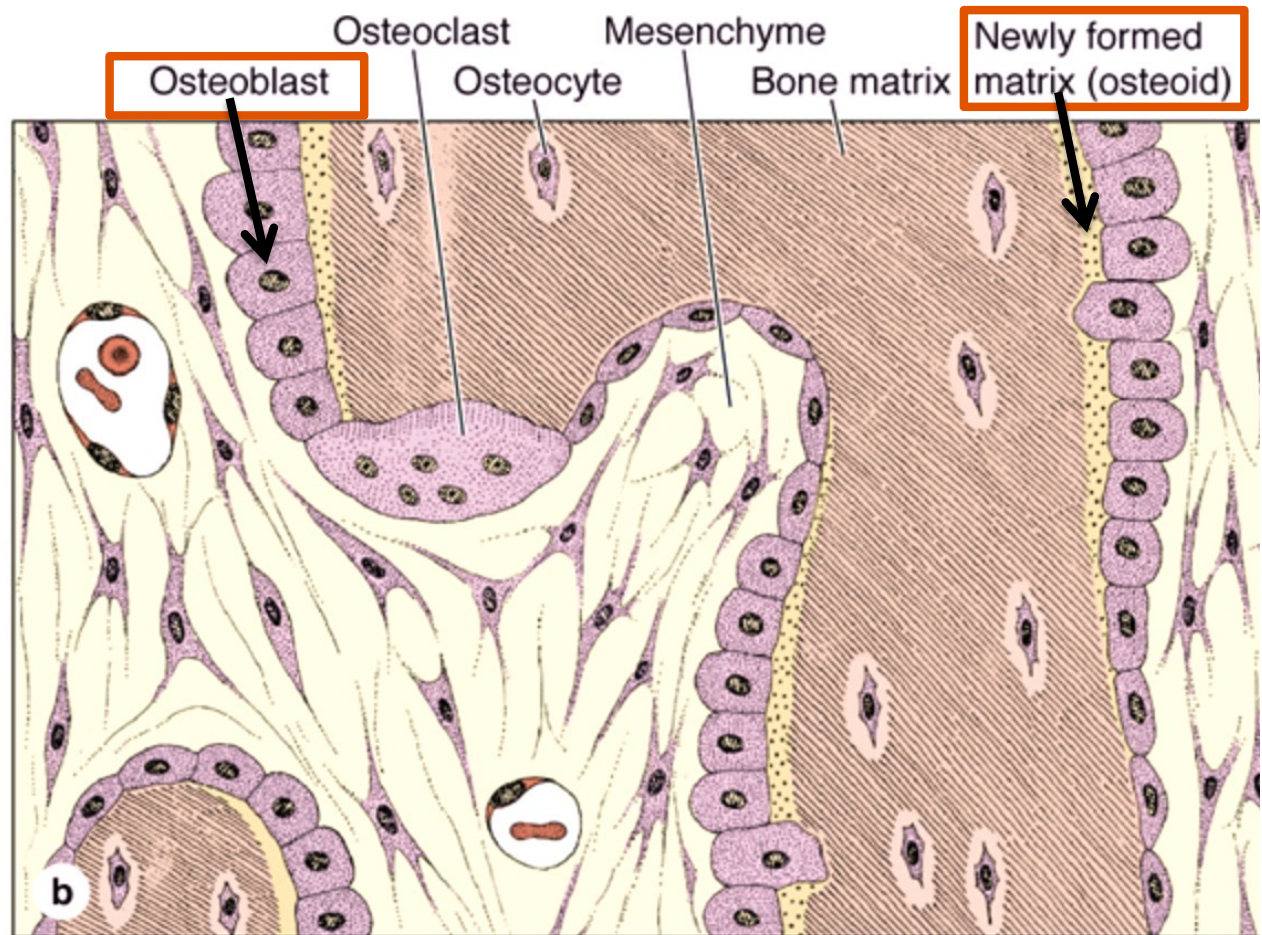
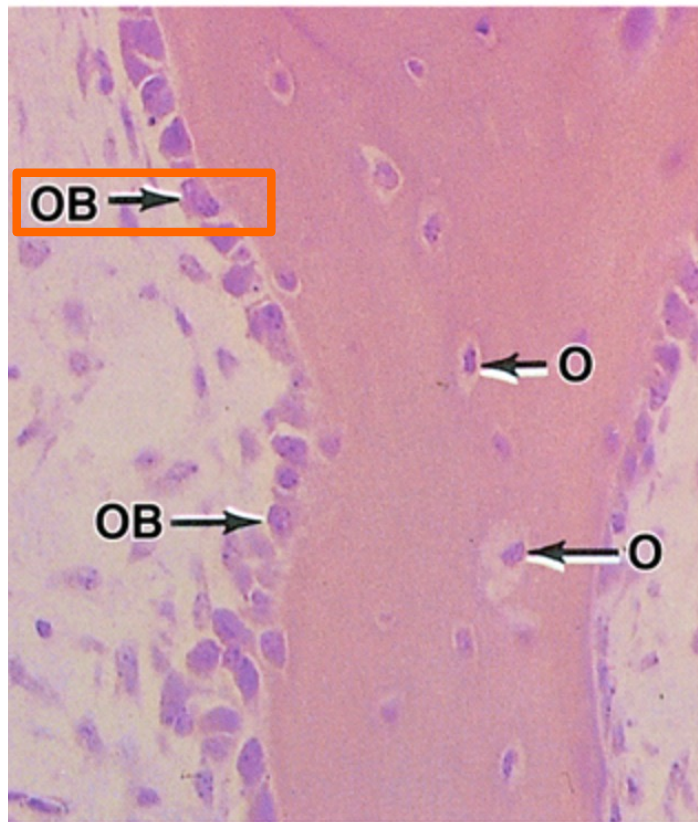
- Osteoblasts: produce bone matrix
- Osteocytes: lie in lacunae
- Osteoclasts: resorb bone

Extracellular matrix

- Two parts: organic part and inorganic part.
- Organic part (“osteoid”) consists of type I collagen fibers and ground substance
- Inorganic part consists of hydroxyapatite crystals: $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$

Osteoblasts

- Found along edge of bone, with osteoid underneath.
- Active osteoblasts are cuboidal-columnar; inactive osteoblasts are more flattened.

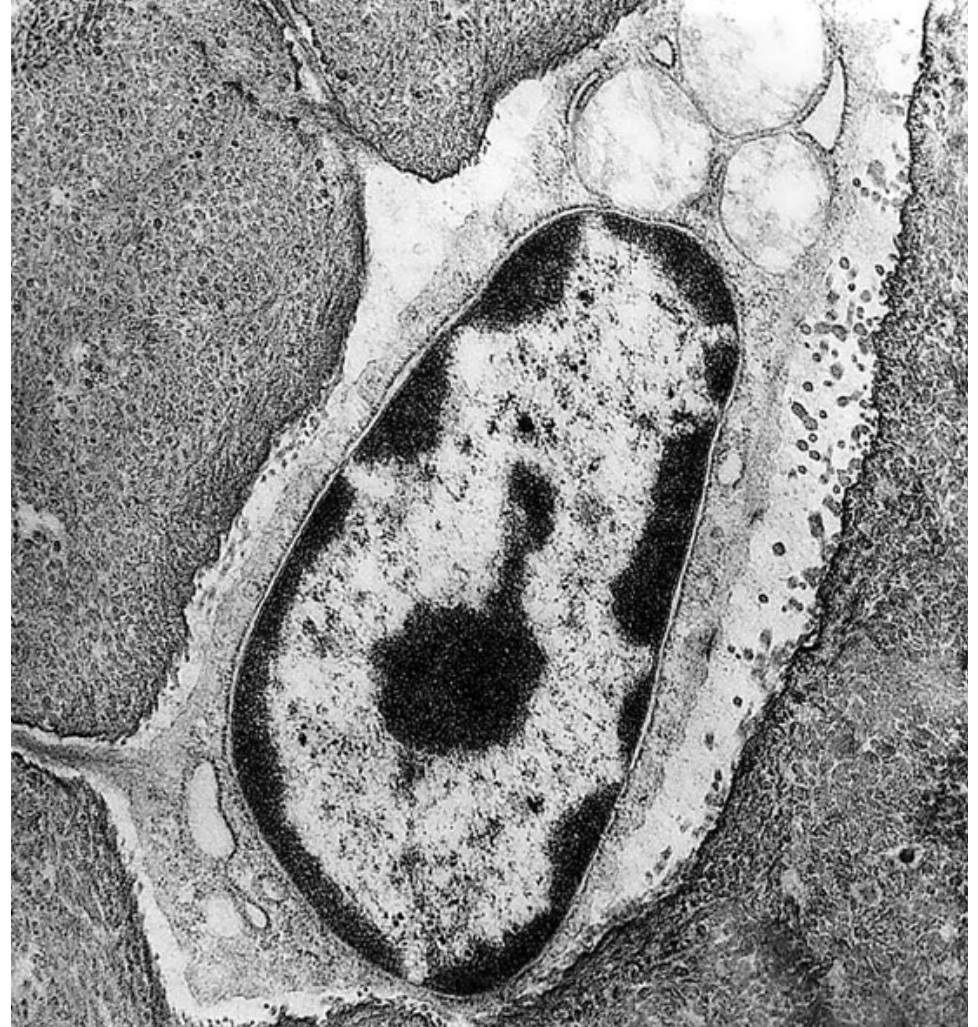


Osteoblast Functions

- Make bone!
- Produce organic part of matrix, then deposit inorganic part.
- Bone formation promoted by testosterone, estrogen, growth hormone, weight-bearing exercise and muscle use.

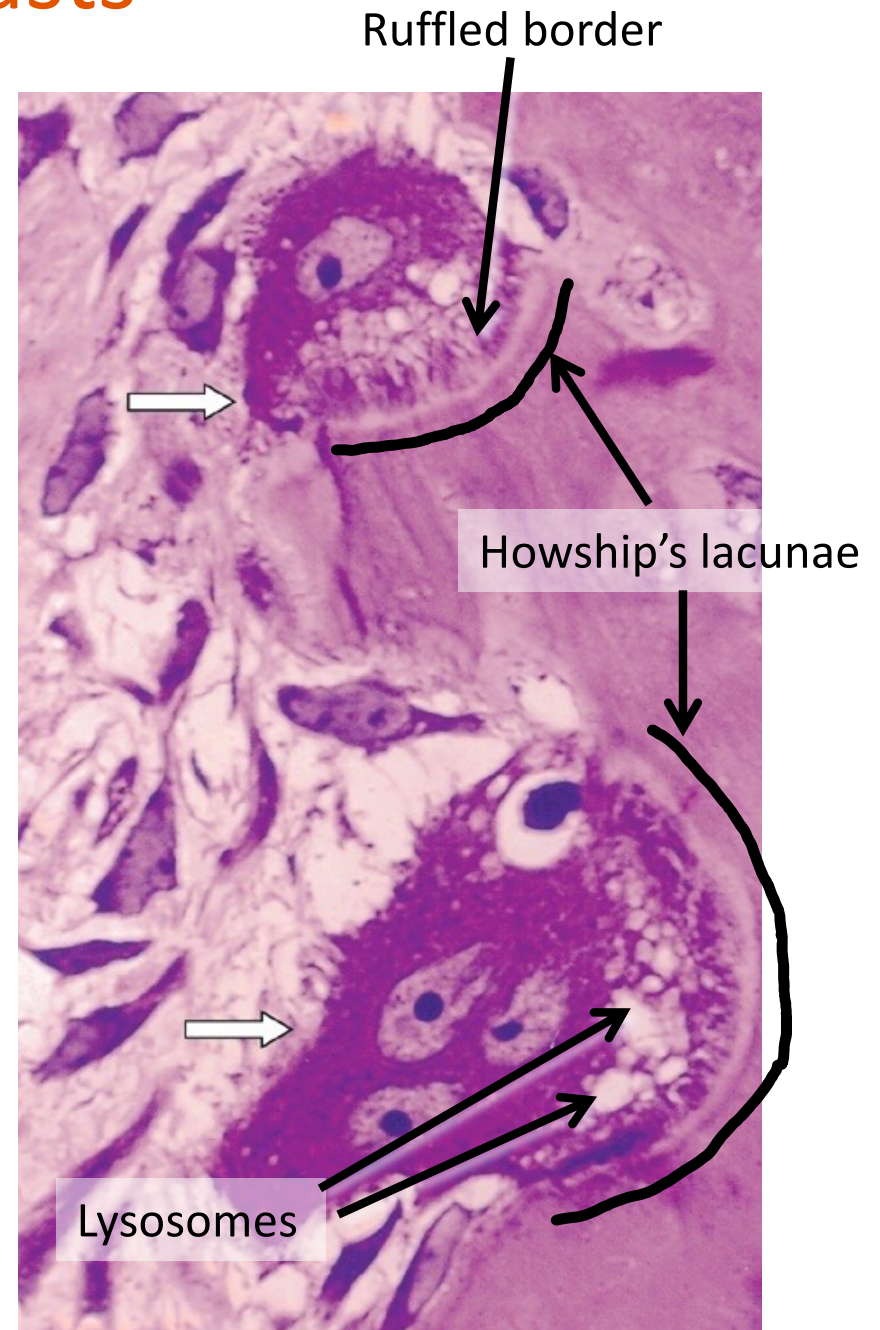
Osteocytes

- Osteocytes are involved in maintenance of bone matrix. Their death results in resorption of matrix.
- Each osteocyte sits in its own lacuna.
- Osteocytes have small, dark, flattened nuclei with minimal rough ER and Golgi.



Osteoclasts

- Multinucleated giant cells (20-100 μm). Lie in Howship's lacunae.
- Arise from fusion of blood monocytes.
- Numerous lysosomes.
- Actively resorbing osteoclasts adjacent to bone have cytoplasmic membrane branching ("ruffled border").



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Two Gross Types of Bone

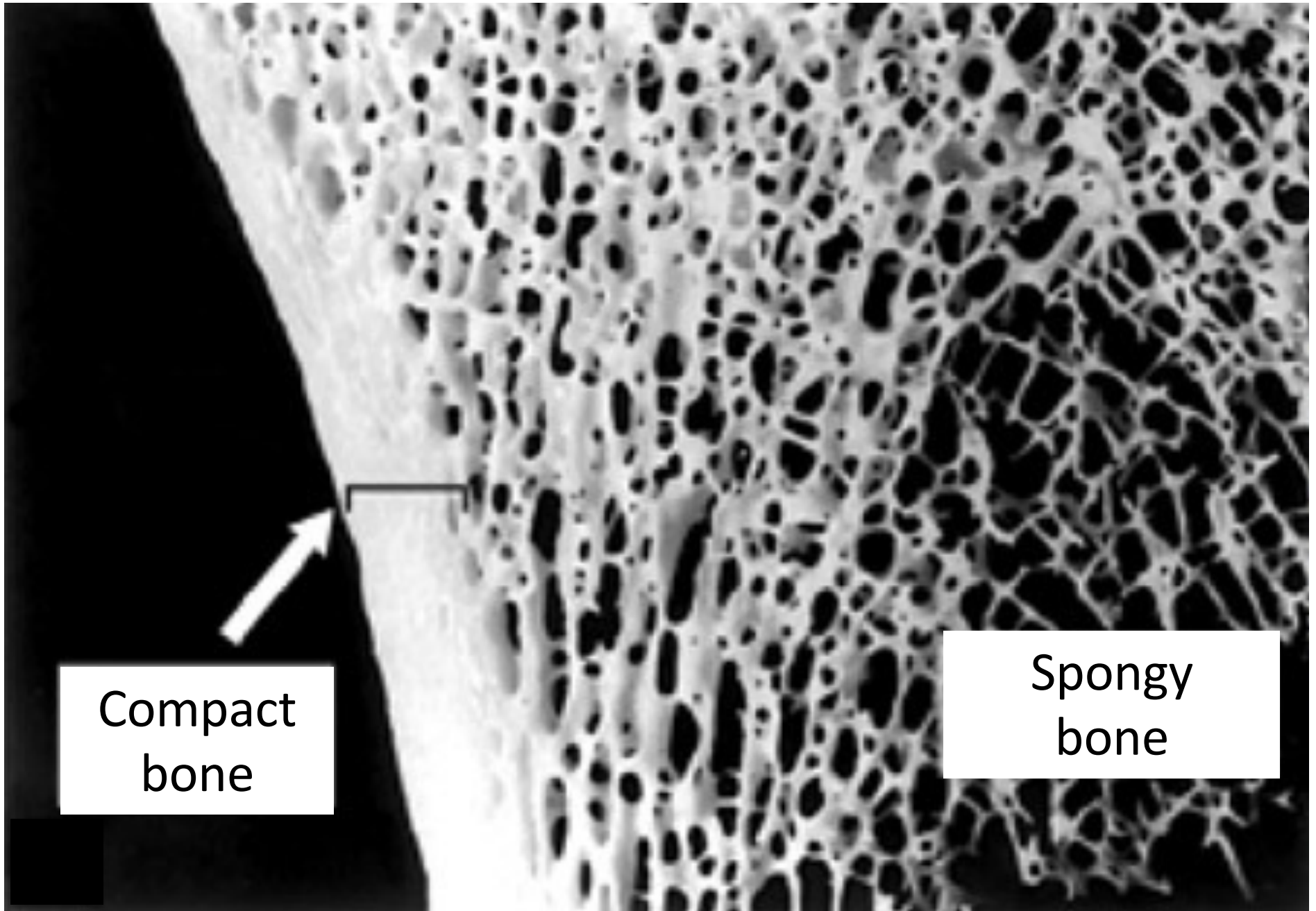
Compact bone

Very dense, solid structure.

Spongy bone

Open, loose structure.

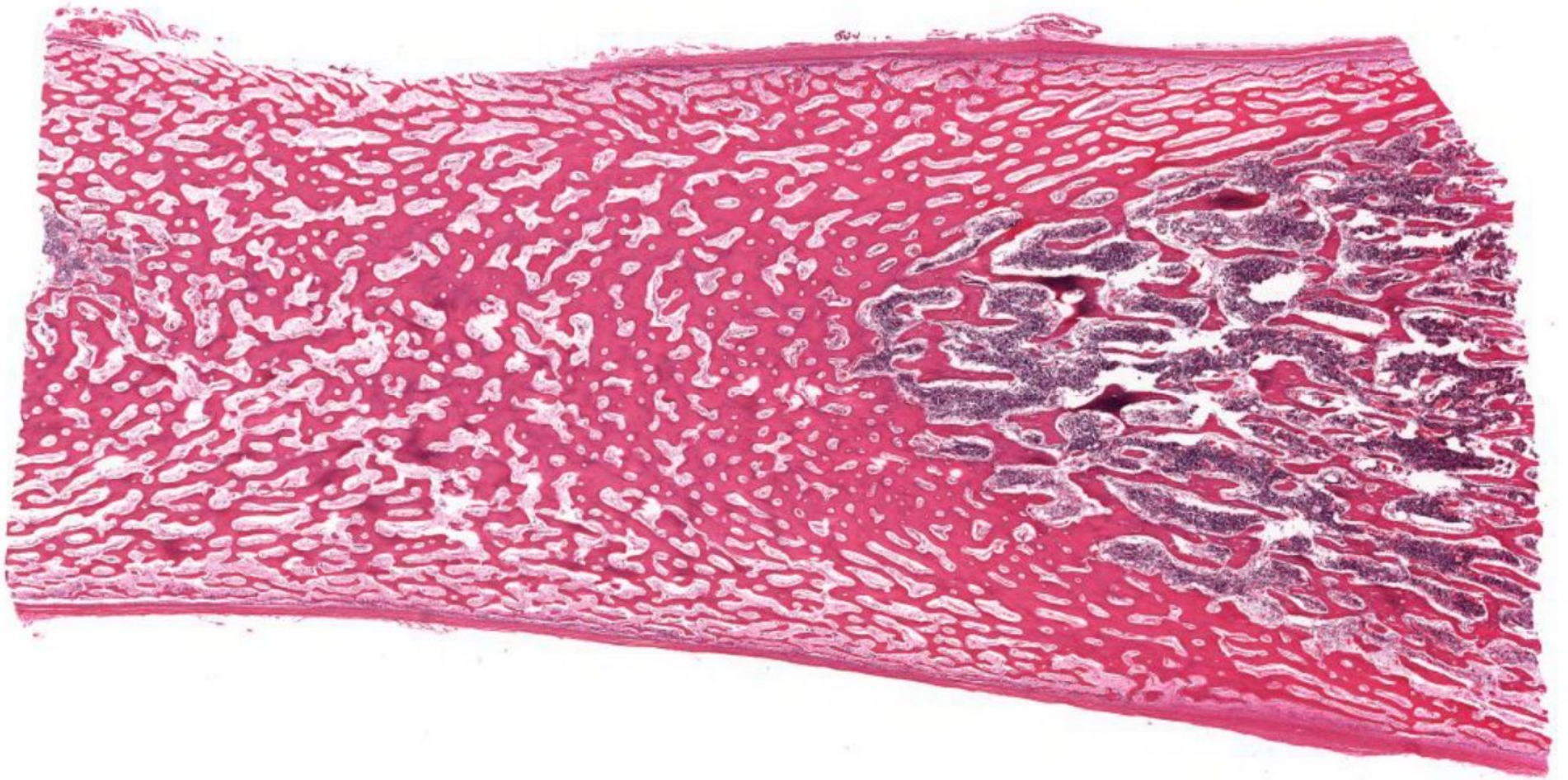
Compact Bone and Spongy Bone



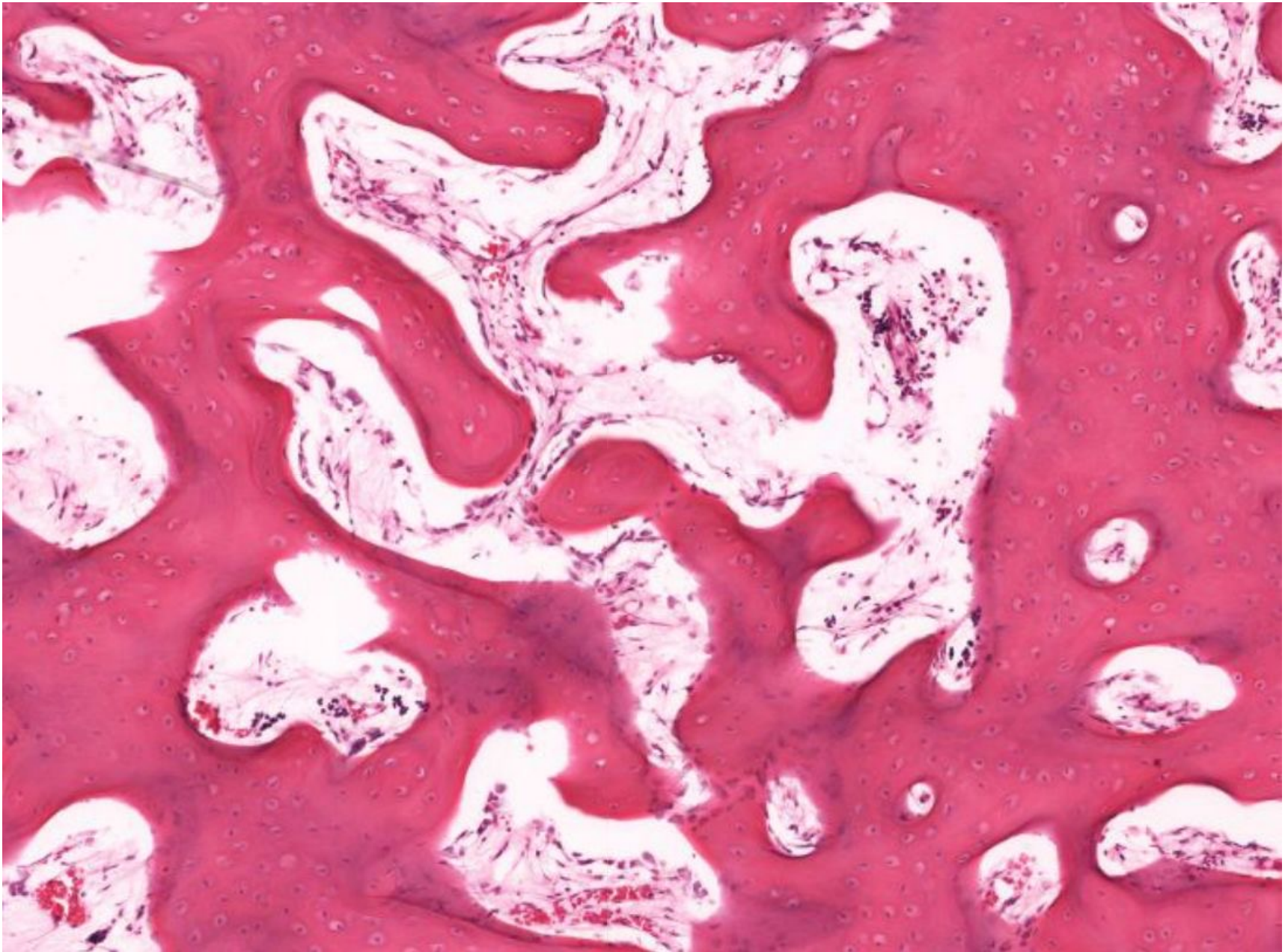
Two Microscopic Types of Bone

Immature (primary, woven) bone

The first bone laid down. Formed quickly. Later replaced by mature bone.



Immature bone: super low-power view



Immature bone: high-power view

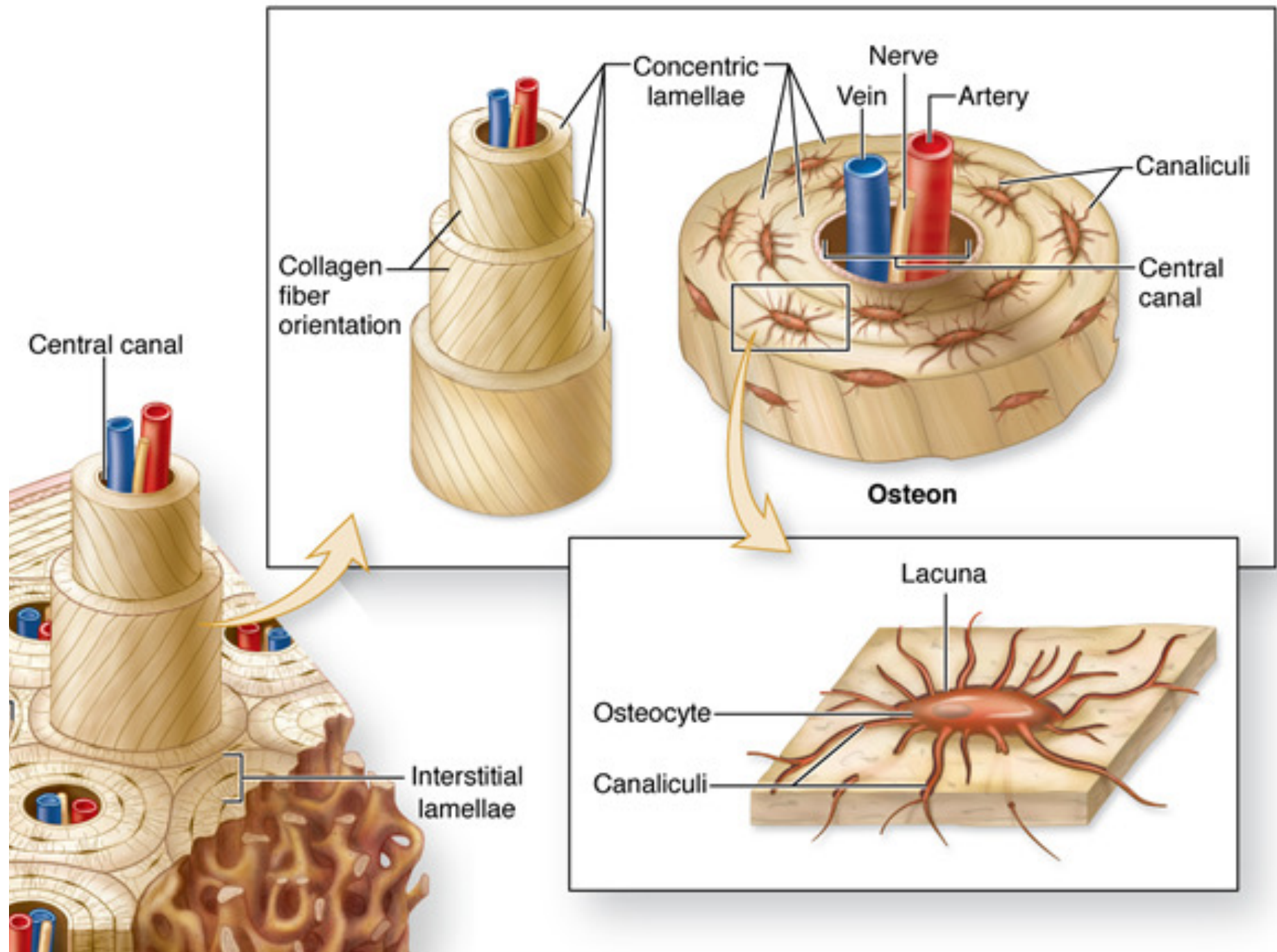
Two Microscopic Types of Bone

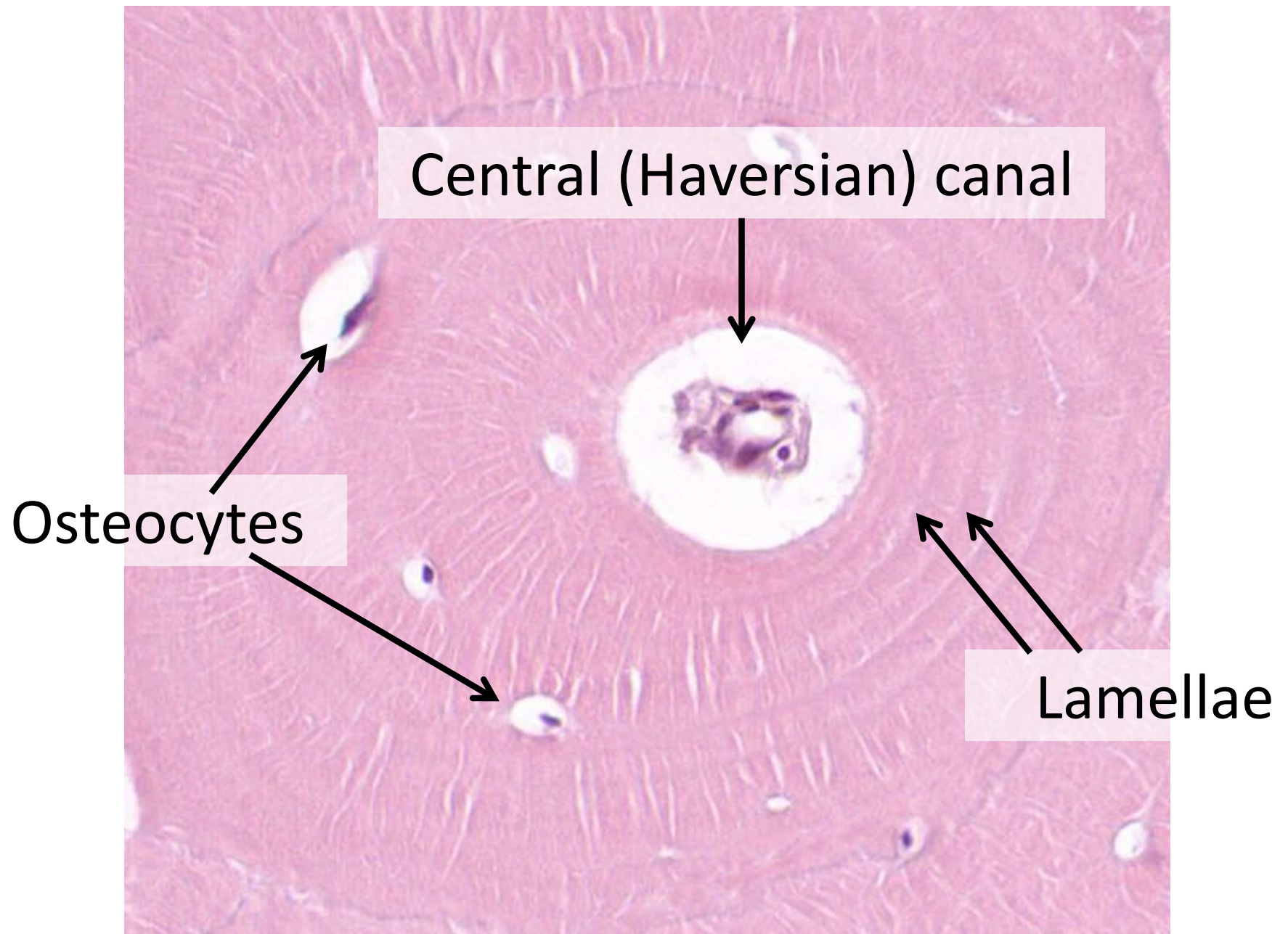
Immature (primary, woven) bone

The first bone laid down. Formed quickly. Later replaced by mature bone.

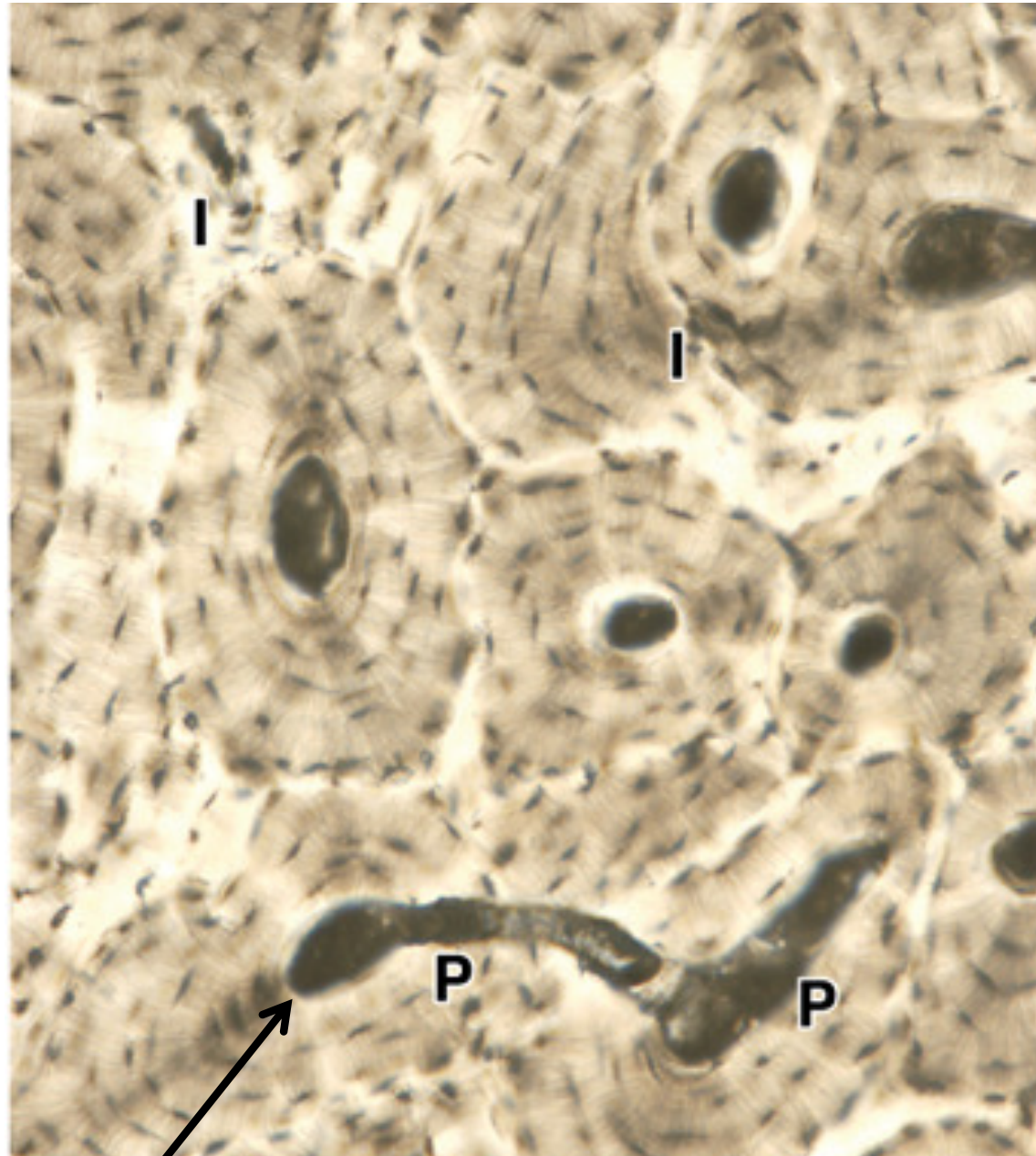
Mature (secondary, lamellar) bone

Arranged in osteons: layers (lamellae) of bone around little canals.





Osteon

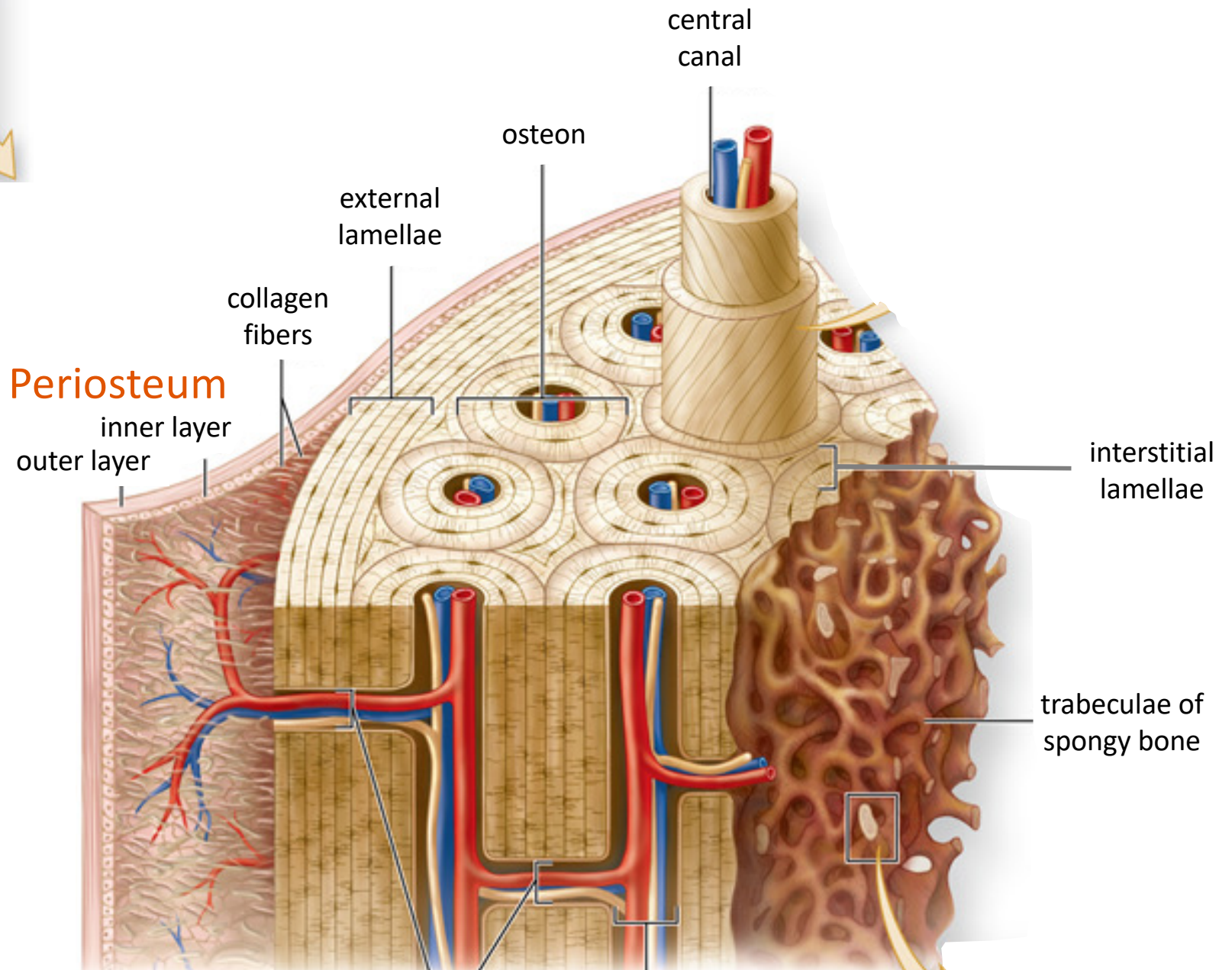
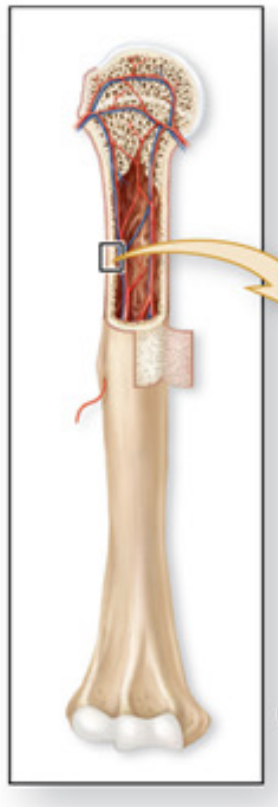


Volkman (perforating) canals connect osteons

Periosteum and Endosteum

Periosteum lines the outer surface of compact bone.

- Two layers: outer dense connective tissue layer and inner layer of osteoprogenitor cells.
- Collagen fibers tightly attach the periosteum to the bone matrix.
- Contains blood vessels for nutrition of bone.
- Contains osteoblasts for bone growth, repair and remodeling.

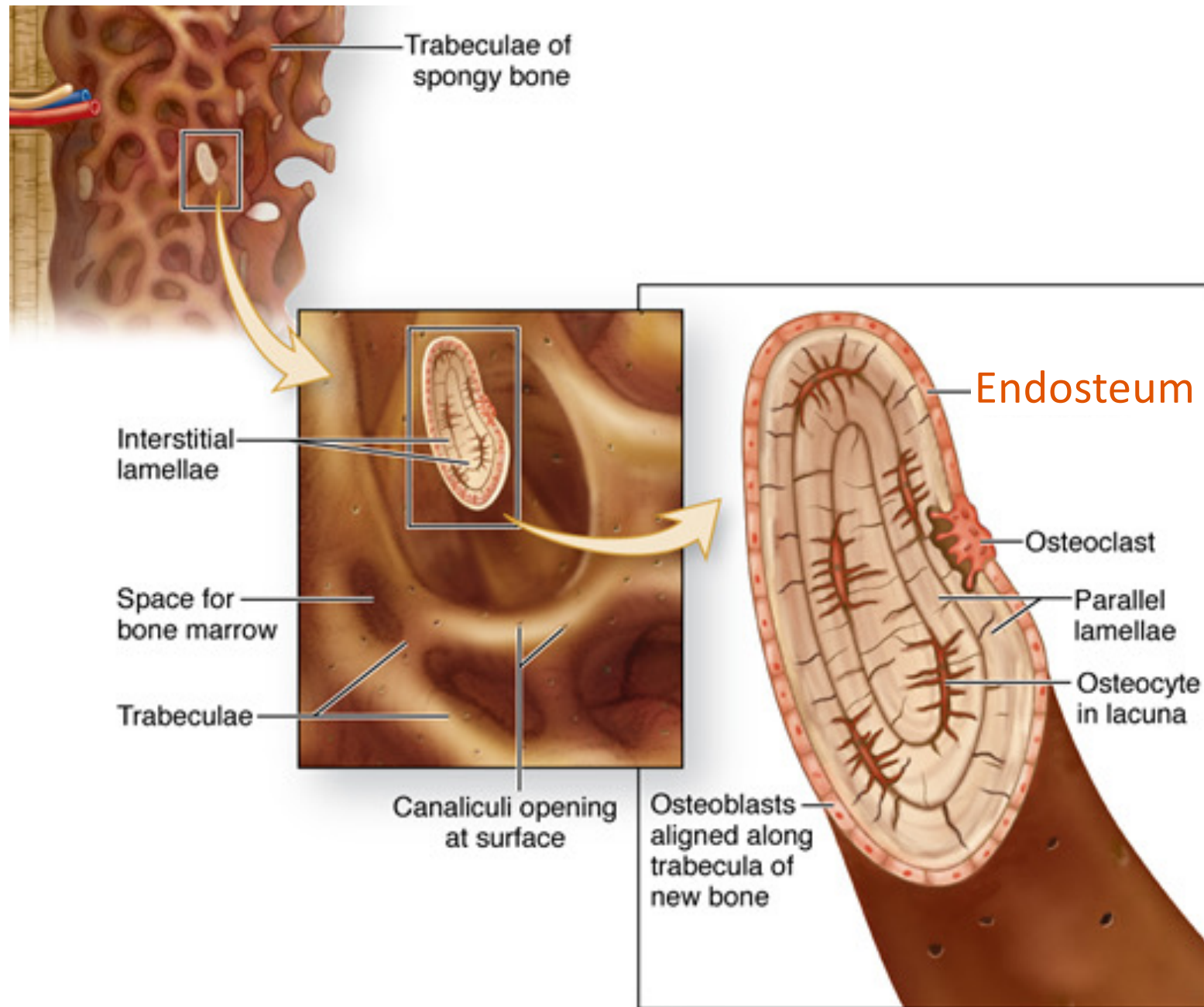


Periosteum and Endosteum

Periosteum lines the outer surface of compact bone.

Endosteum lines the inner surface of compact bone.

- Also lines the surface of bony trabeculae of spongy bone, and the Haversian canals.
- Contains osteoblasts for bone growth, repair and remodeling.



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Bone Development (Osteogenesis)

Bone can be formed in two ways:

Intramembranous ossification

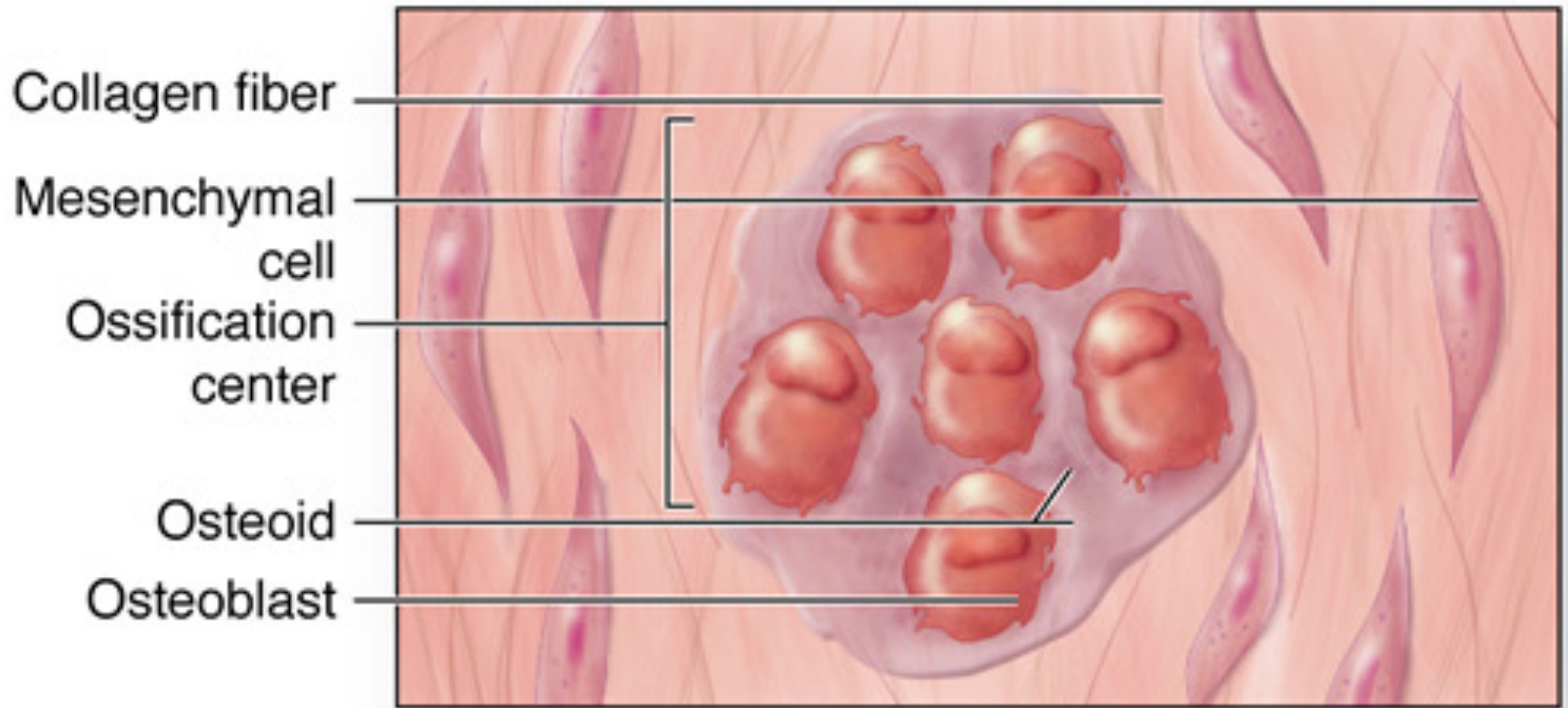
Occurs in flat bones (most of skull, including maxilla and mandible).

Endochondral ossification

Occurs in long bones and irregular bones.

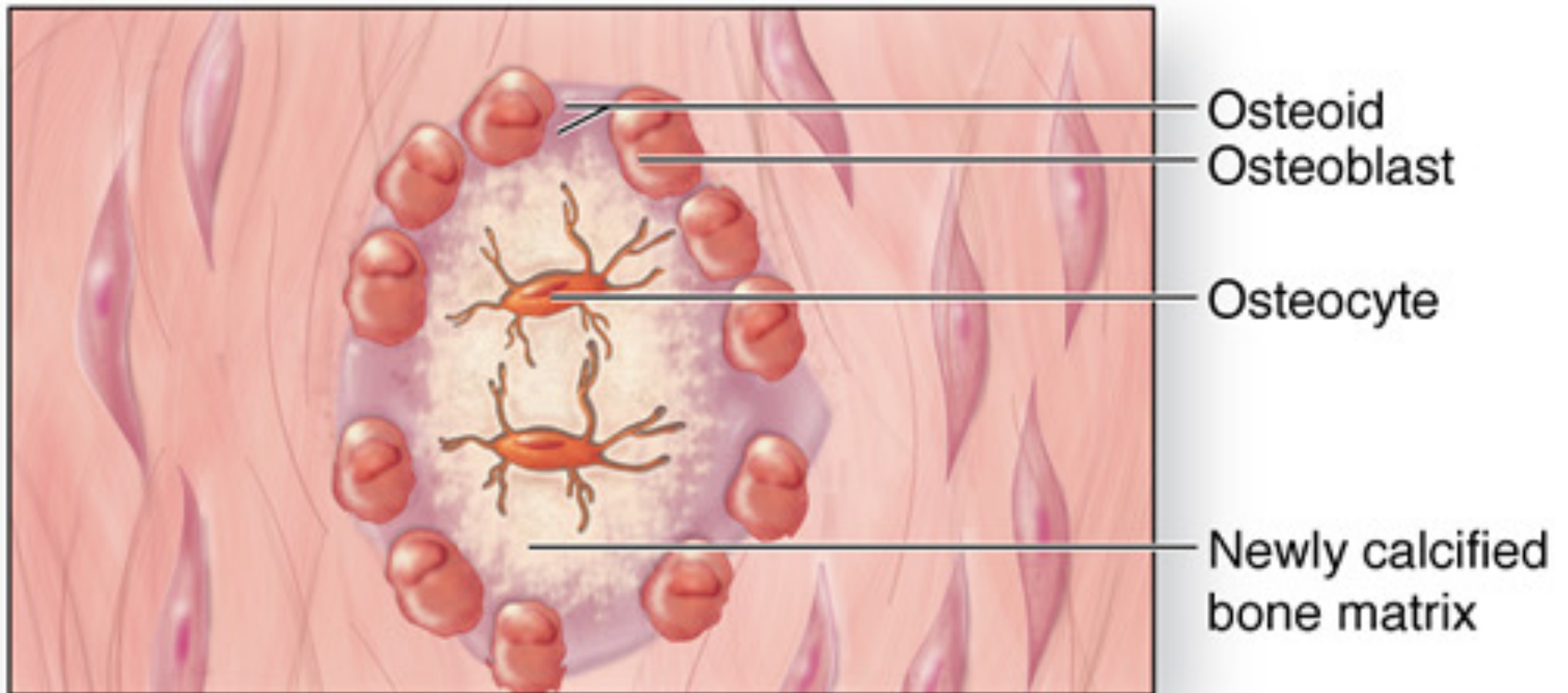
Intramembranous Ossification

Ossification centers form within thickened regions of mesenchyme.



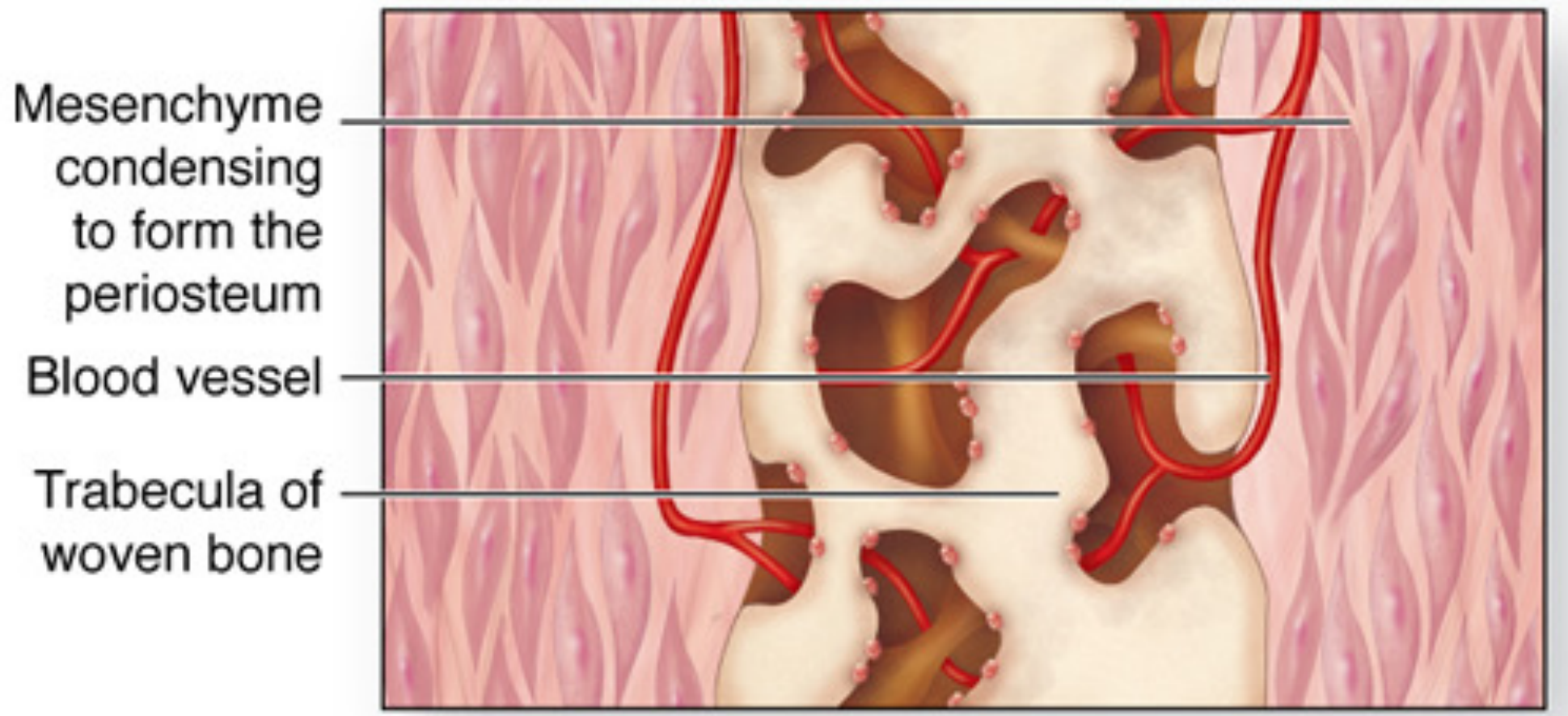
Intramembranous Ossification

Osteoid undergoes calcification.



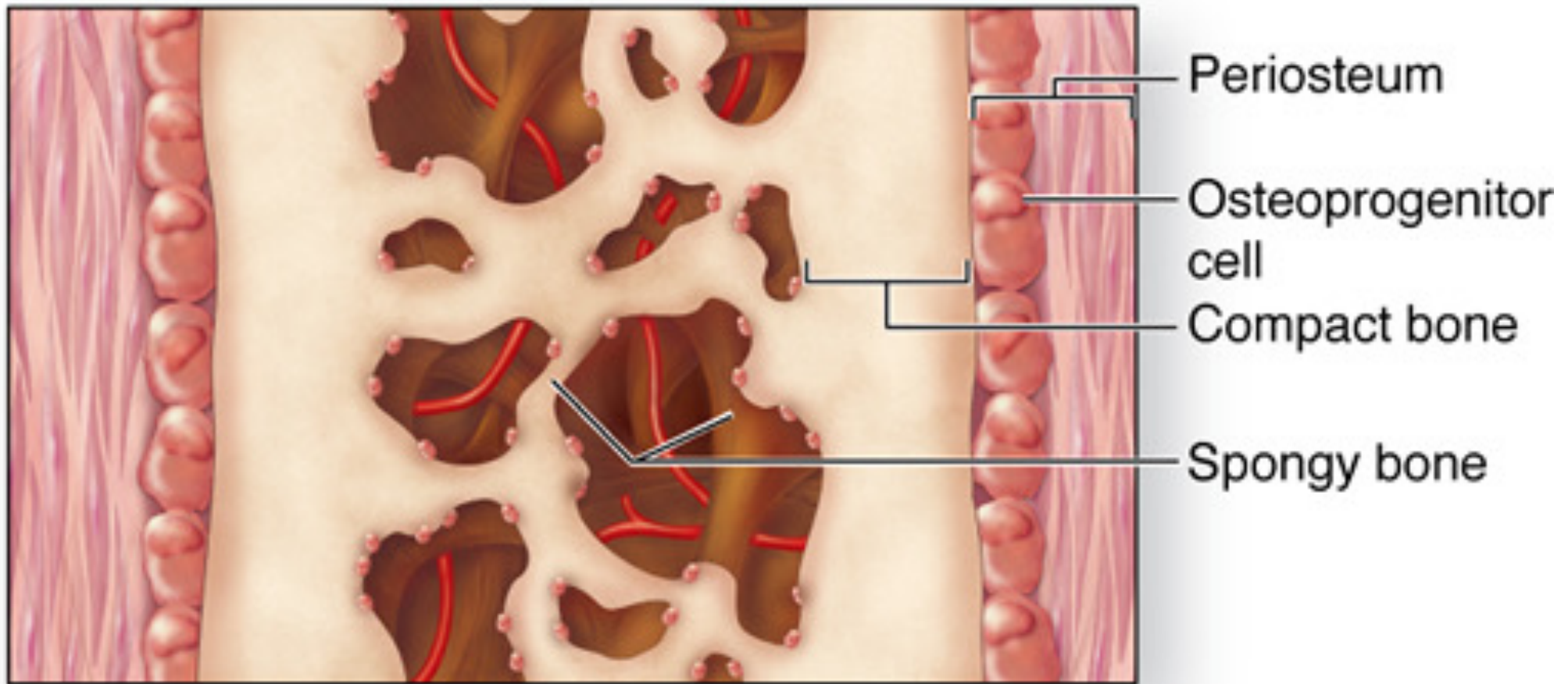
Intramembranous Ossification

Woven bone and surrounding periosteum form.

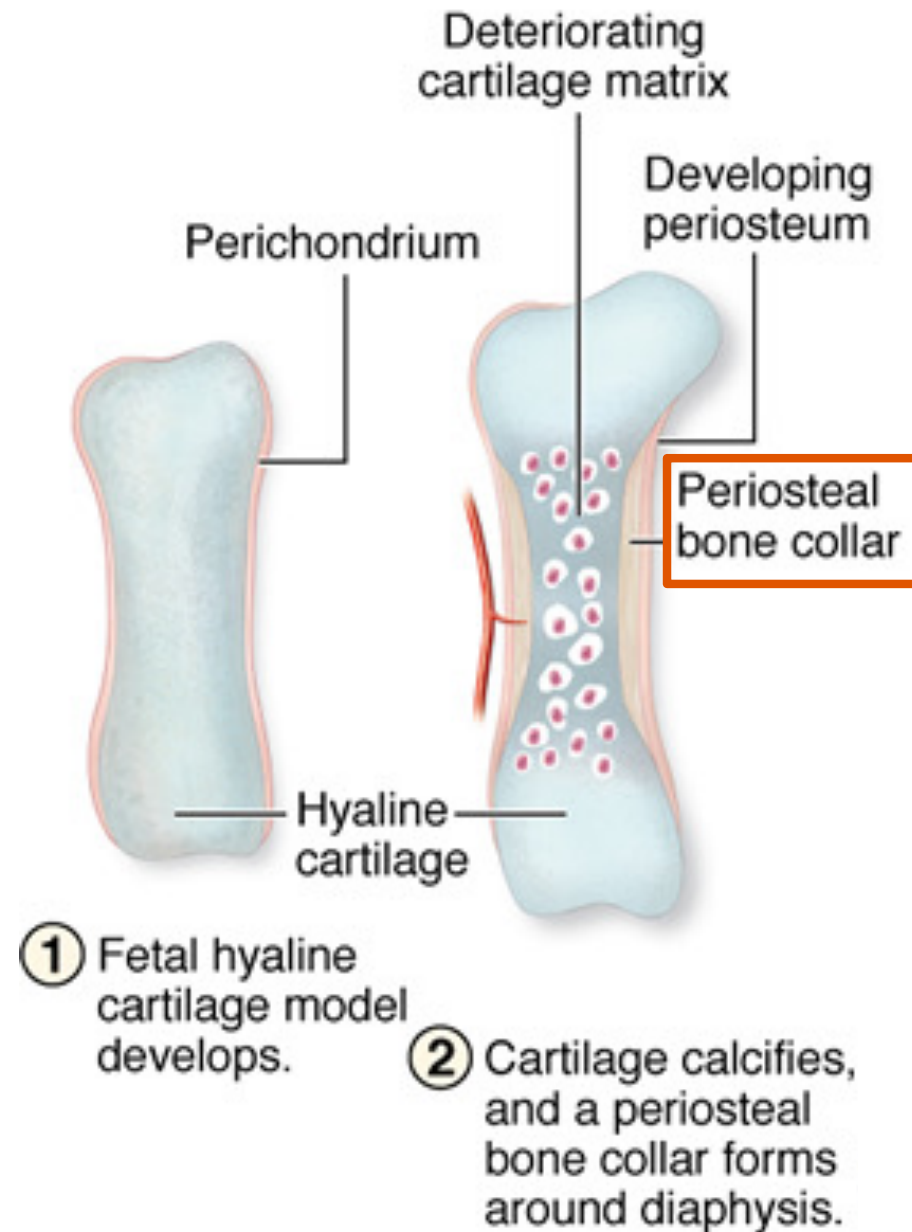


Intramembranous Ossification

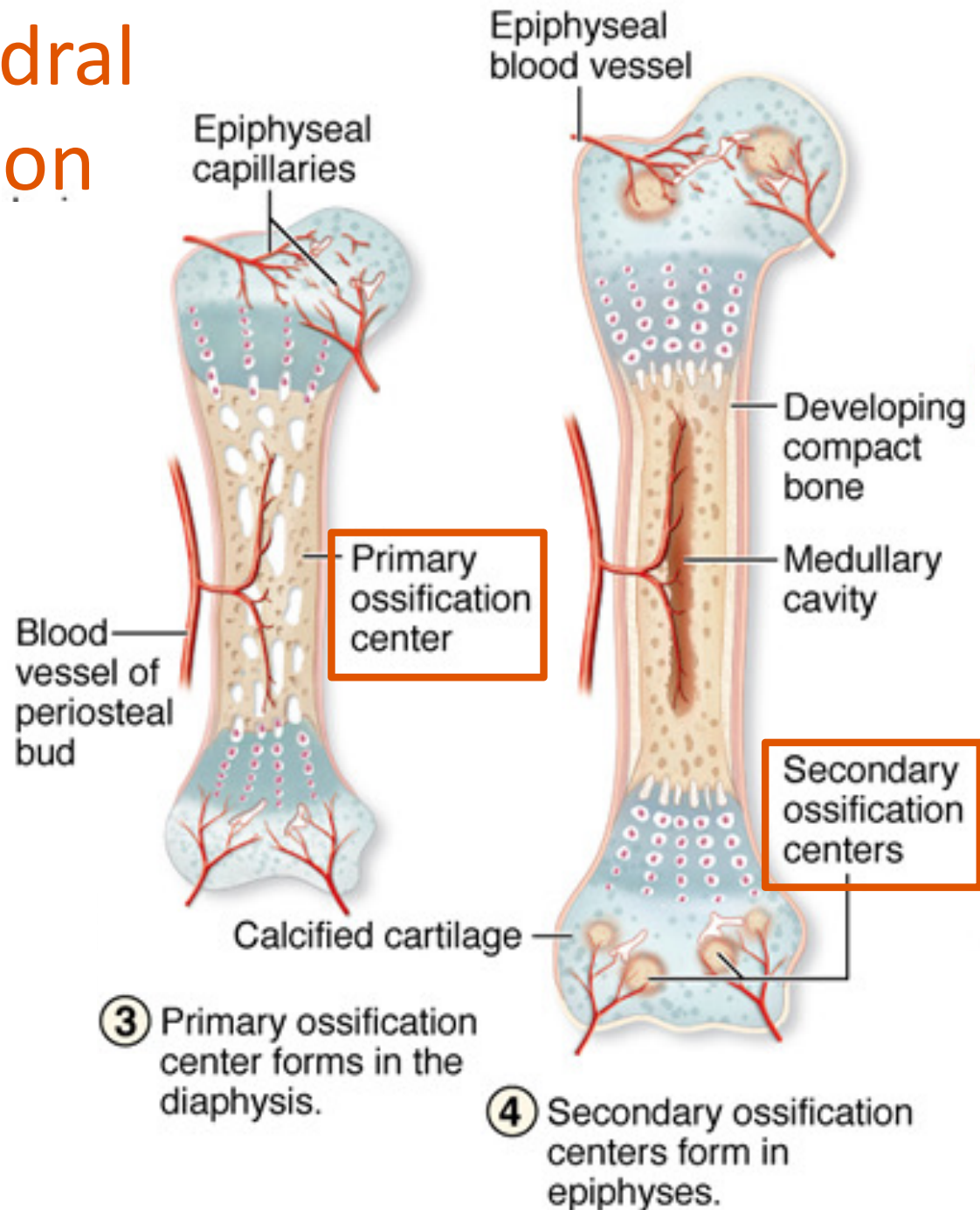
Lamellar bone replaces woven bone, as compact and spongy bone form.



Endochondral Ossification



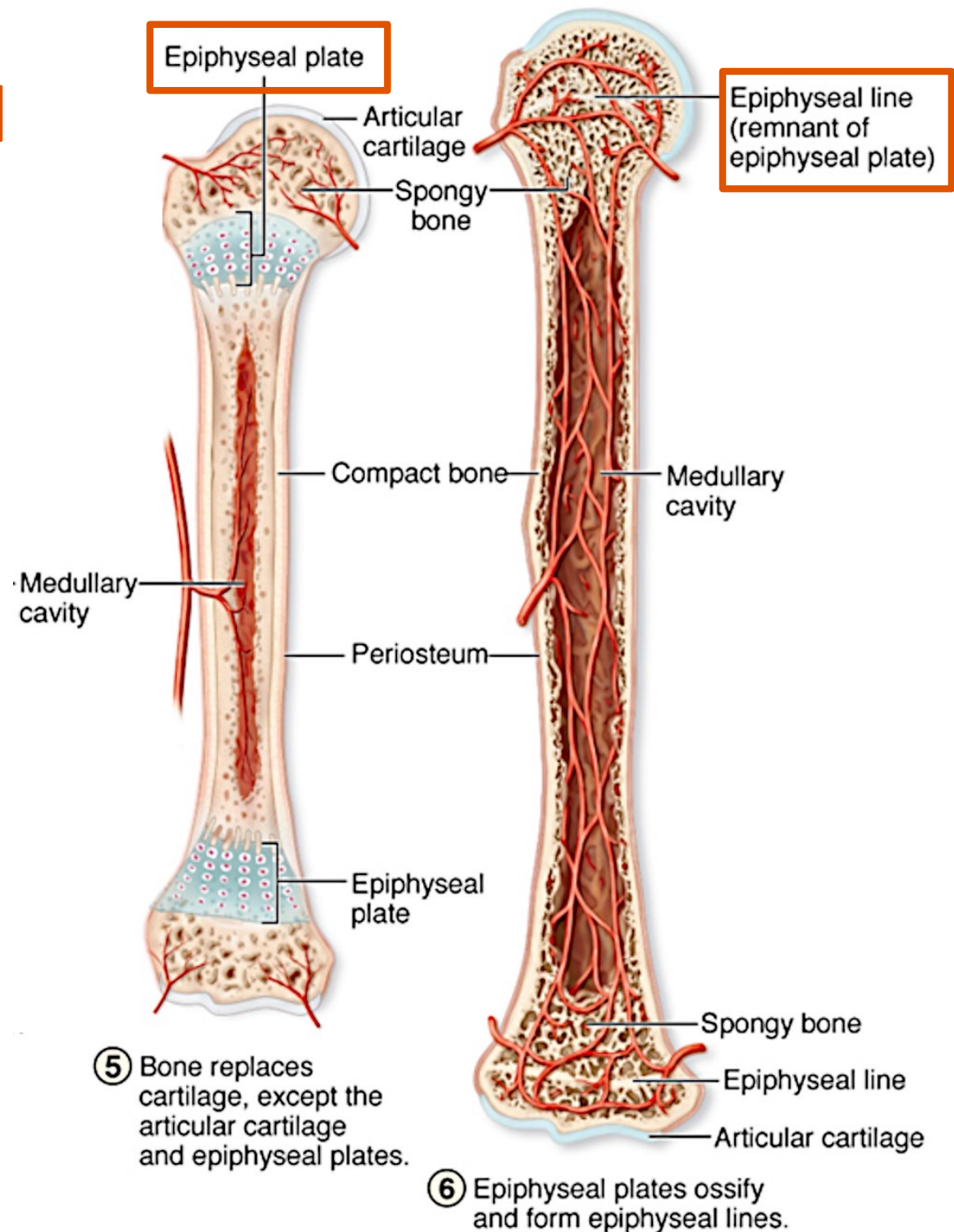
Endochondral Ossification

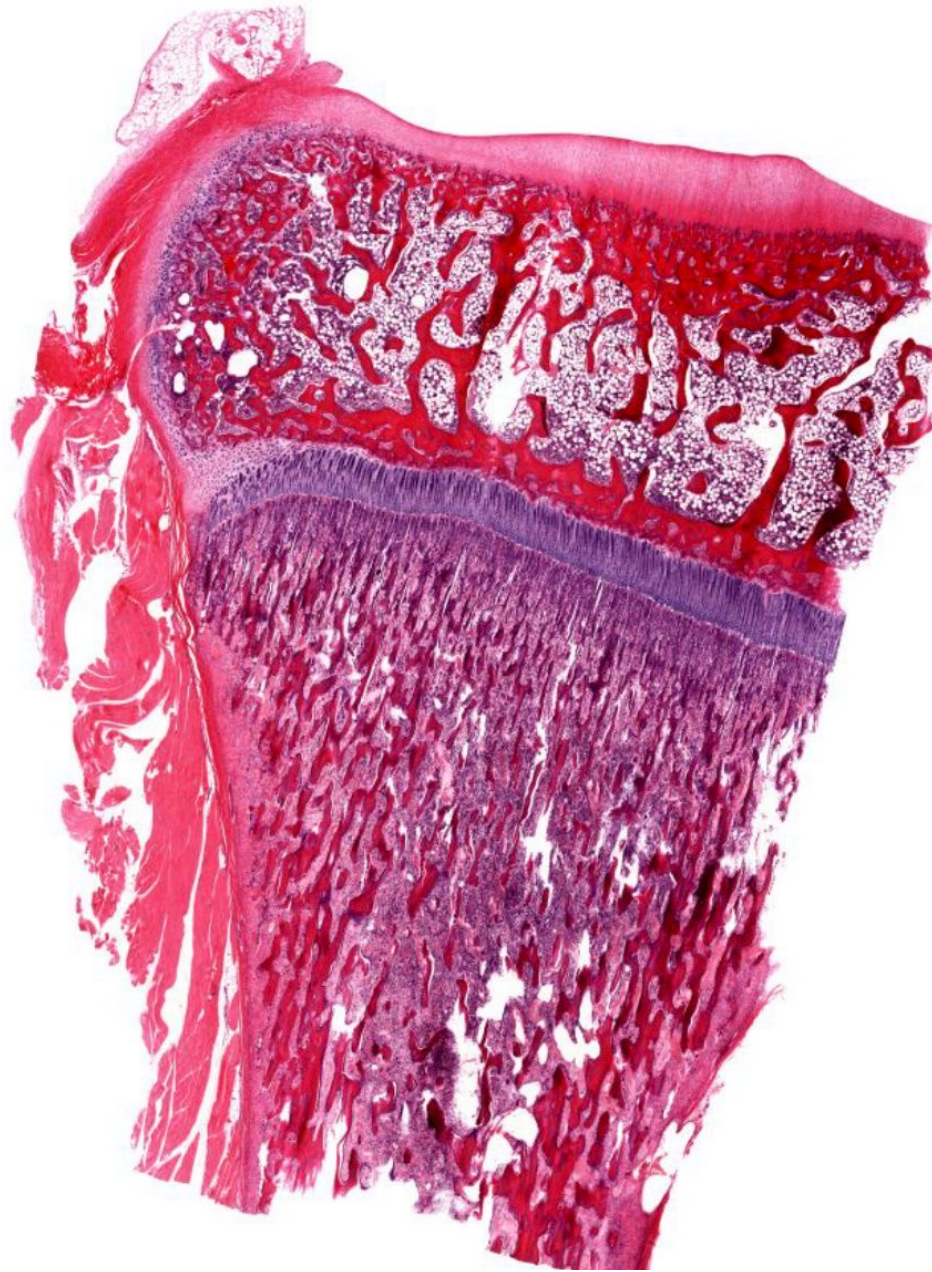


Endochondral Ossification

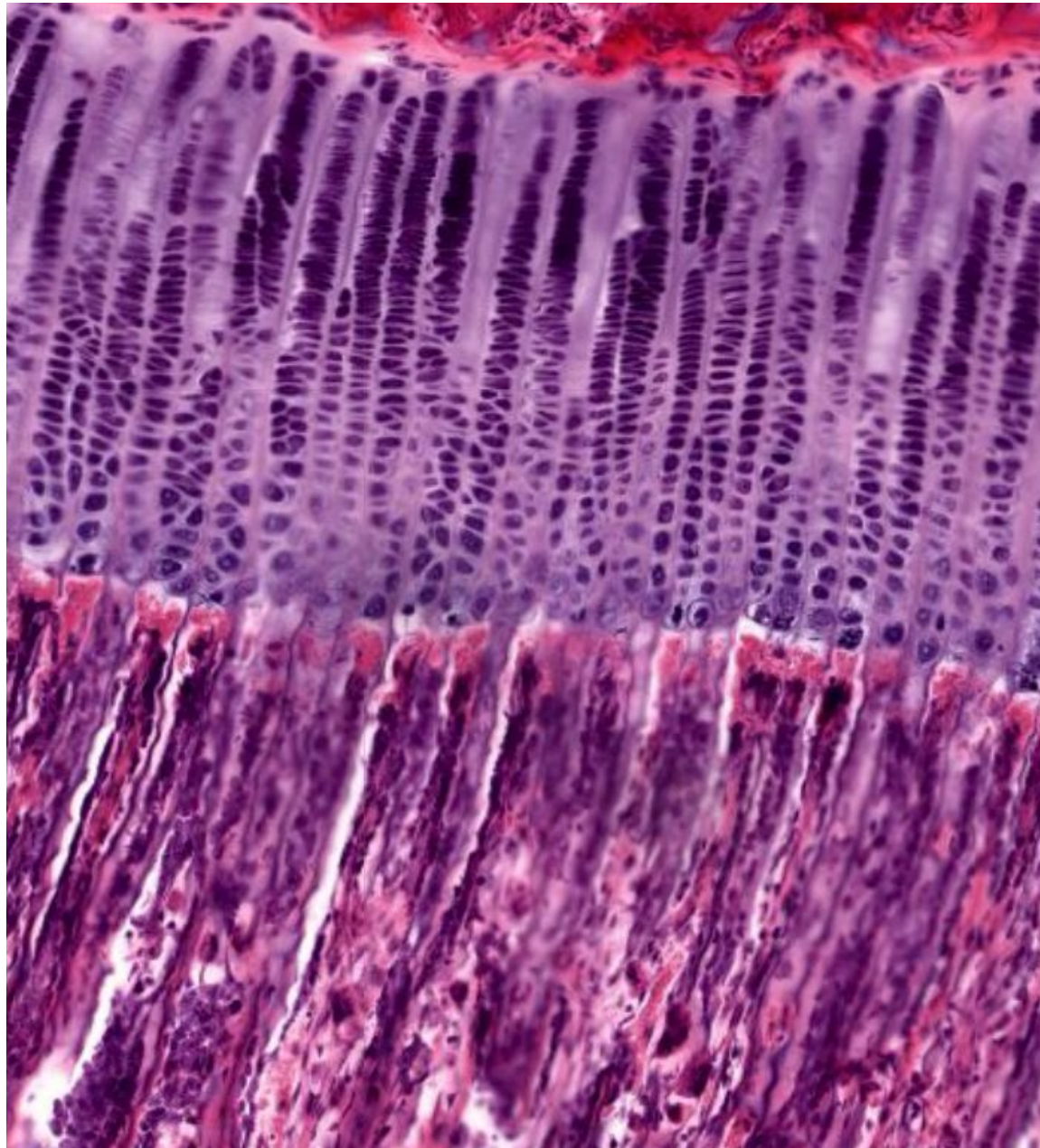
Epiphysis: the end of a long bone. Consists primarily of spongy bone, with a layer of compact bone on the outside.

Diaphysis: the shaft of a long bone. Consists of compact bone on the outside and a marrow cavity inside.





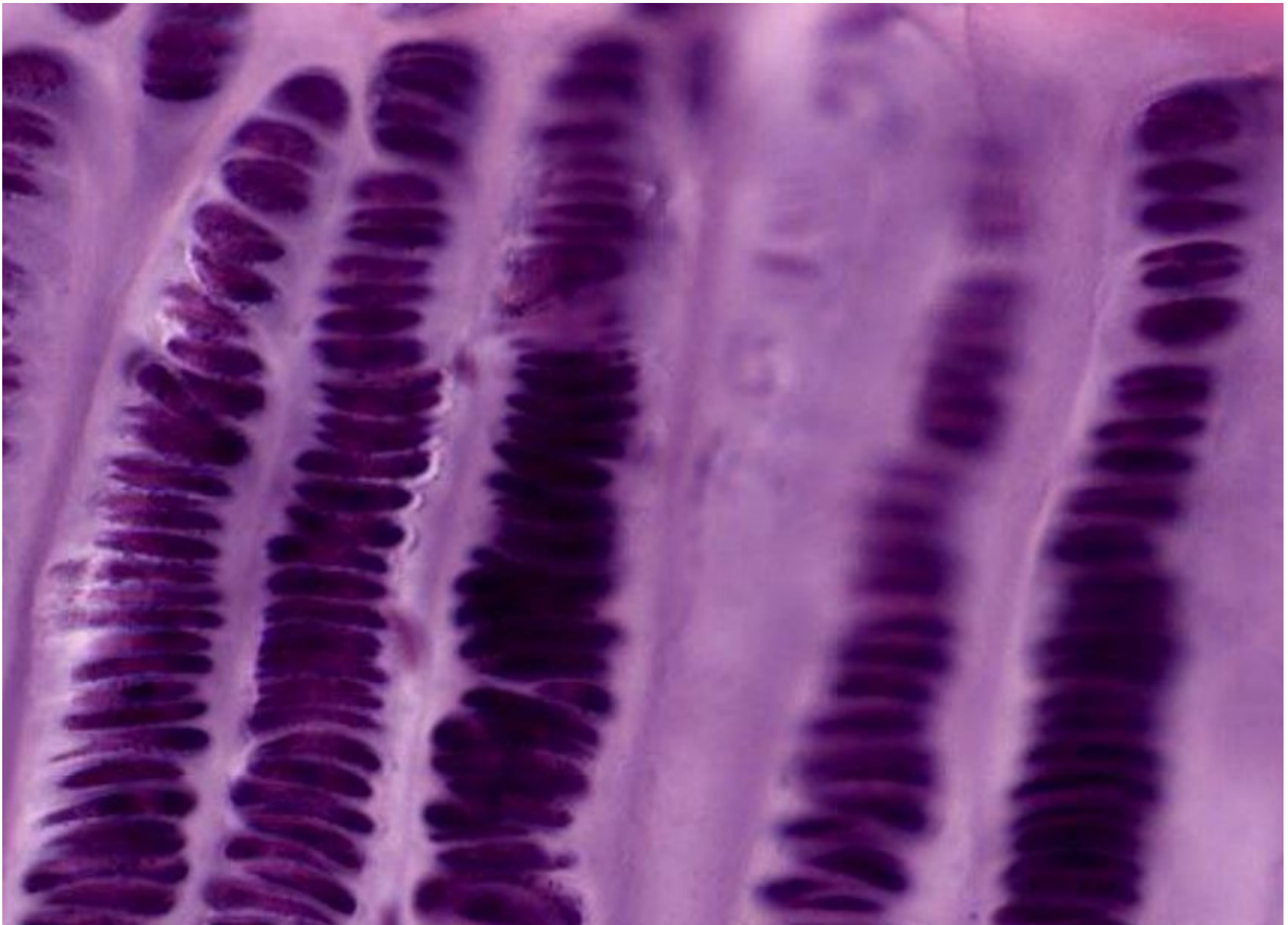
Endochondral bone formation: super low-power view



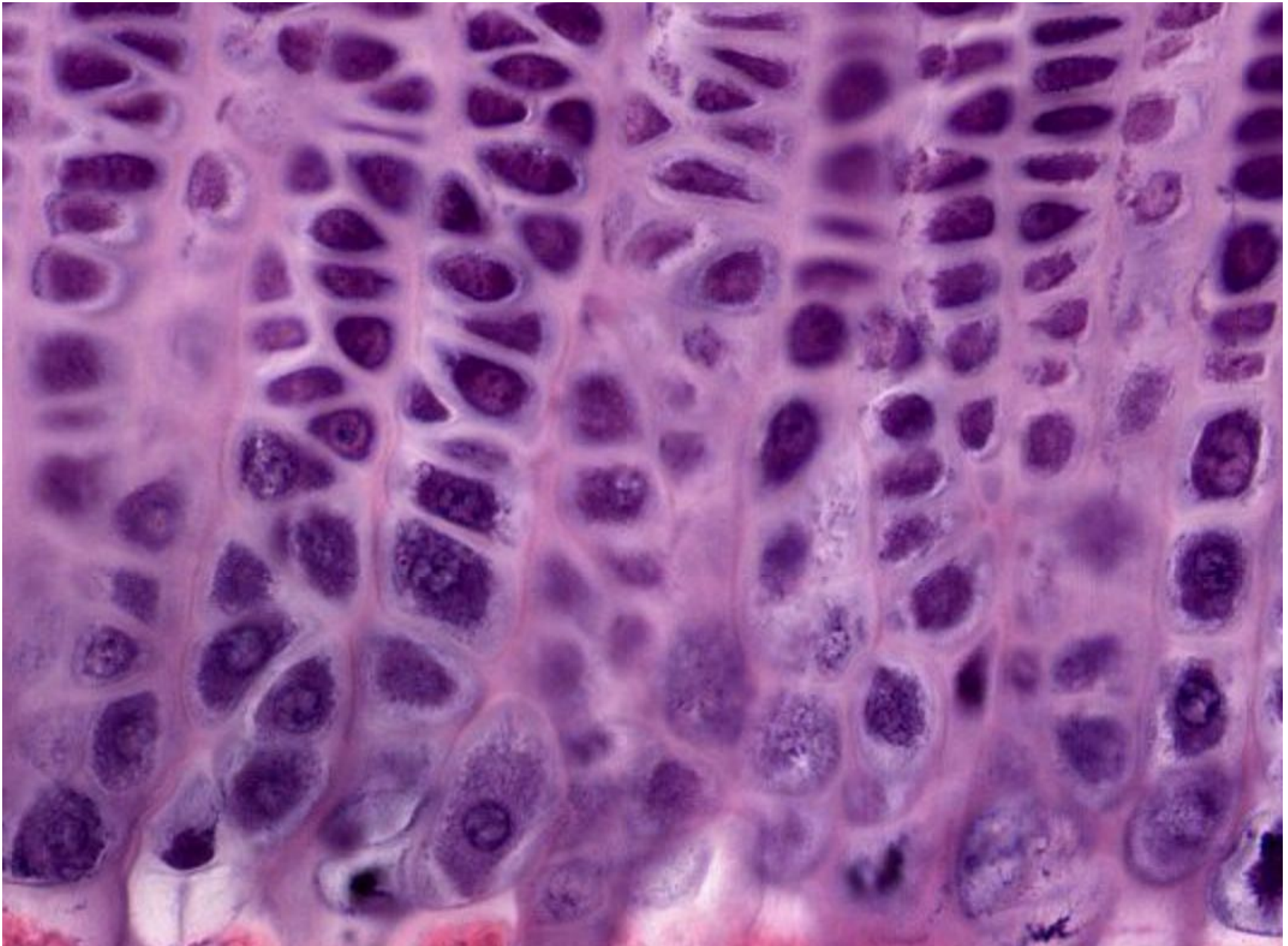
Epiphyseal plate: zones of maturation



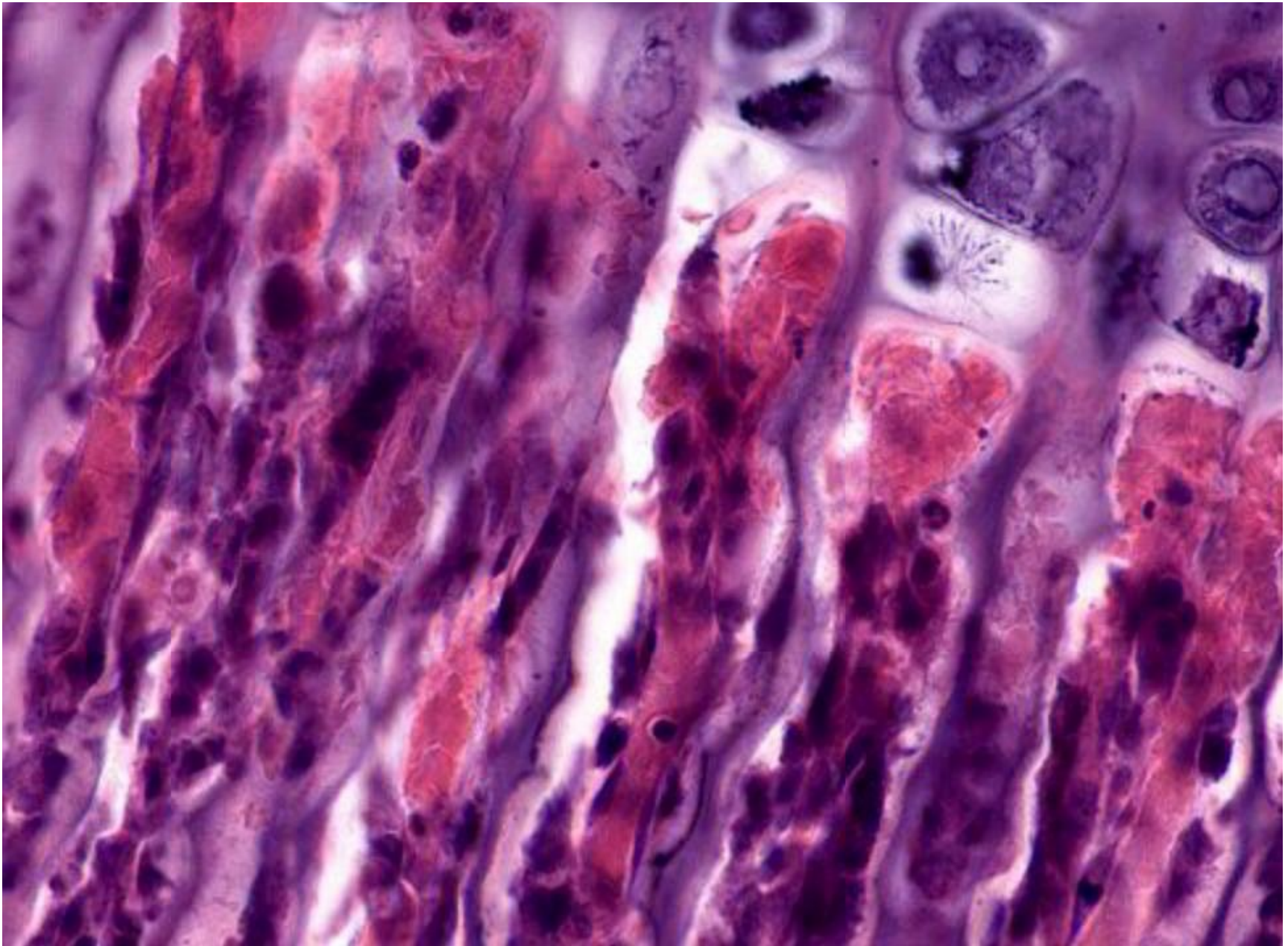
Resting zone



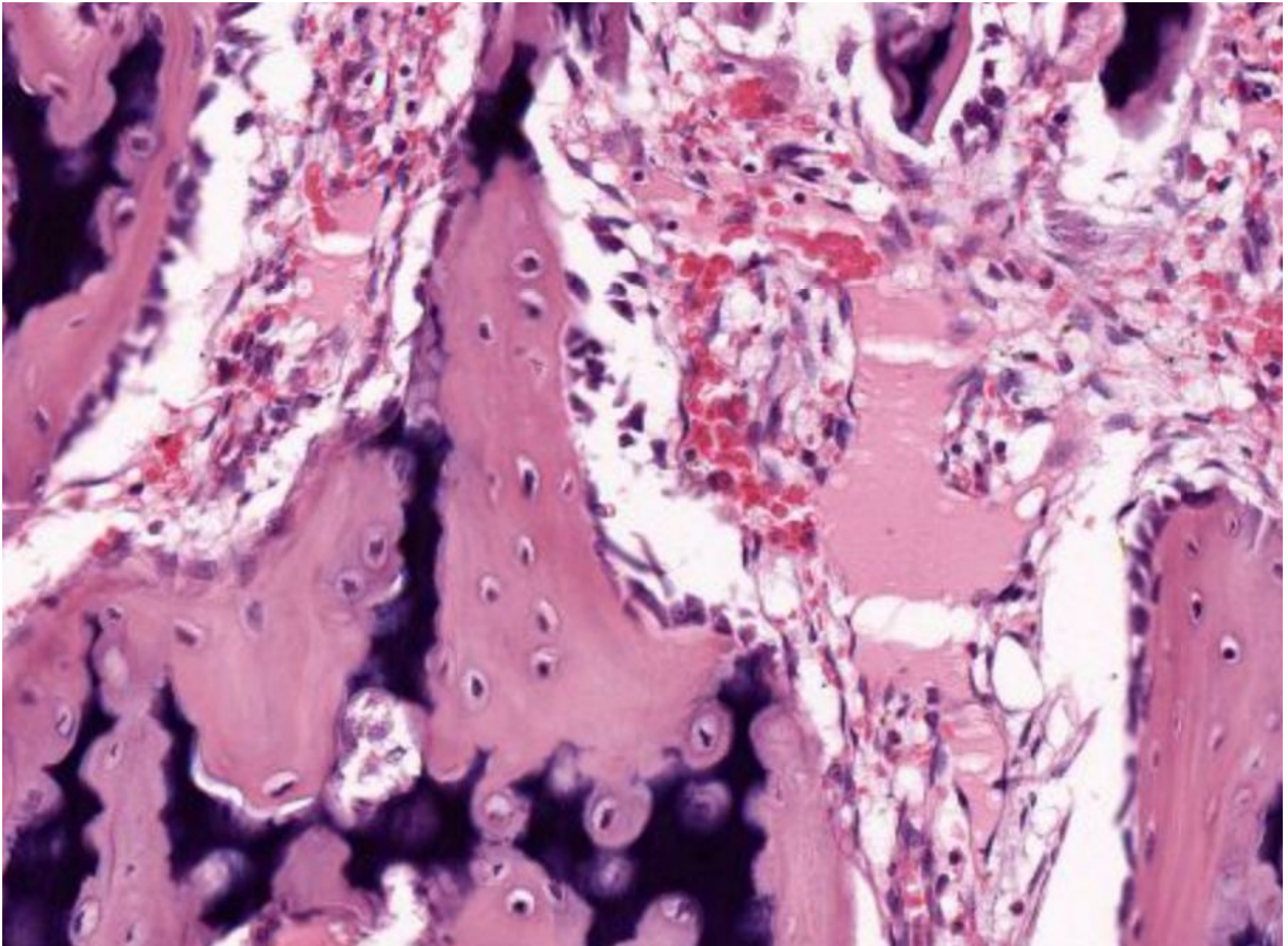
Proliferative zone



Zone of hypertrophy



Zone of calcification



Zone of ossification

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