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M1 Musculoskeletal Sequence Histology

Bone Formation and Remodeling

Fall 2009

University of Michigan Medical School

Bone

Cells: Osteoblasts, Osteocytes, Osteoclasts

Fibers: Type 1 Collagen

Bone Matrix:

Ground Substance

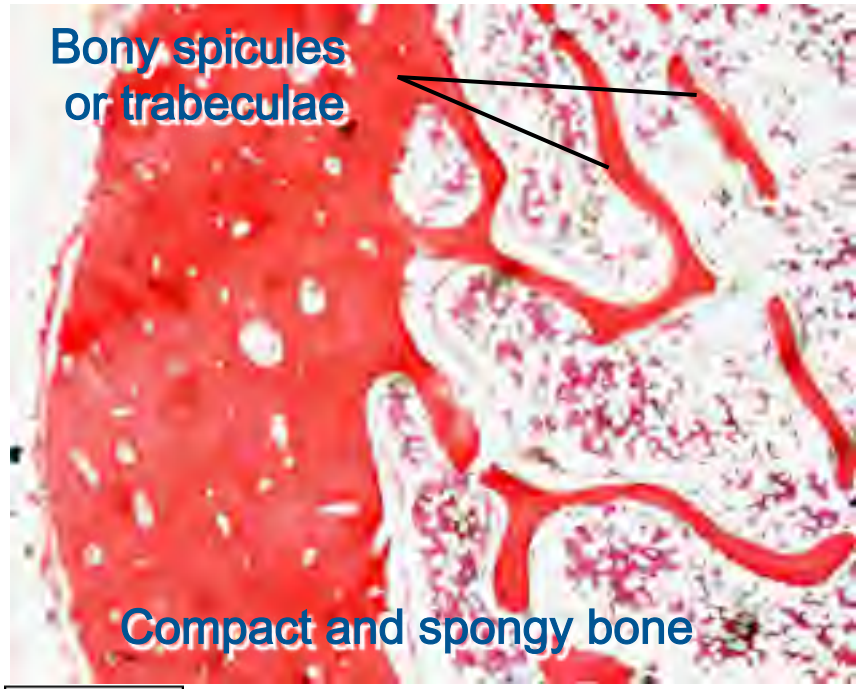
GAGs: Hyaluronan, Chondroitin & Keratan Sulfate

Proteoglycans: short core proteins and relatively fewer GAG side chains than in cartilage.

Hydroxyapatite crystals [$Ca_{10}(PO4)_6(OH)_2$]:

Calcium phosphate

Haversian system or osteon



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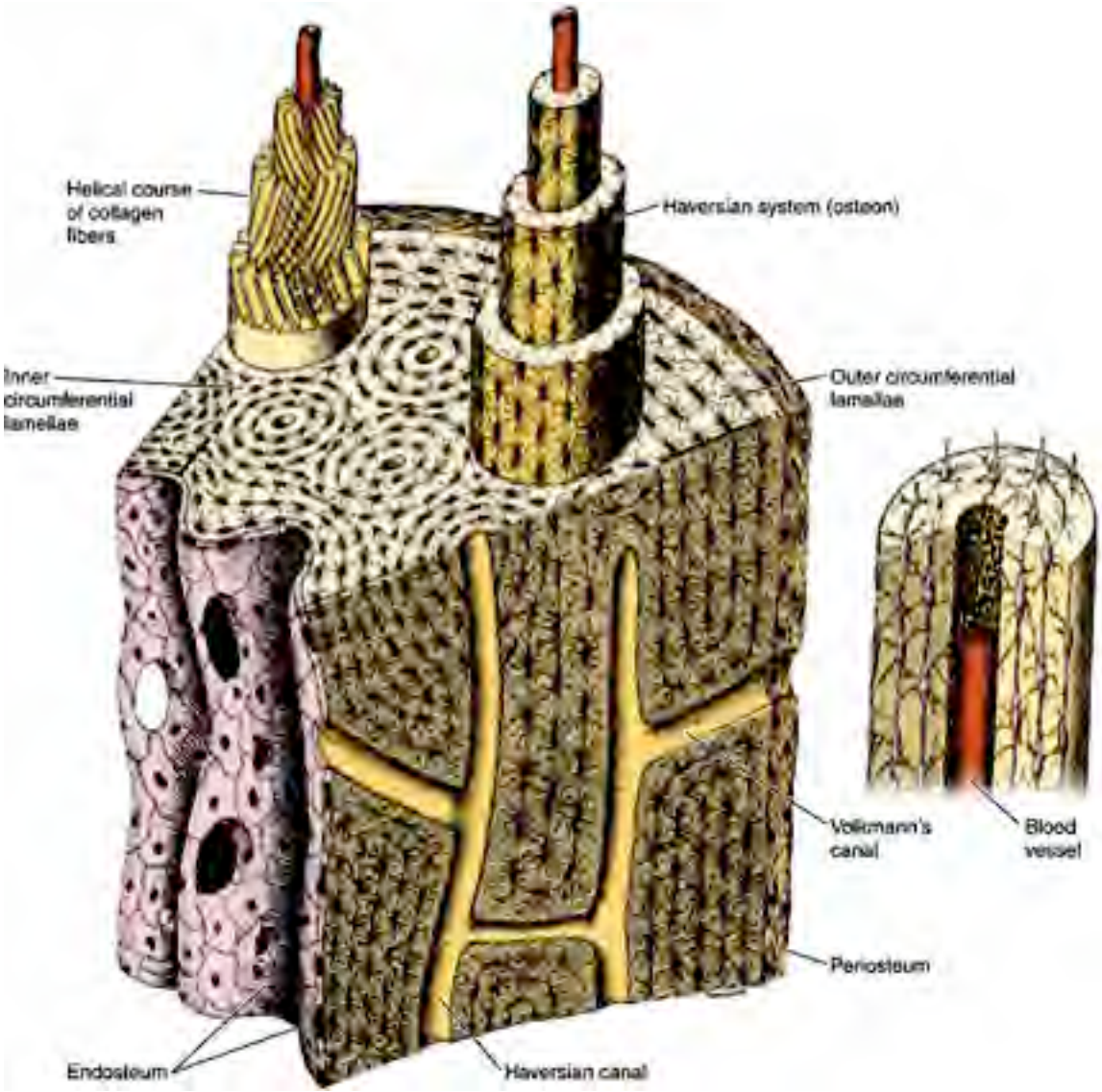
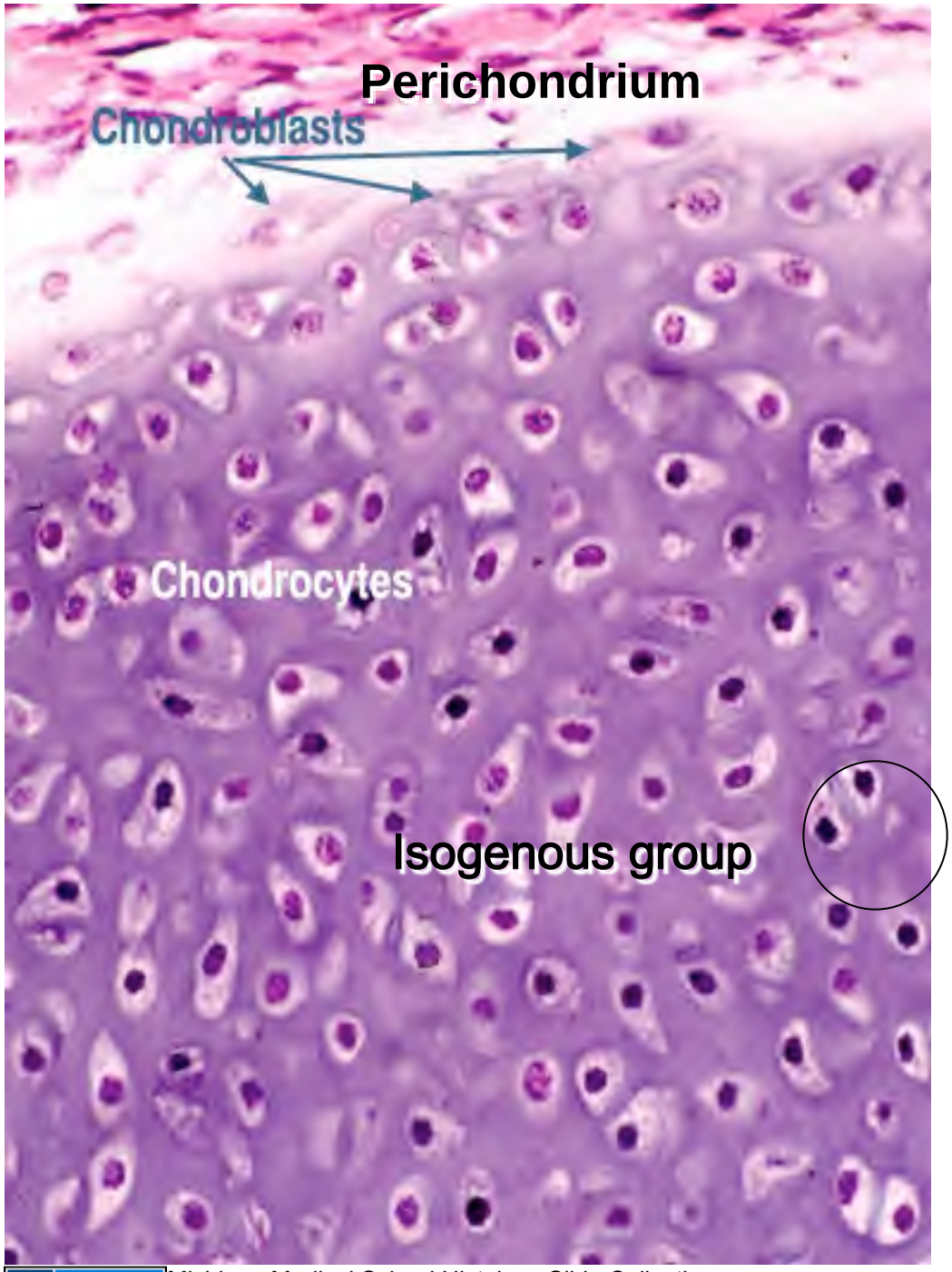


PD-INEL Junqueera & Carneiro, 10th ed. p. 144

Differentiation of chondrogenic cells



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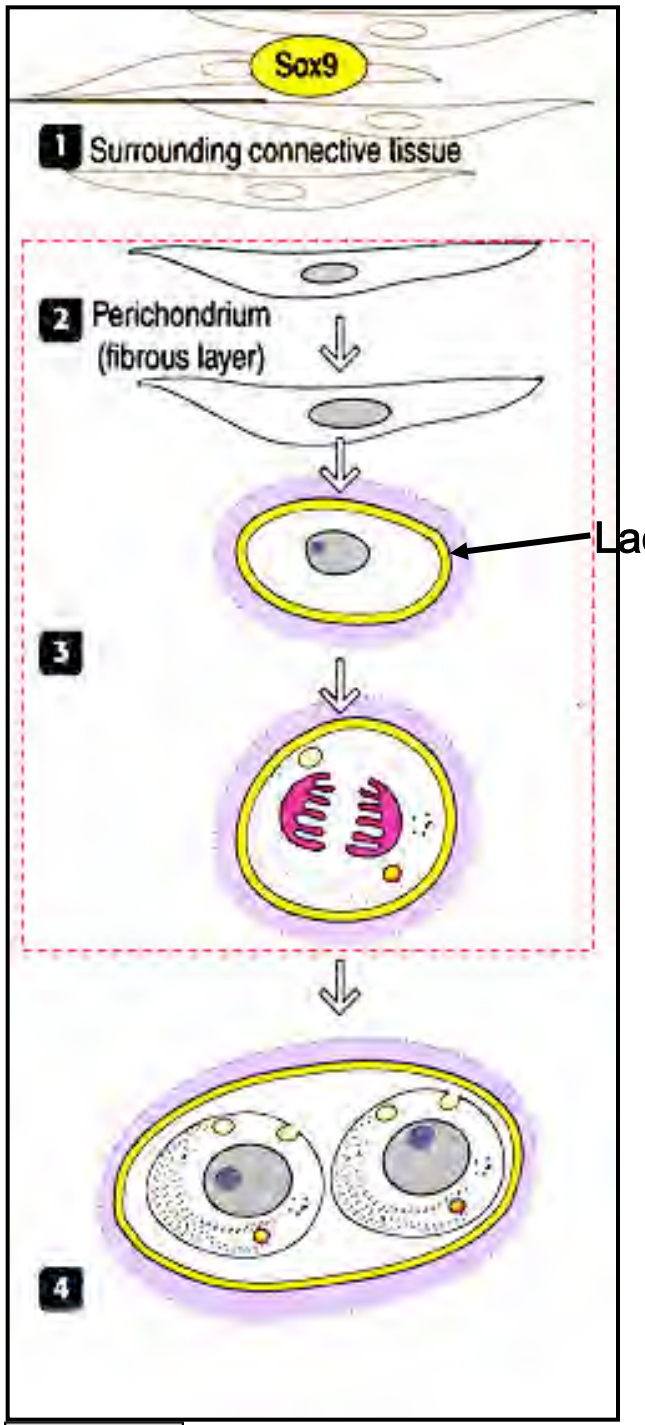
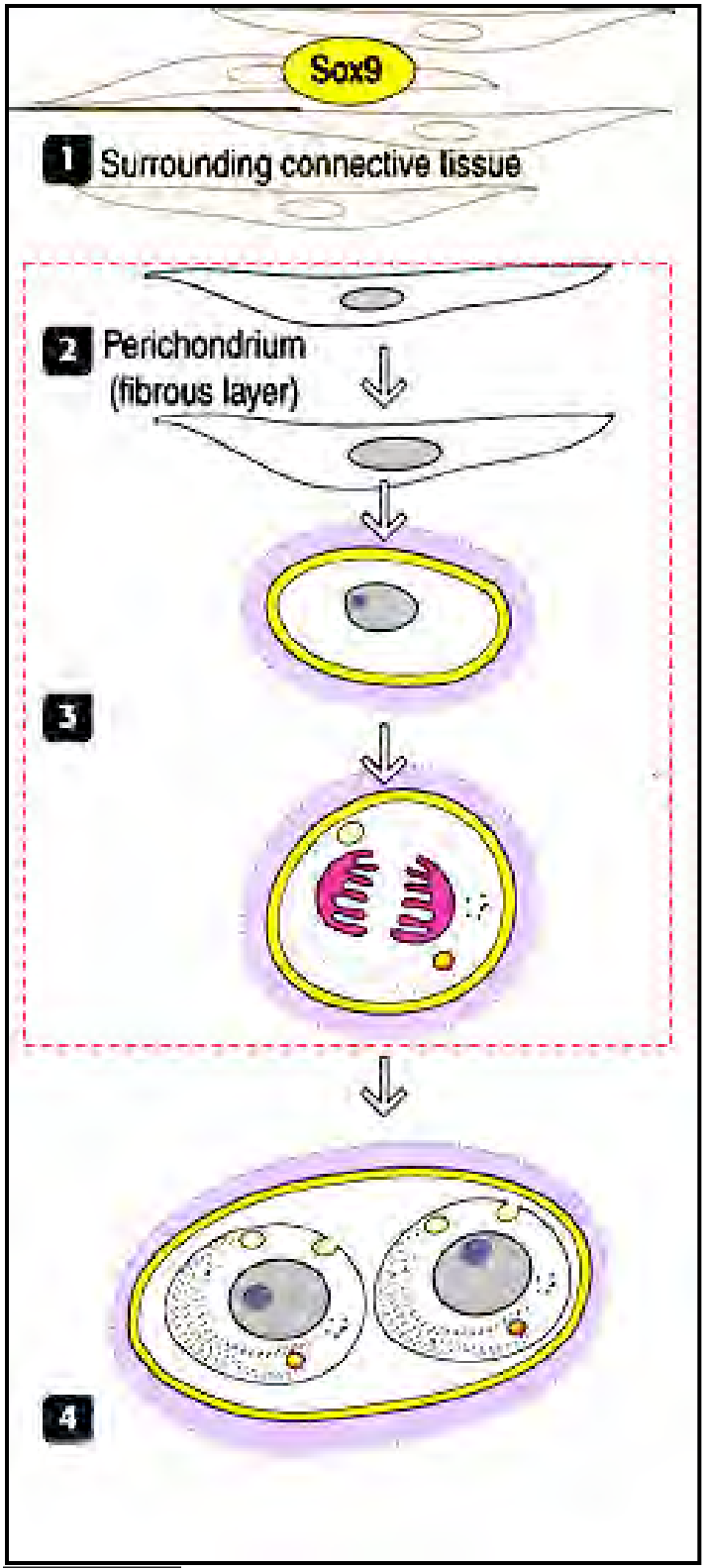
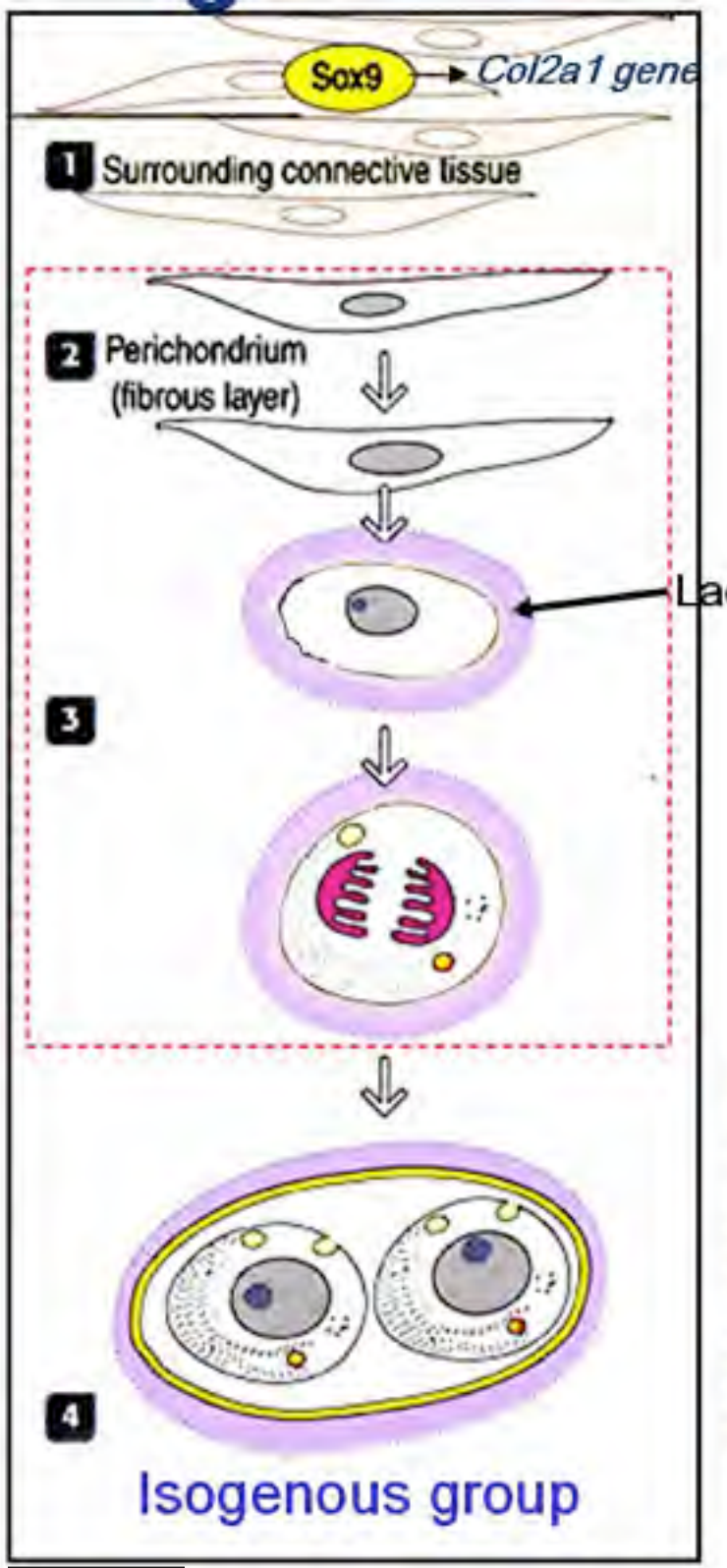


PD-INEL Kierszenbaum, p. 115



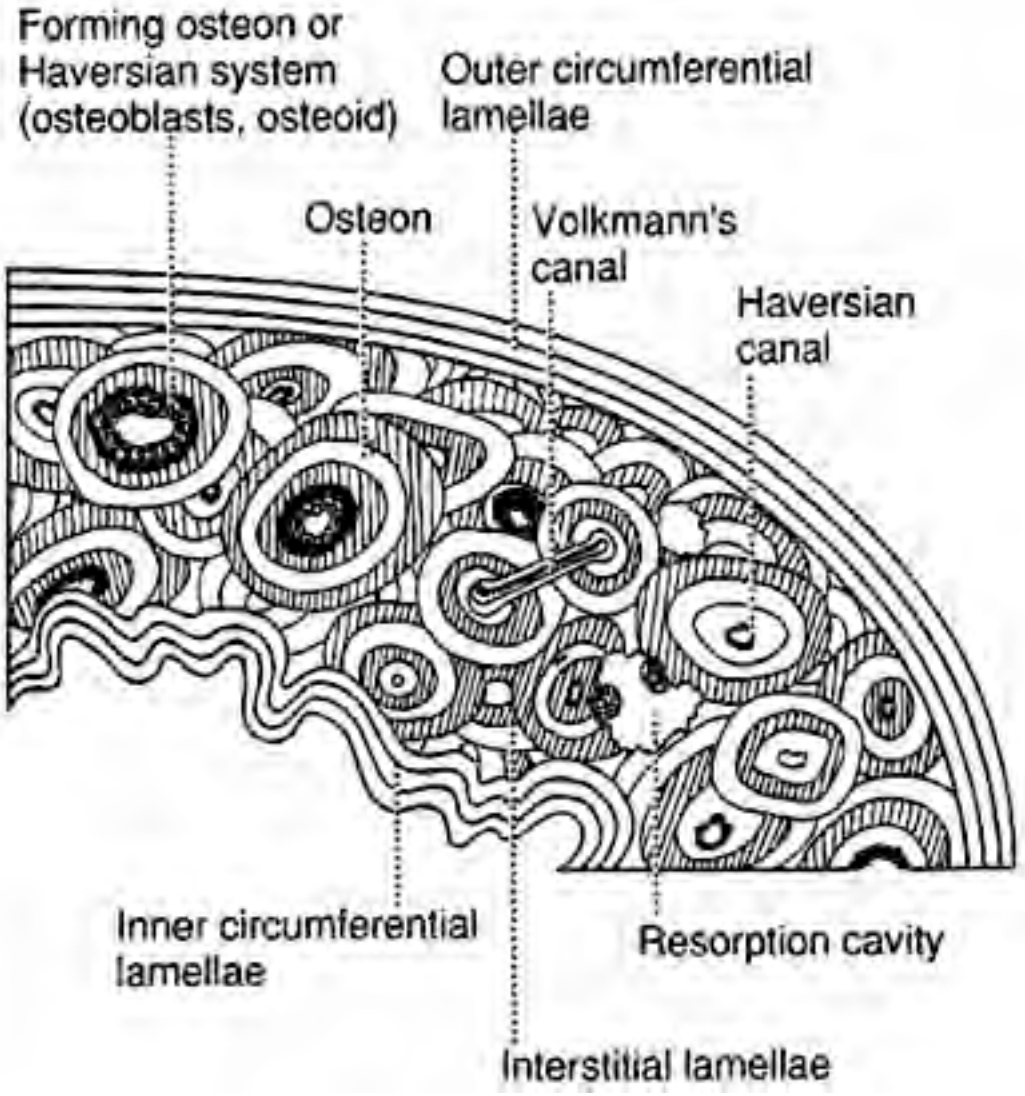
 Kierszenbaum, p. 115



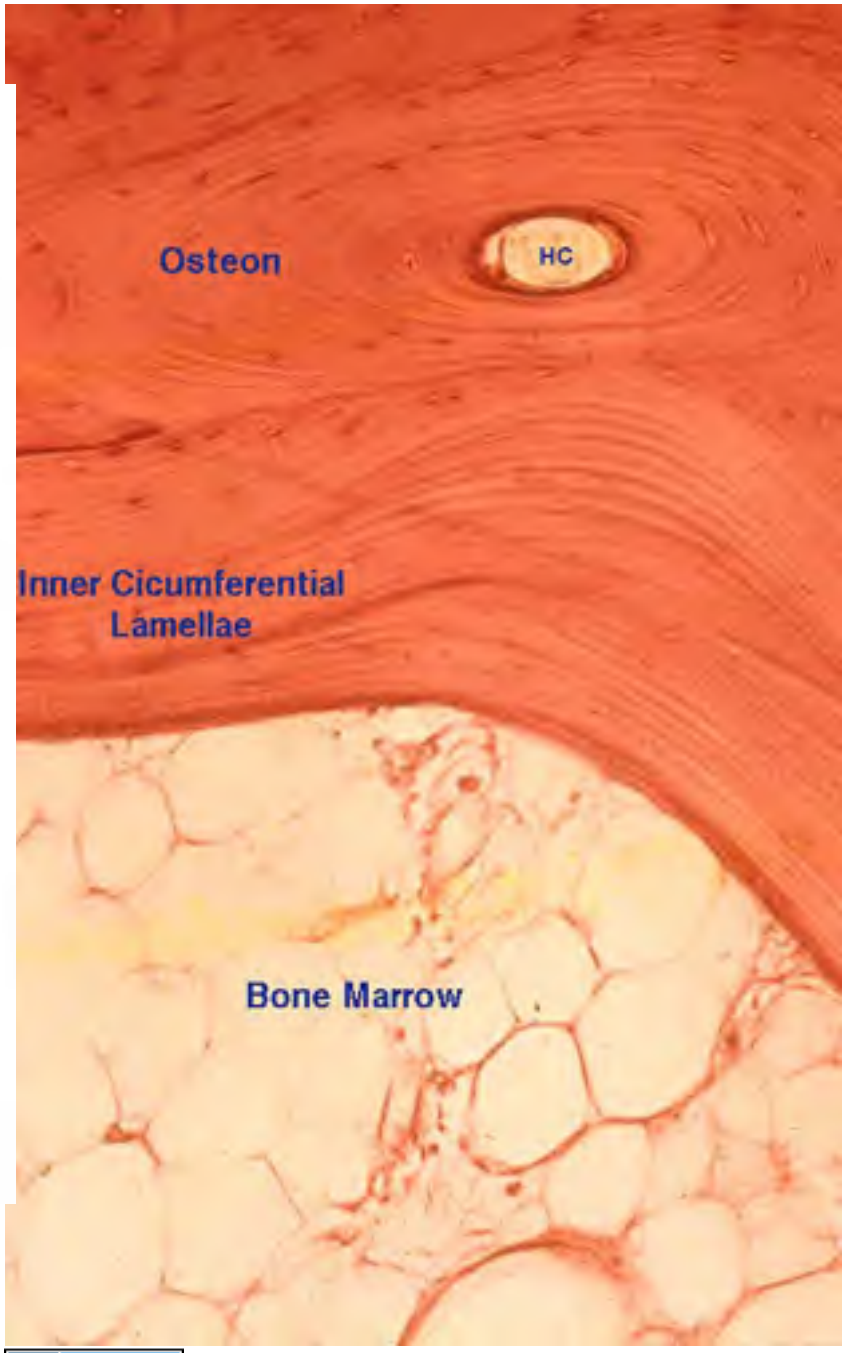
 Kierszenbaum, p. 115

Kierszenbaum, p. 115

Inner and outer circumferential lamellae

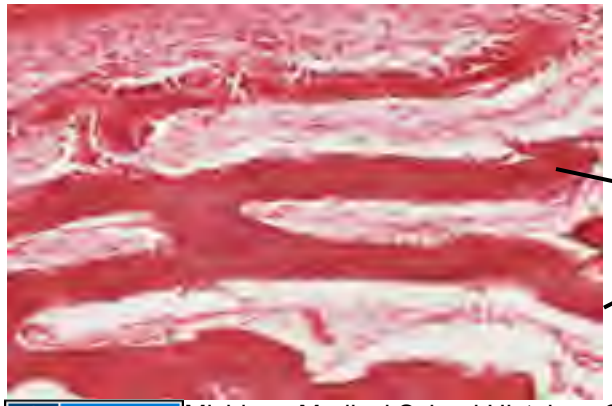


PD-INEL Weiss, 6th ed., p. 222



PD-INEL Source Undetermined

Sponge, cancellous or trabecular Bone



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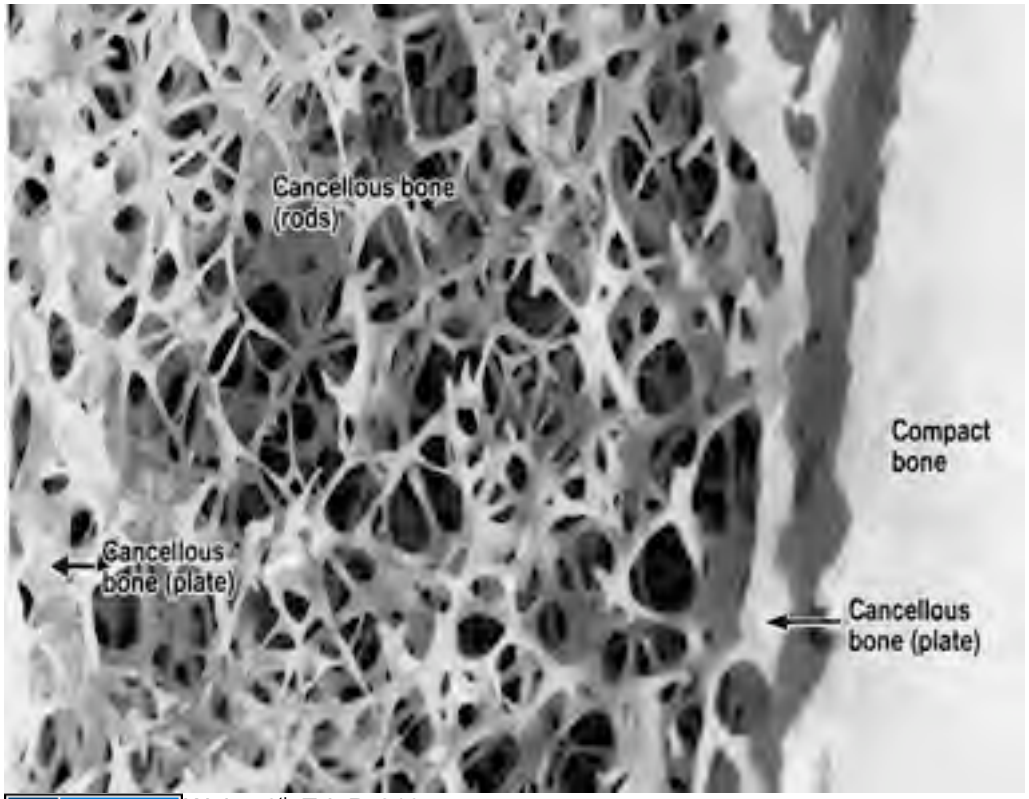
Bony spicules form trabeculae or trabecular network



PD-INEL Weiss 6th Ed. P. 219

Cells of bone

PD-INEL Michigan Medical School Histology Slide Collection

Bone Formation

Intramembranous Ossification:

Forms directly from the embryonic mesenchyme.

(Most flat bones of the skull and face)

Endochondral Ossification:

Initially hyaline cartilage model is formed, which is replaced by bone.

(Long bones of the extremities)

Basic Mechanism of Bone Formation

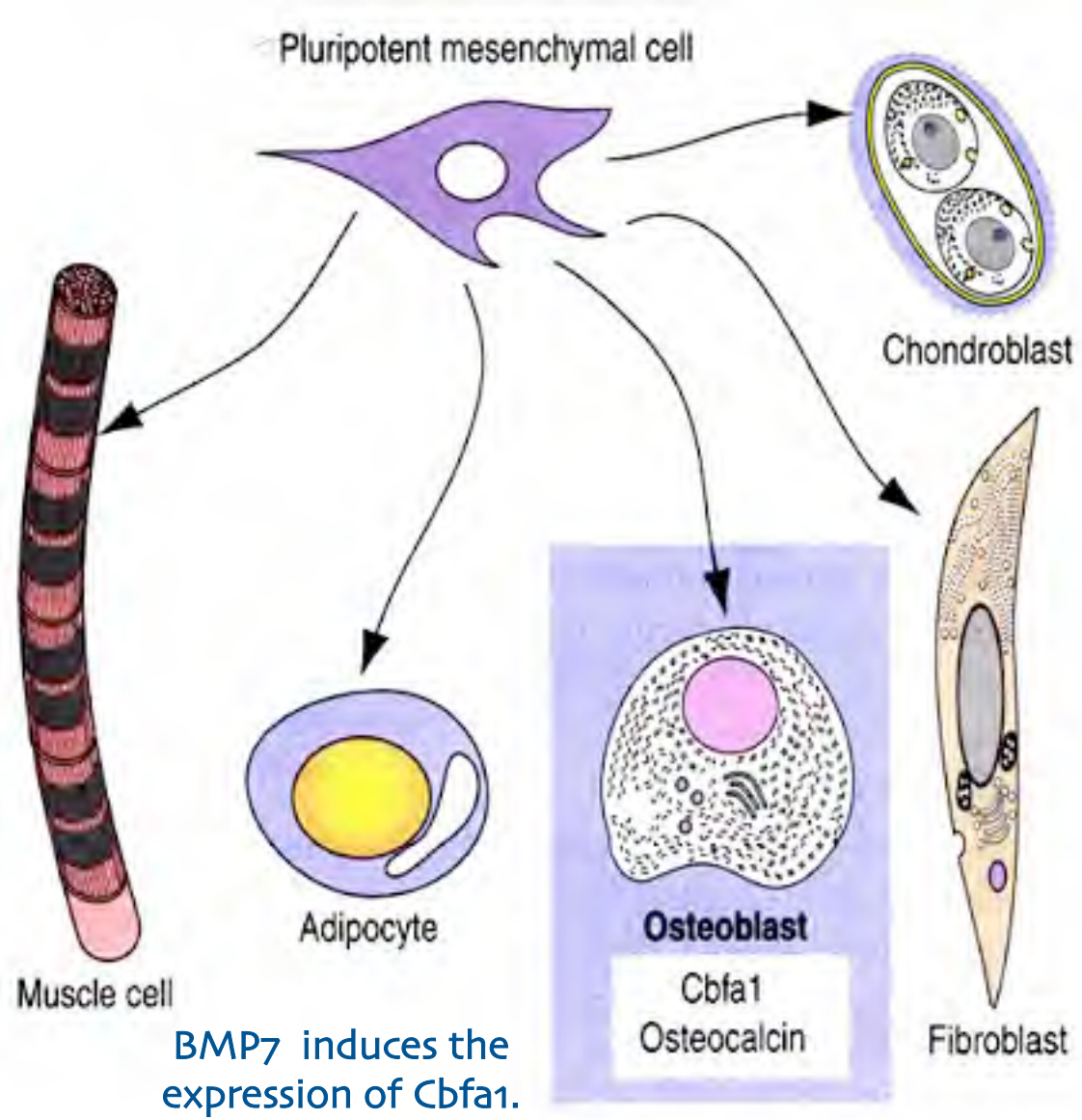
The process of bone deposition is the same in both endochondral and intramembranous ossifications – osteoblasts laying down layers of bone.

Both endochondrial and intramembranous bone formations can make spongy and compact bone.

Long bones start as cartilage and so form endochondrally. Flat bones do not begin as cartilage but rather form intramembranously.

In both types of formation, however, at the cellular level, bone is deposited appositionally.

Osteoblast Differentiation

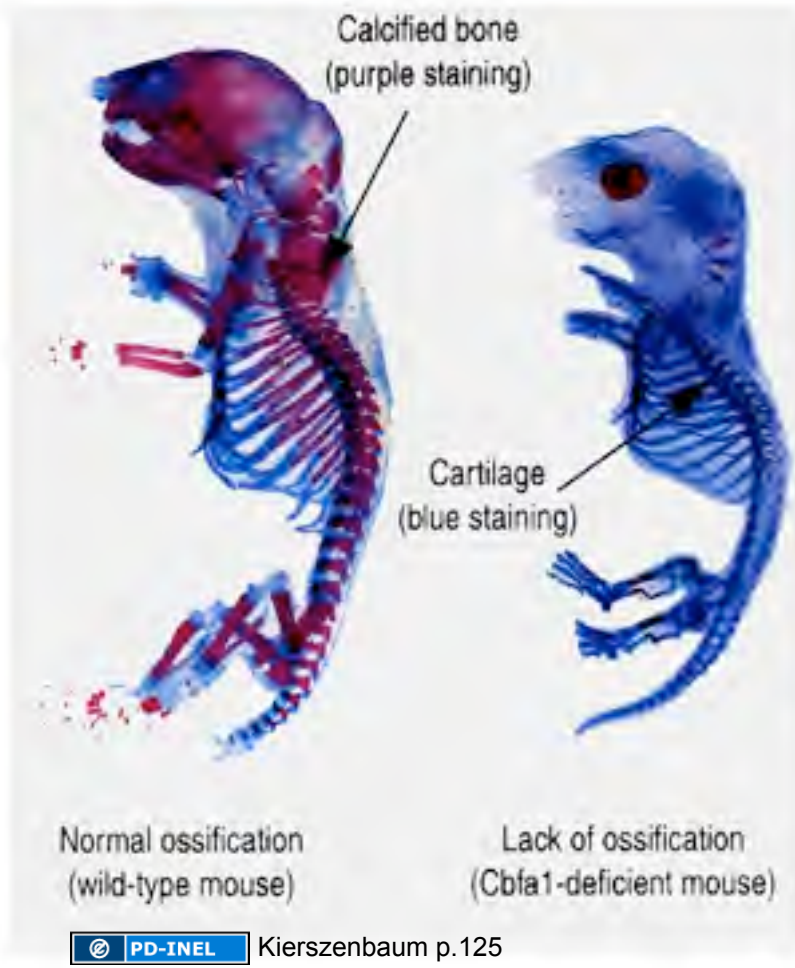


BMP7 induces the expression of Cbfa1.

BMP: bone morphogenetic protein

Cbfa 1: core binding factor family gene

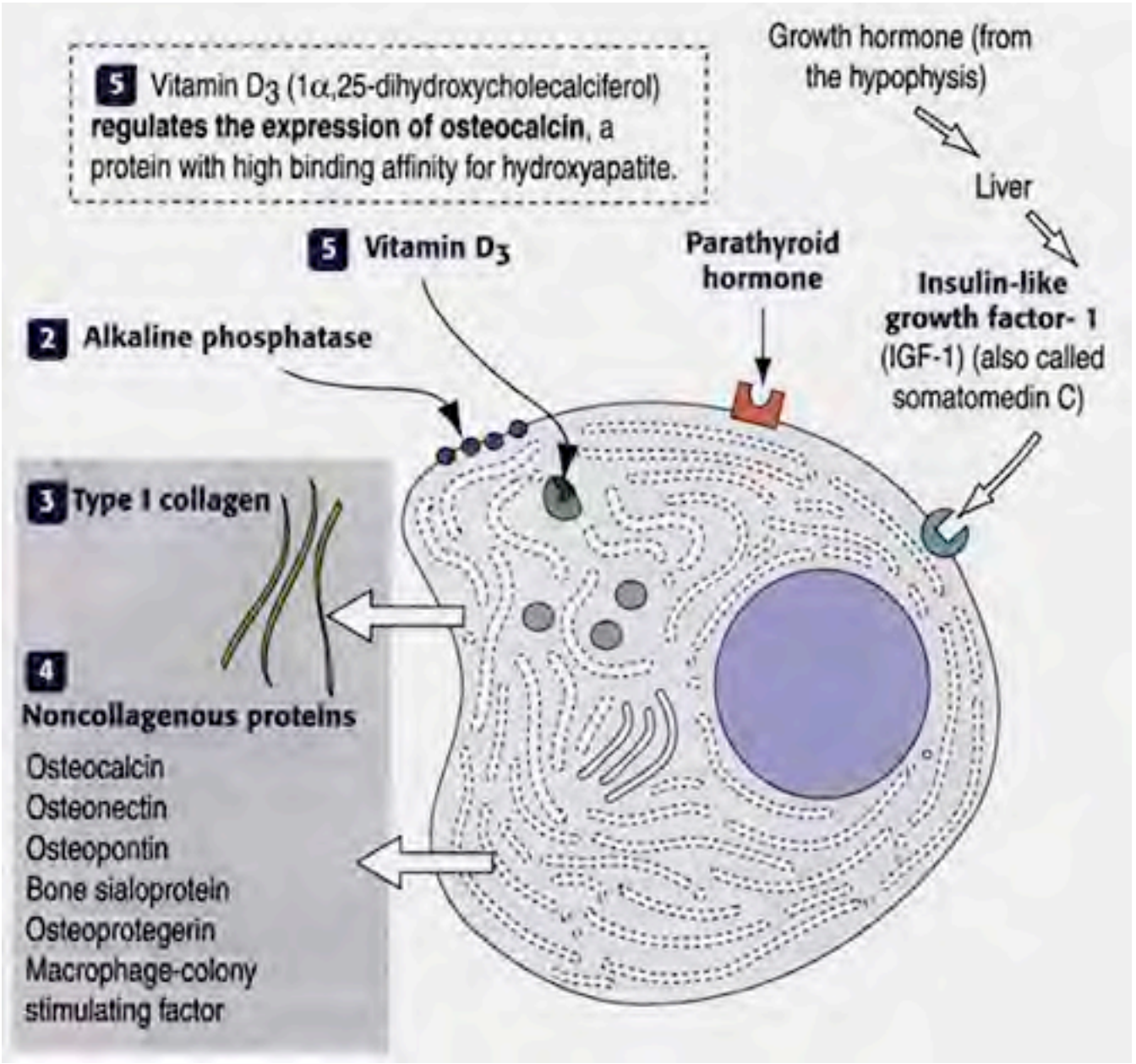
Cbfa1-deficient mice



PD-INEL Kierszenbaum p.125

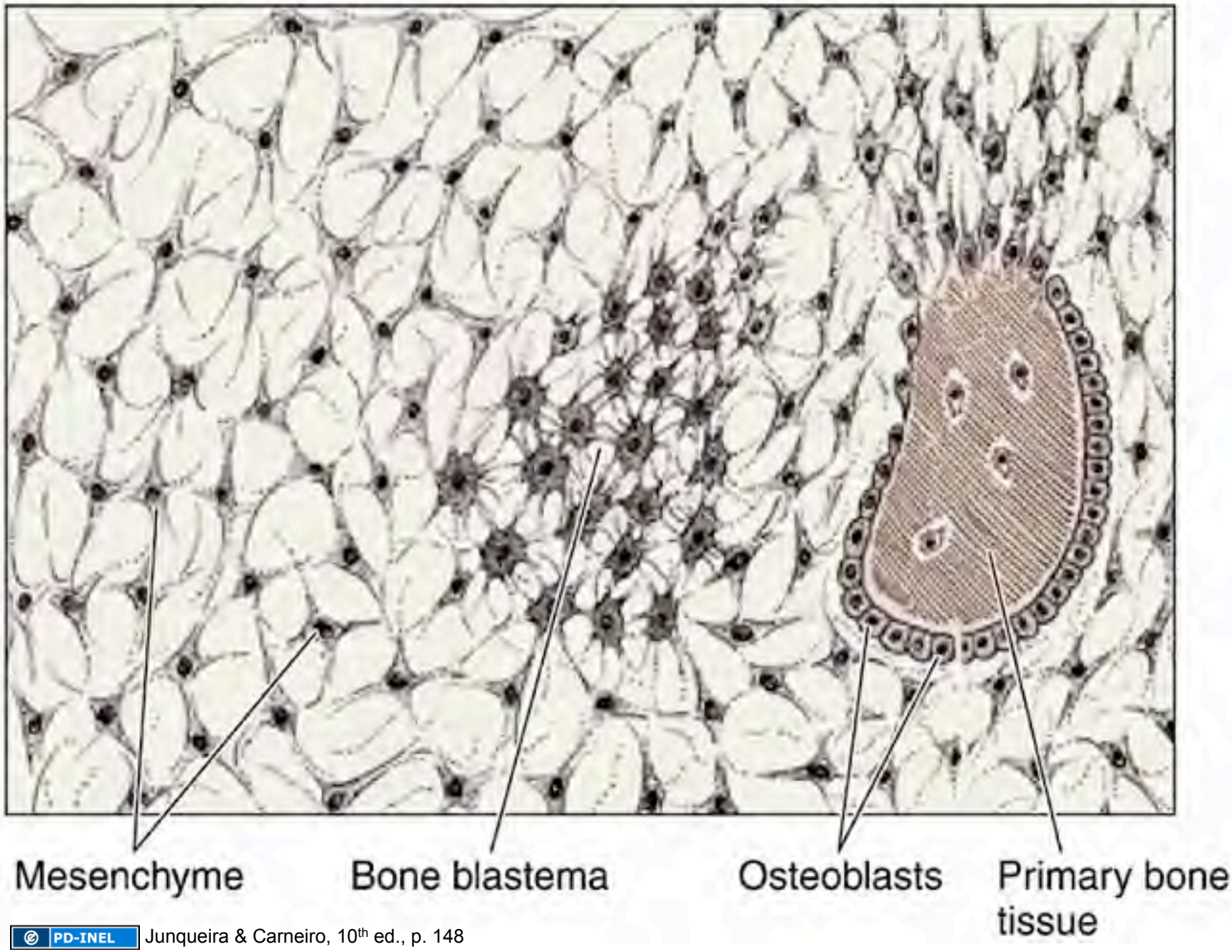
PD-INEL Kierszenbaum, p. 125

Osteoblast



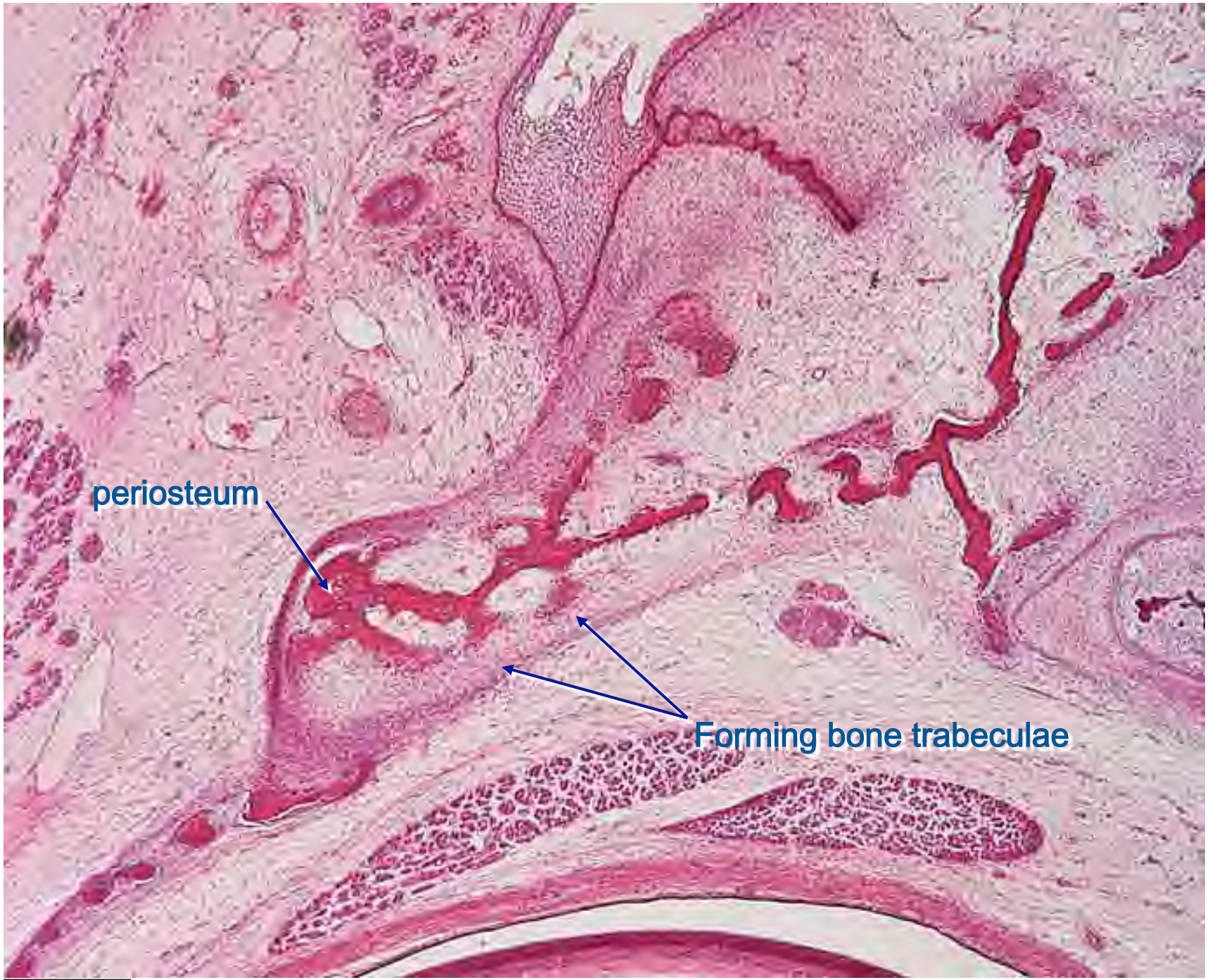
 Kierszenbaum p. 122

Mesenchymal cells and Center of Osteogenesis

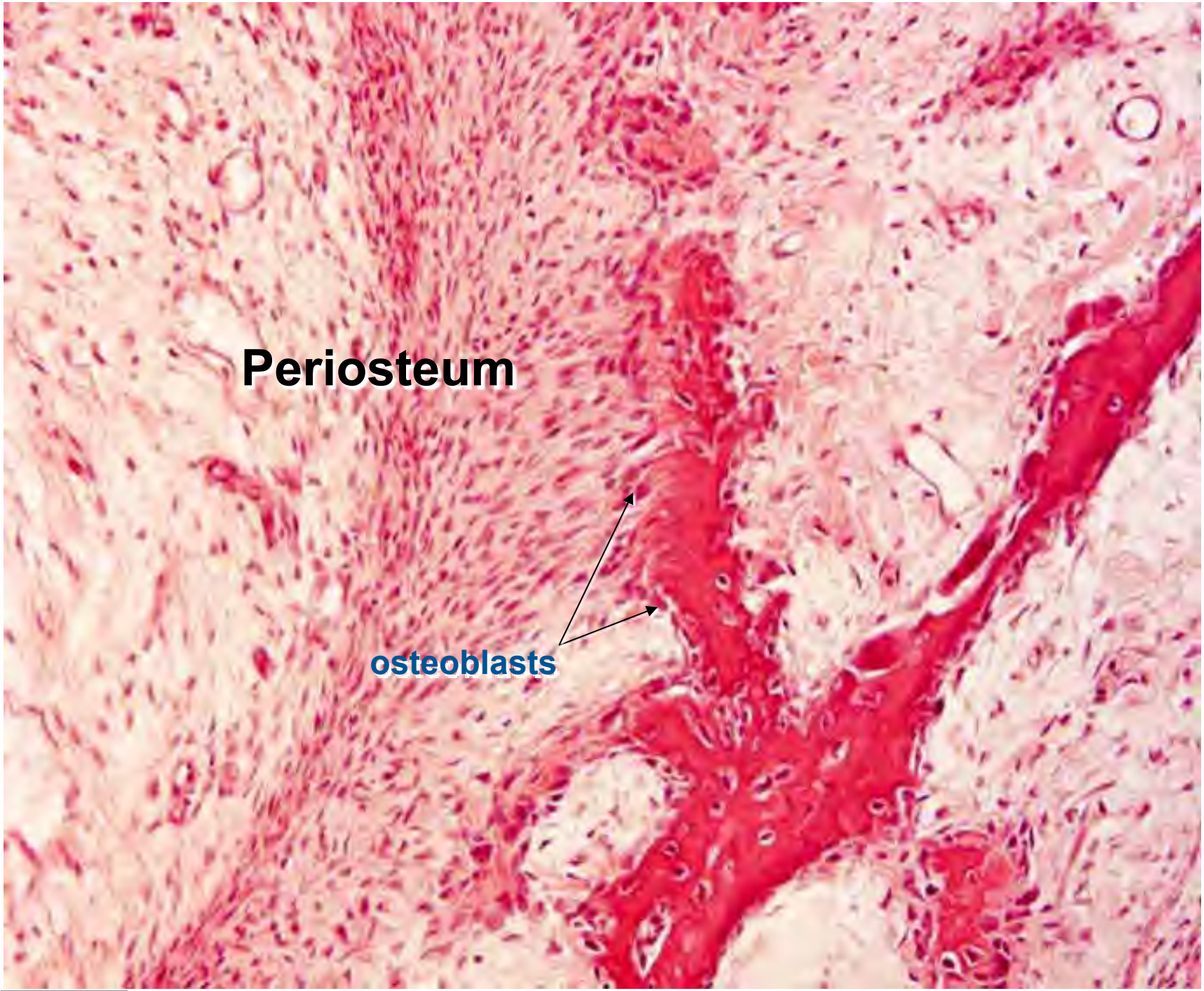


 Junqueira & Carneiro, 10th ed., p. 148

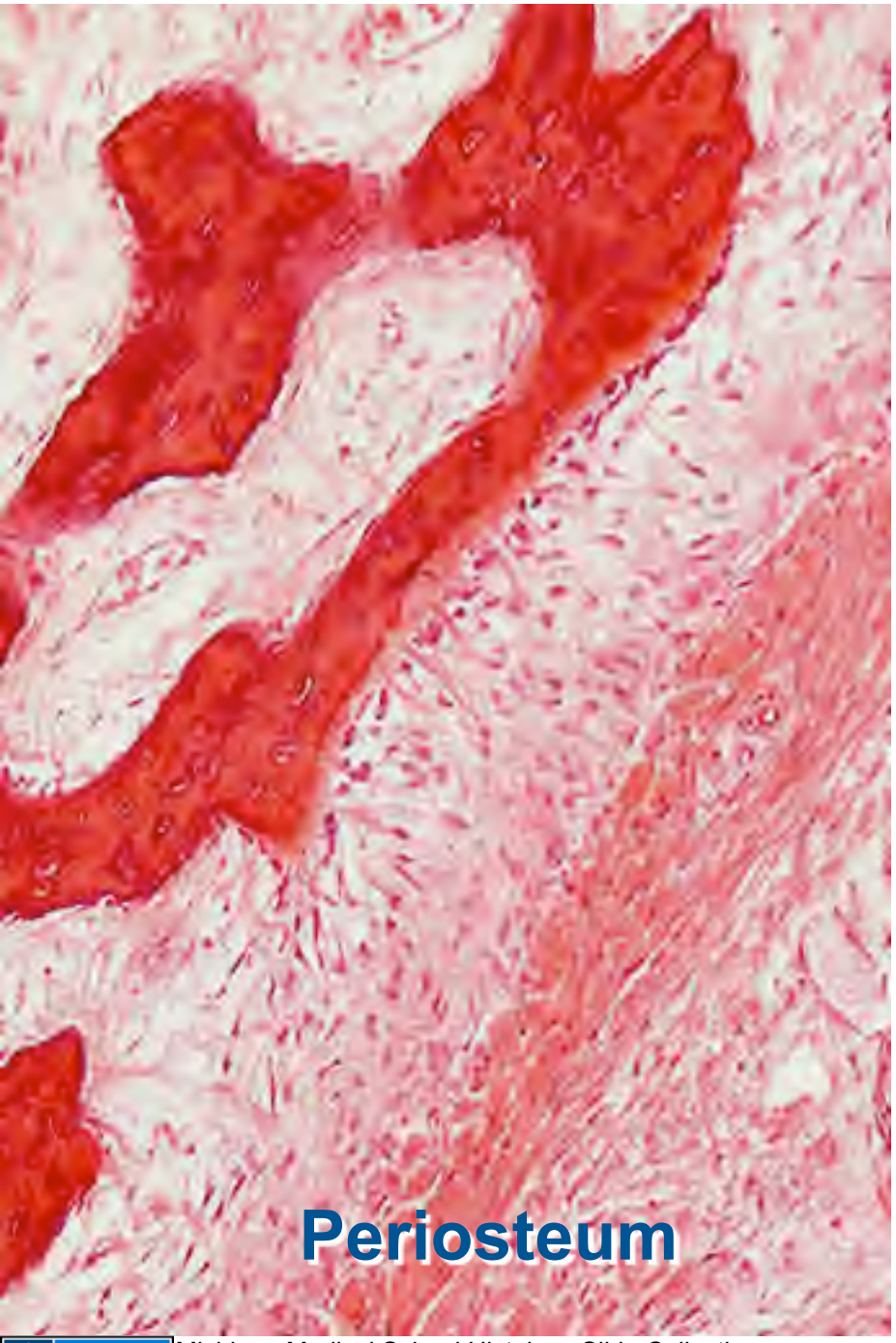
Intramembranous Bone Formation



Intramembranous Bone Formation



Sharpey's Fibers



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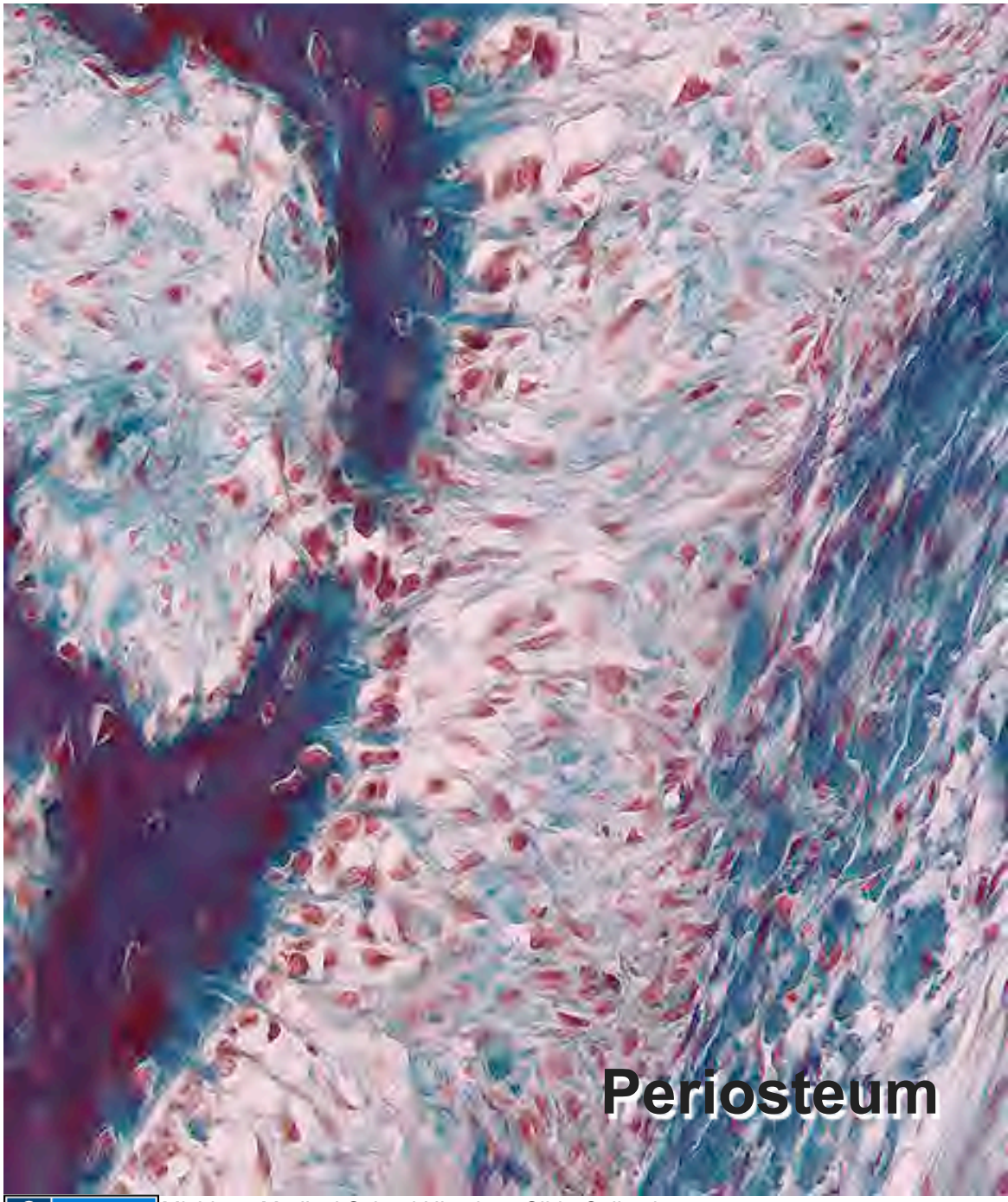

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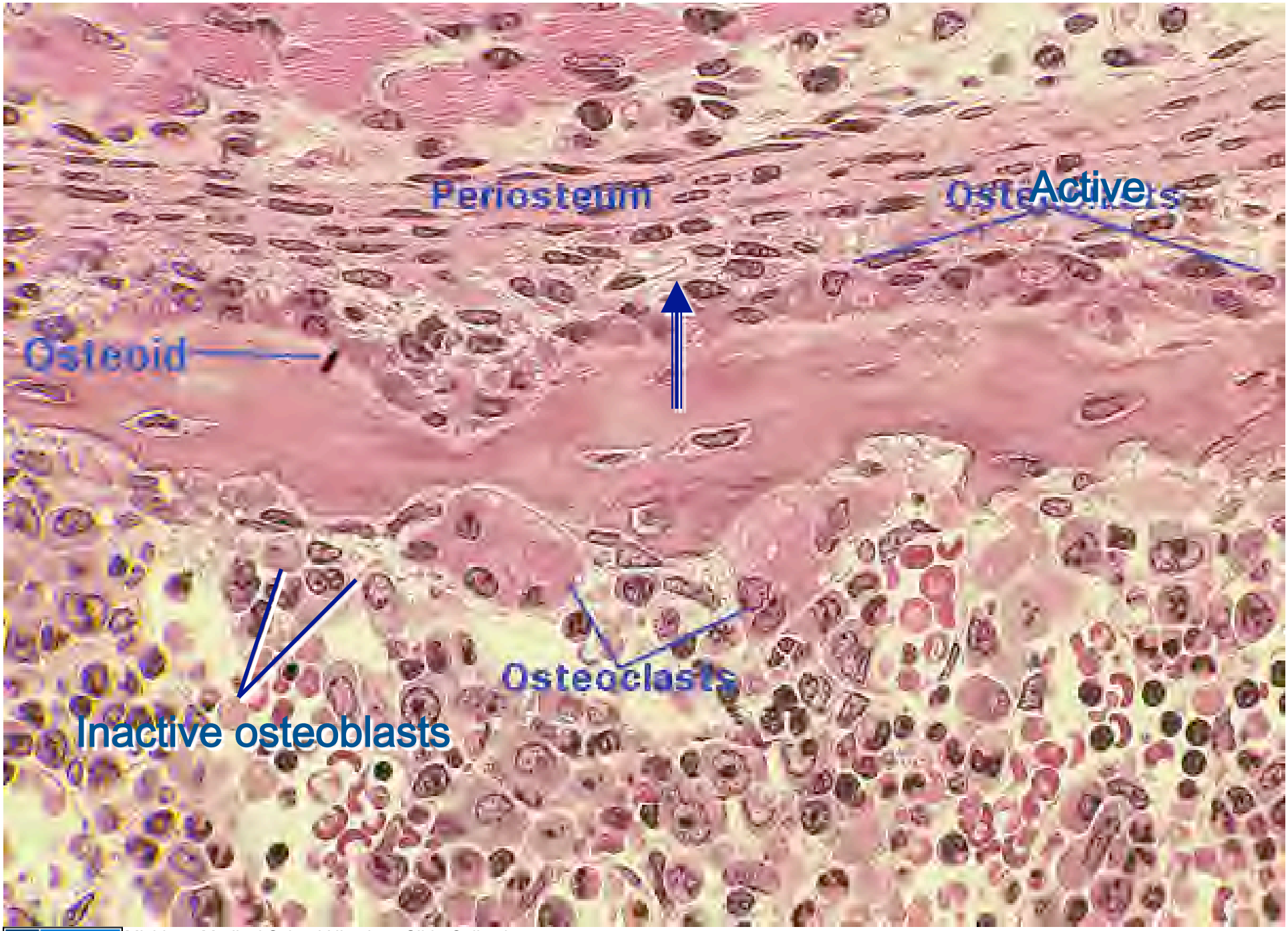
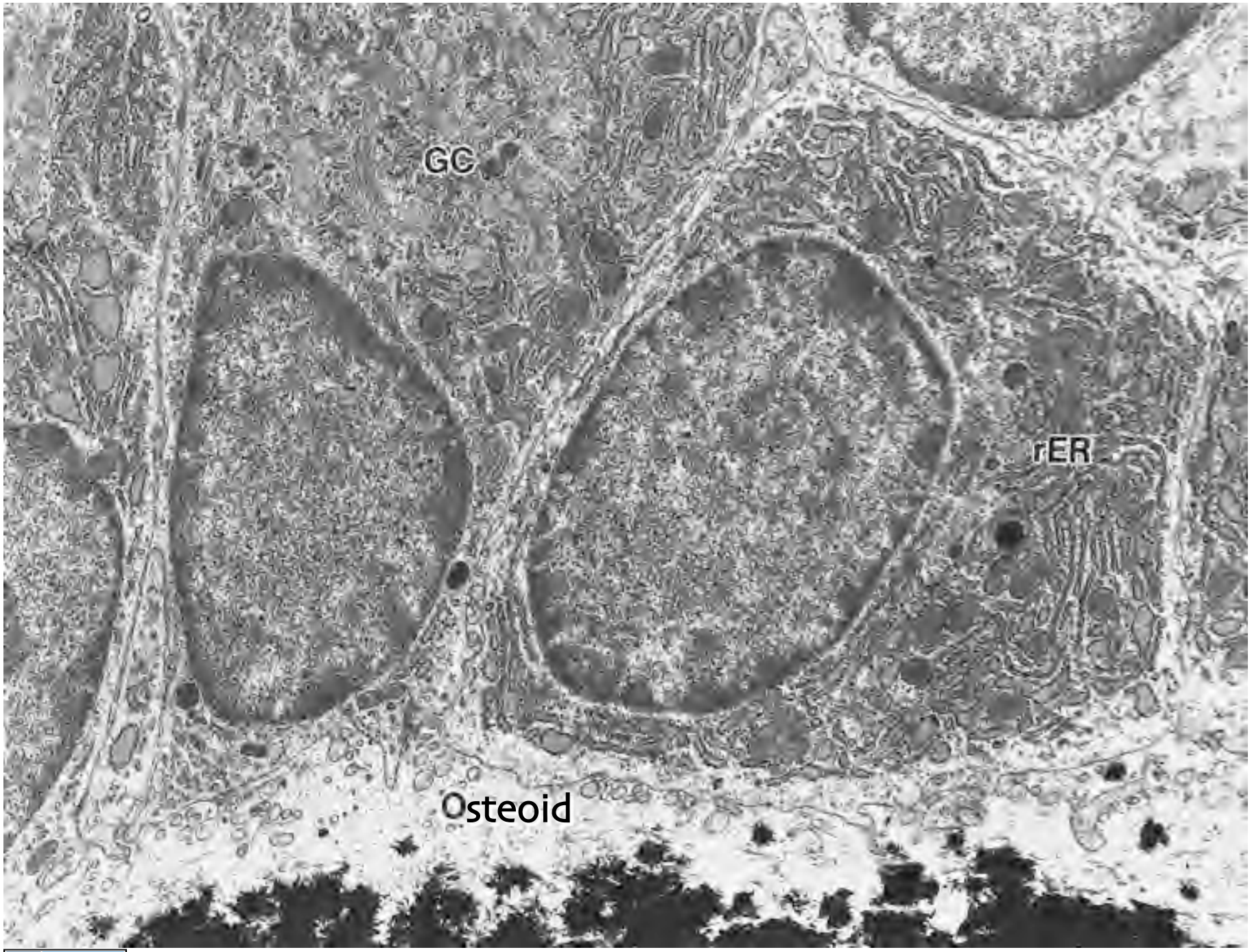
Bone forming cells and bone modeling

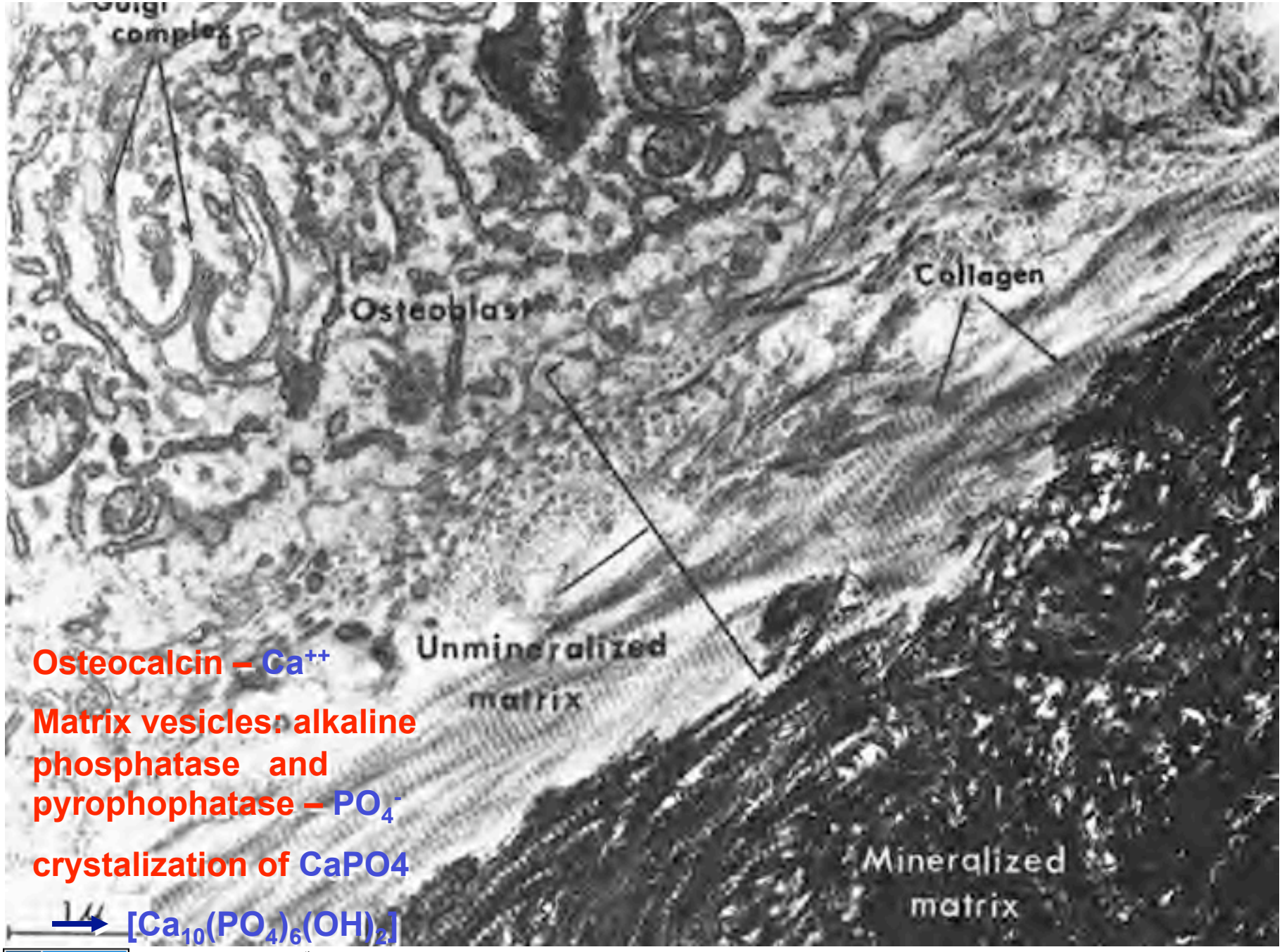


EM of Active Osteoblasts



PD-INEL Weiss, 6th ed., p. 225

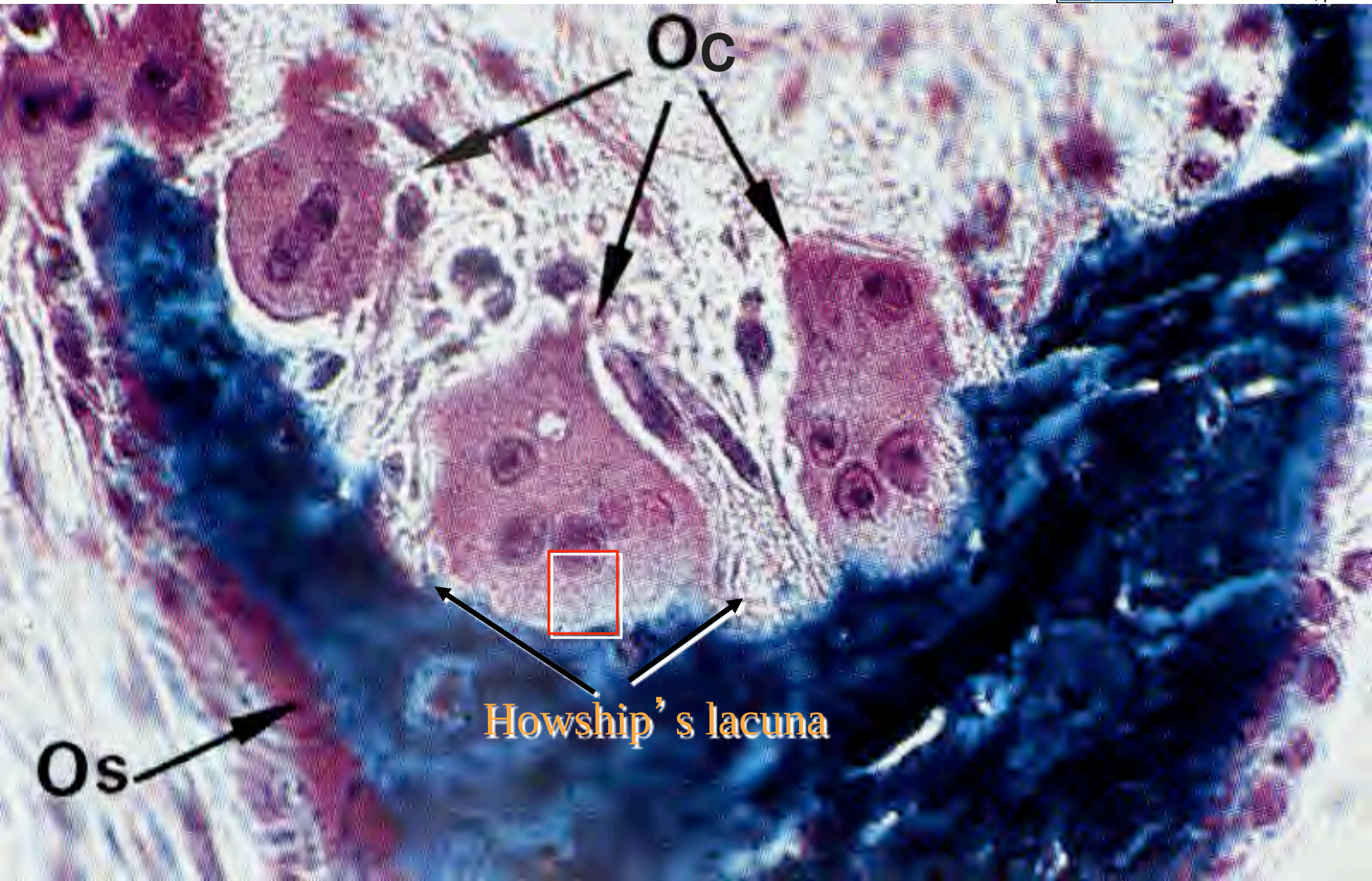
Unmineralized (osteoid) and Mineralized Bone



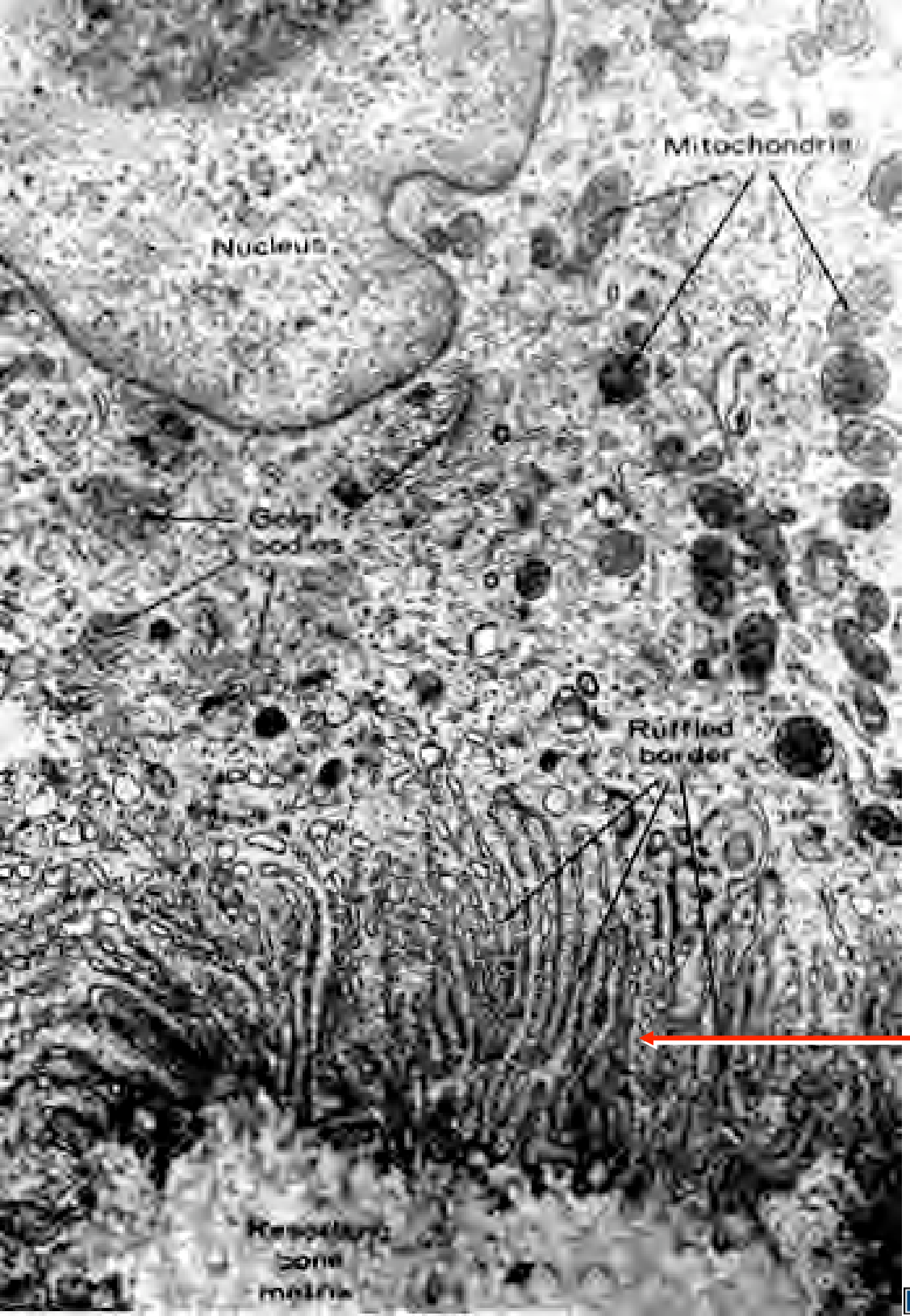
 Bloom & Fawcett, 12th ed., p. 205

Osteoclasts

PD-INEL Wheater's 5th ed., p. 190



Osteoclast (EM)



Note the ruffled border of the cell and resorbing bone matrix

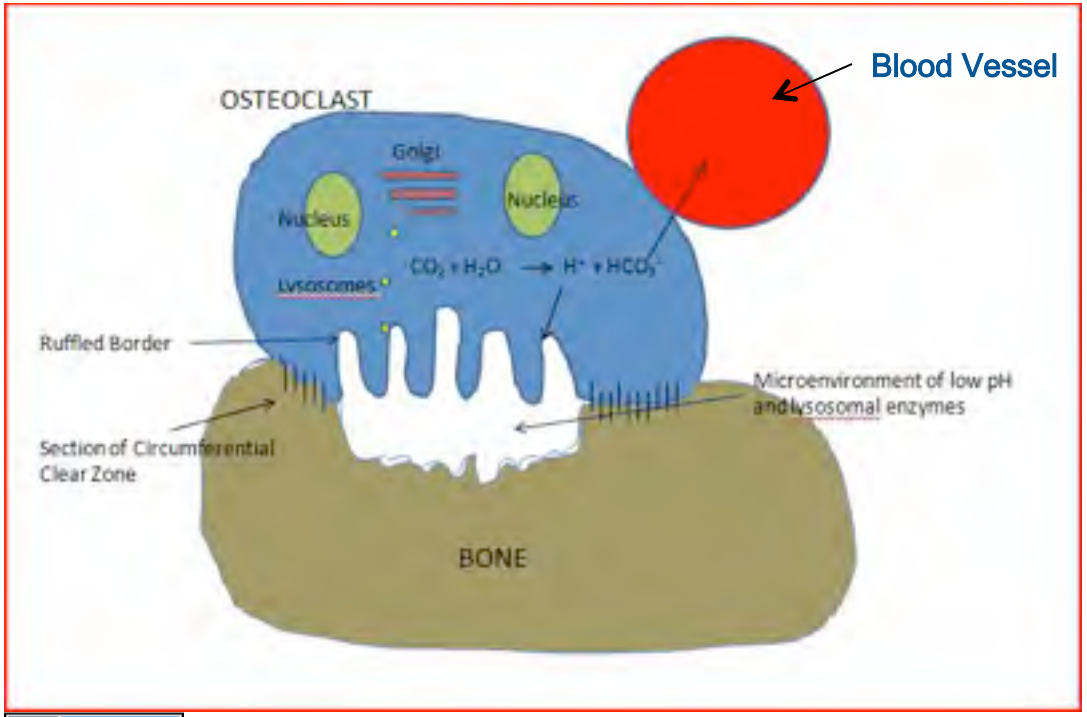
Ruffled border

 Bloom & Fawcett, 12th ed., p. 210

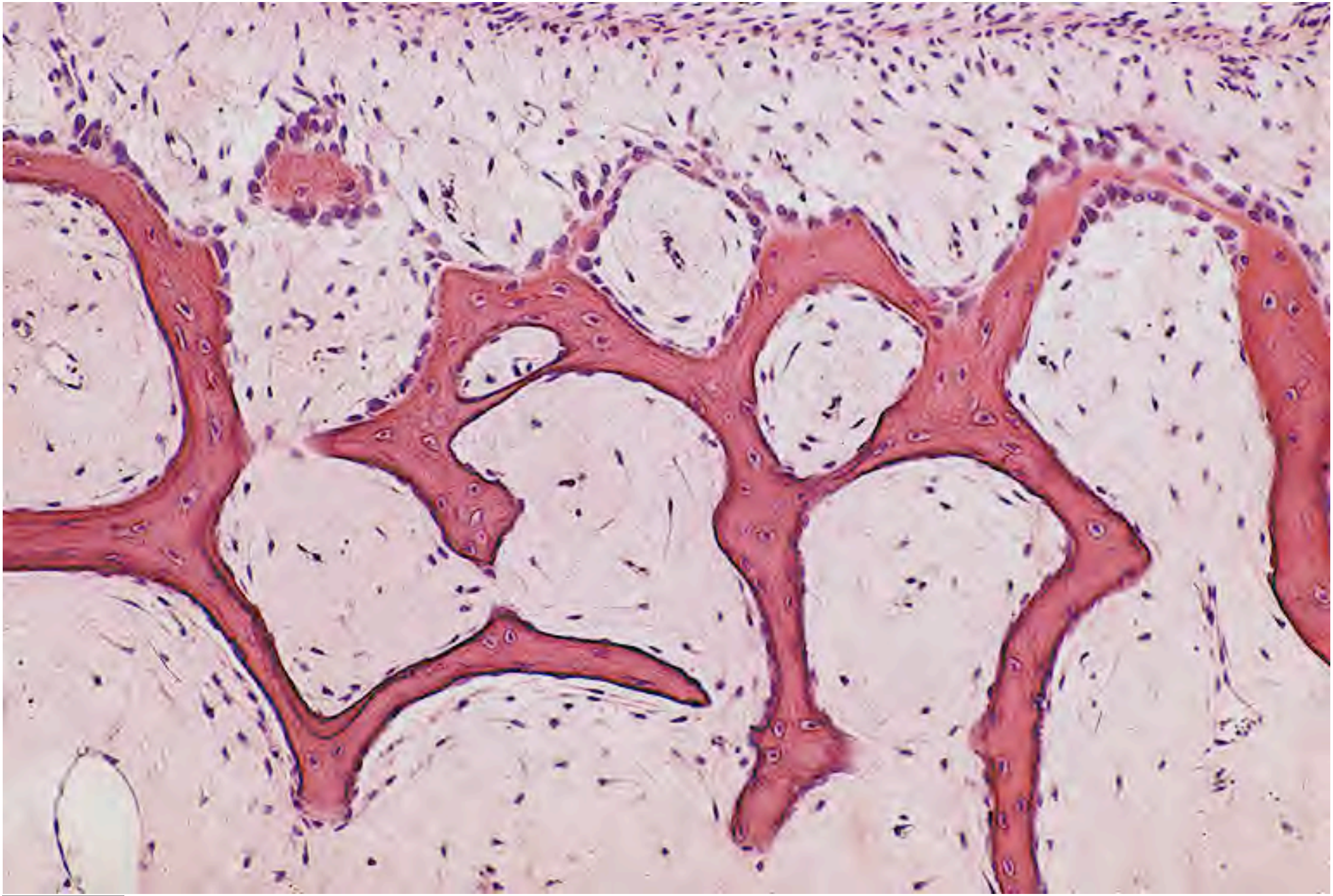
Osteoclast and Bone Resorption

Image of osteoclast physiologic activity removed

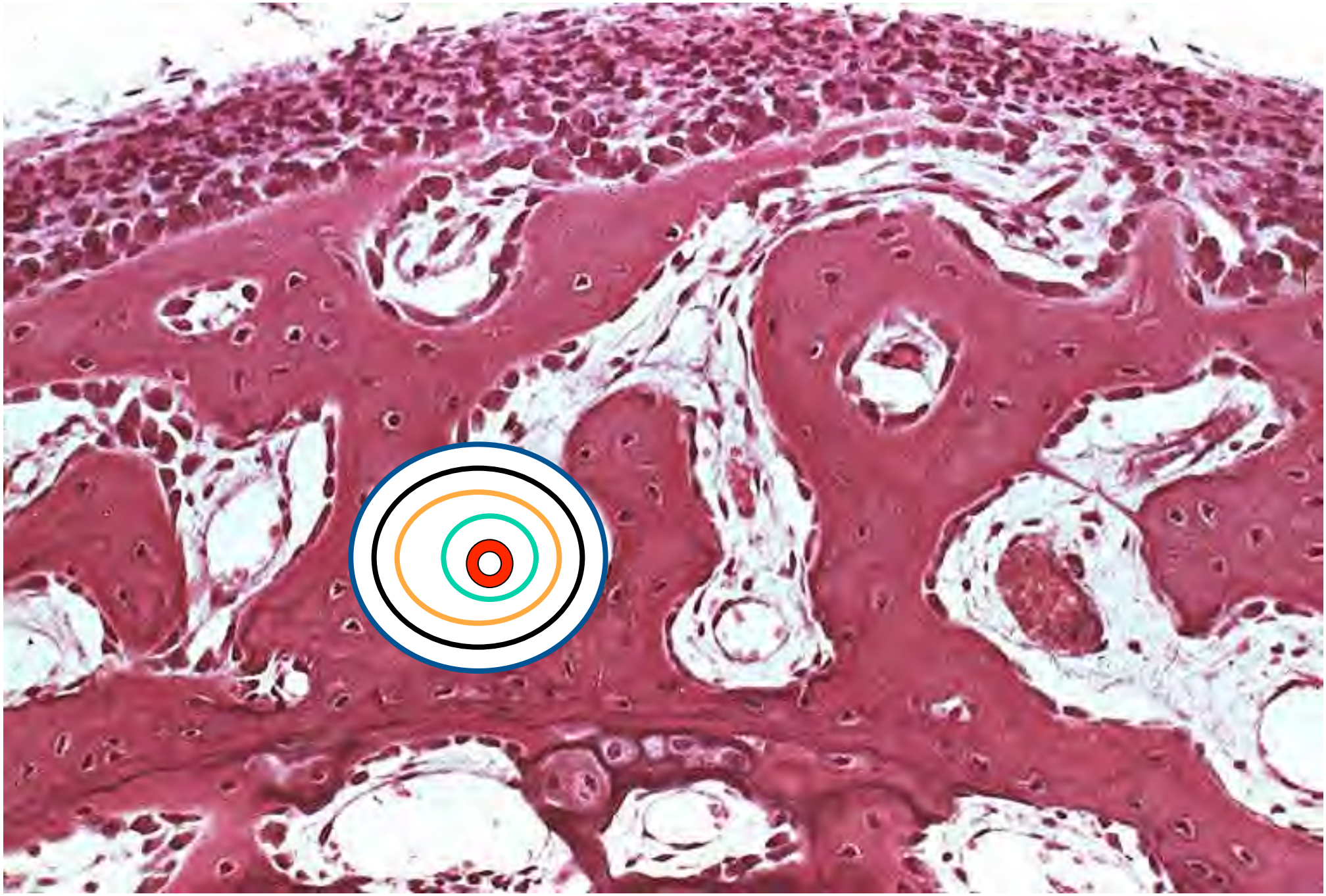
Original source: Kierszenbaum, p. 124



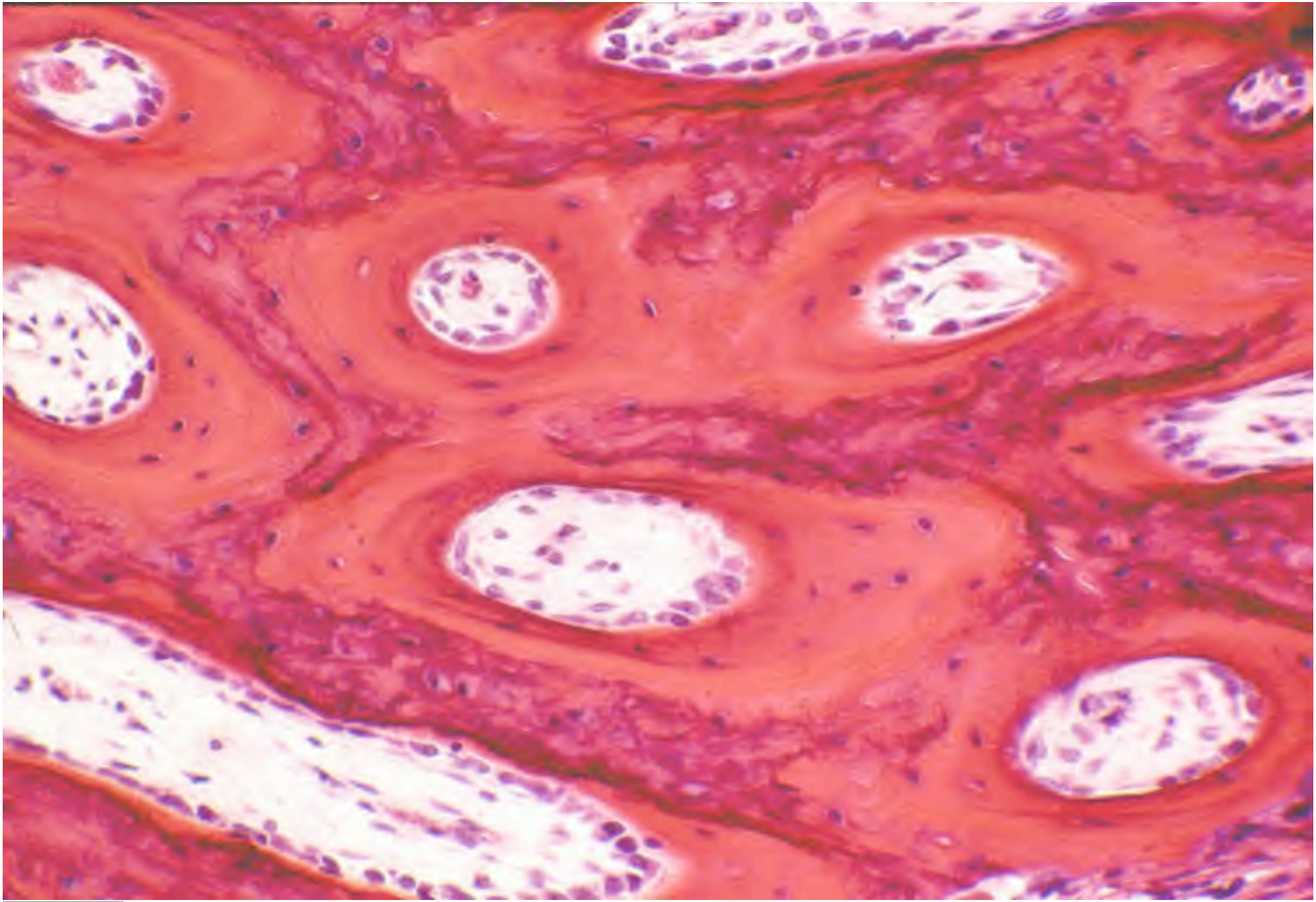
Formation of Bone Trabeculae



Conversion of trabecular bone to compact bone

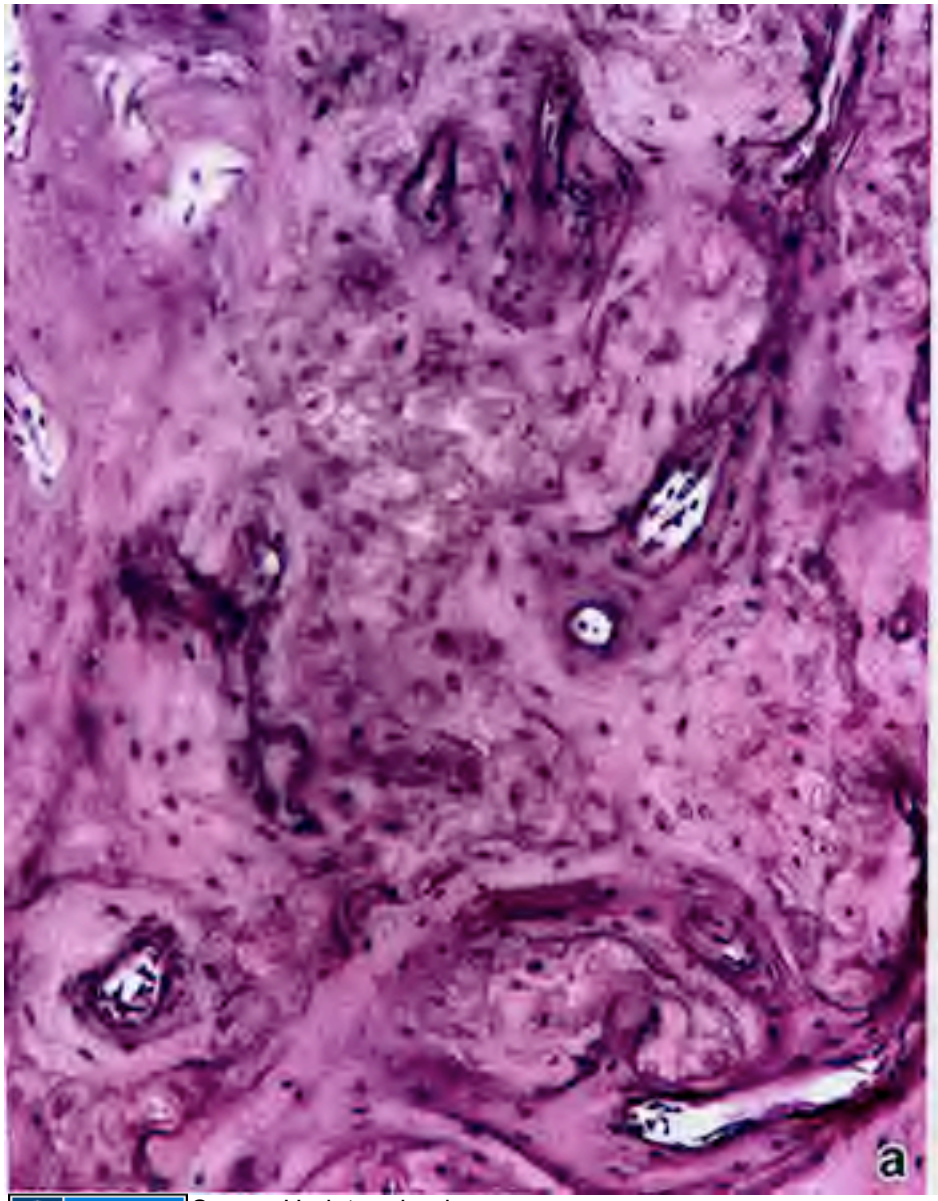


Formation of Osteons



Immature and Mature Bone

(nonlamellar, bundle, or woven bone)



Intramembranous ossification of facial (maxillary) bone

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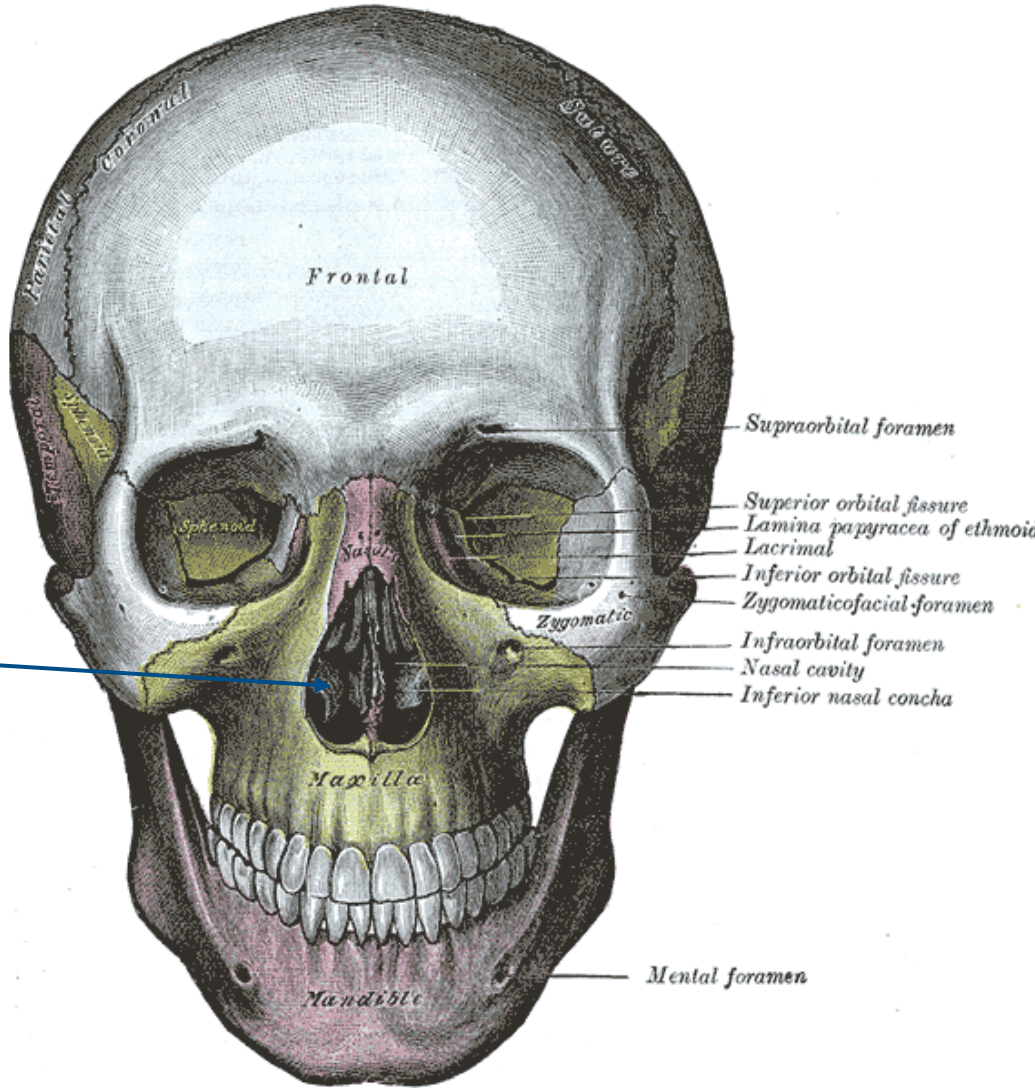
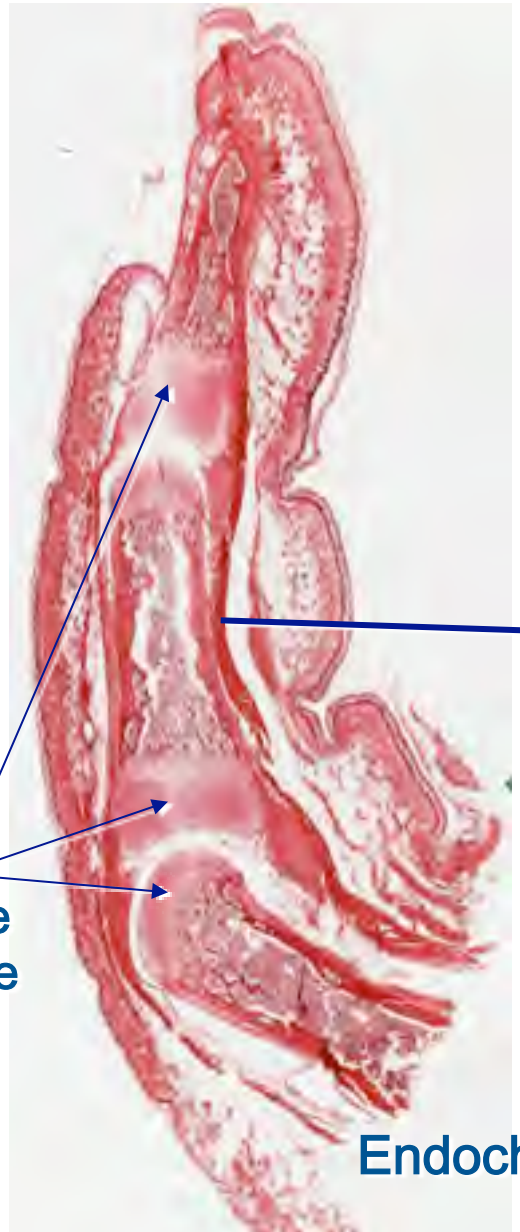


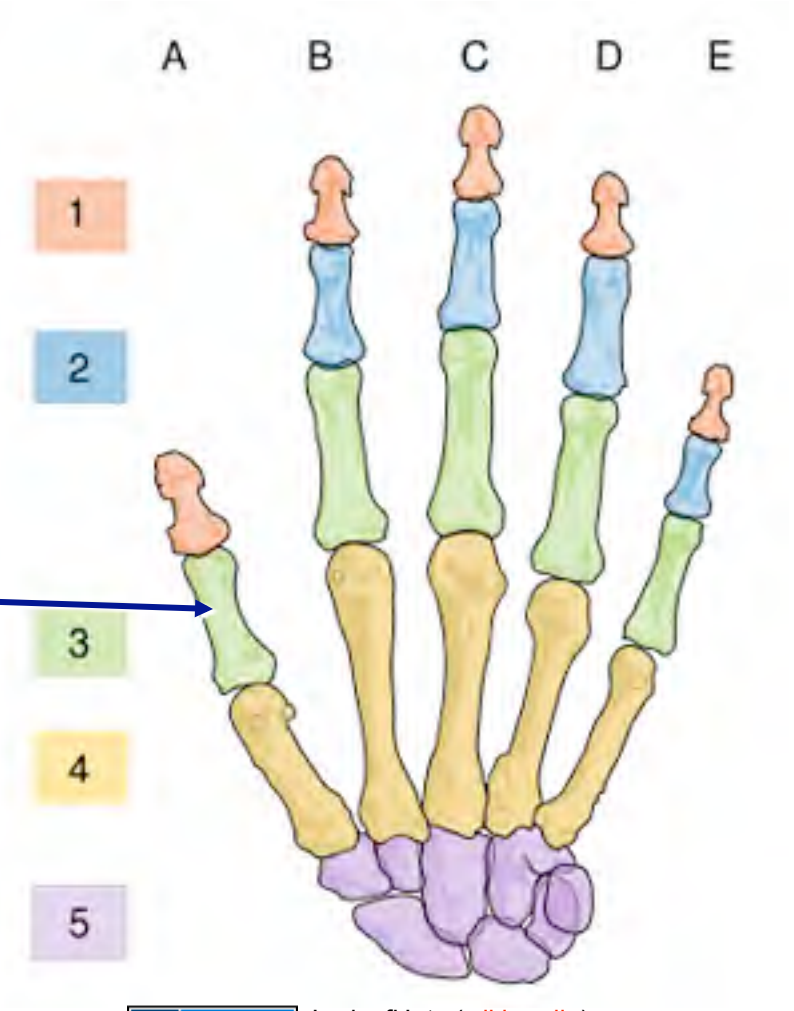
PD-EXP Gray's Anatomy (wikimedia)

Endochondral Bone Formation

Long bones start as cartilage and so form endochondrally. Flat bones form intramembranously and do not begin as cartilage.



Hyaline cartilage



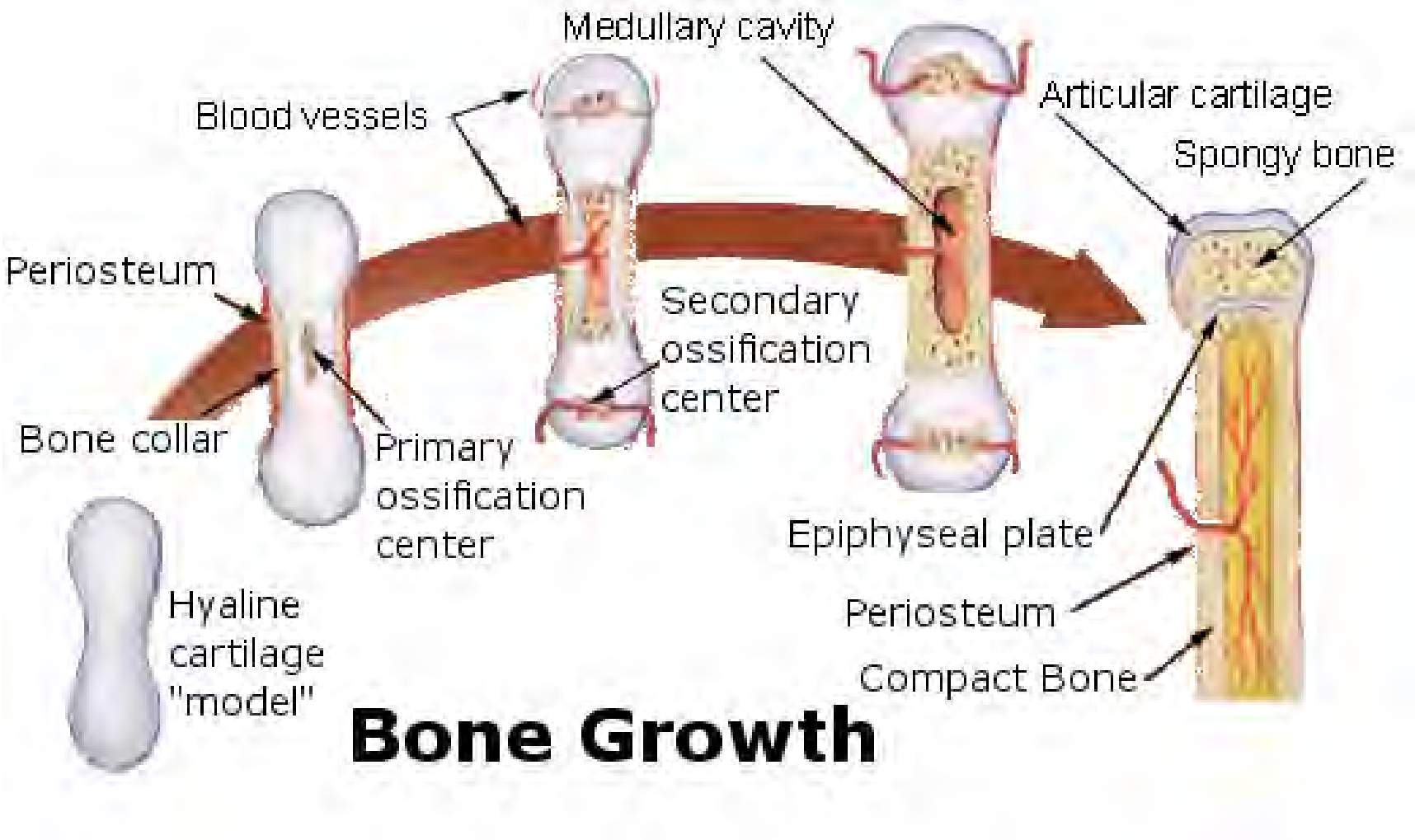
PD-SELF LadyofHats (wikimedia)

Endochondral ossification of phalanges (long bones)

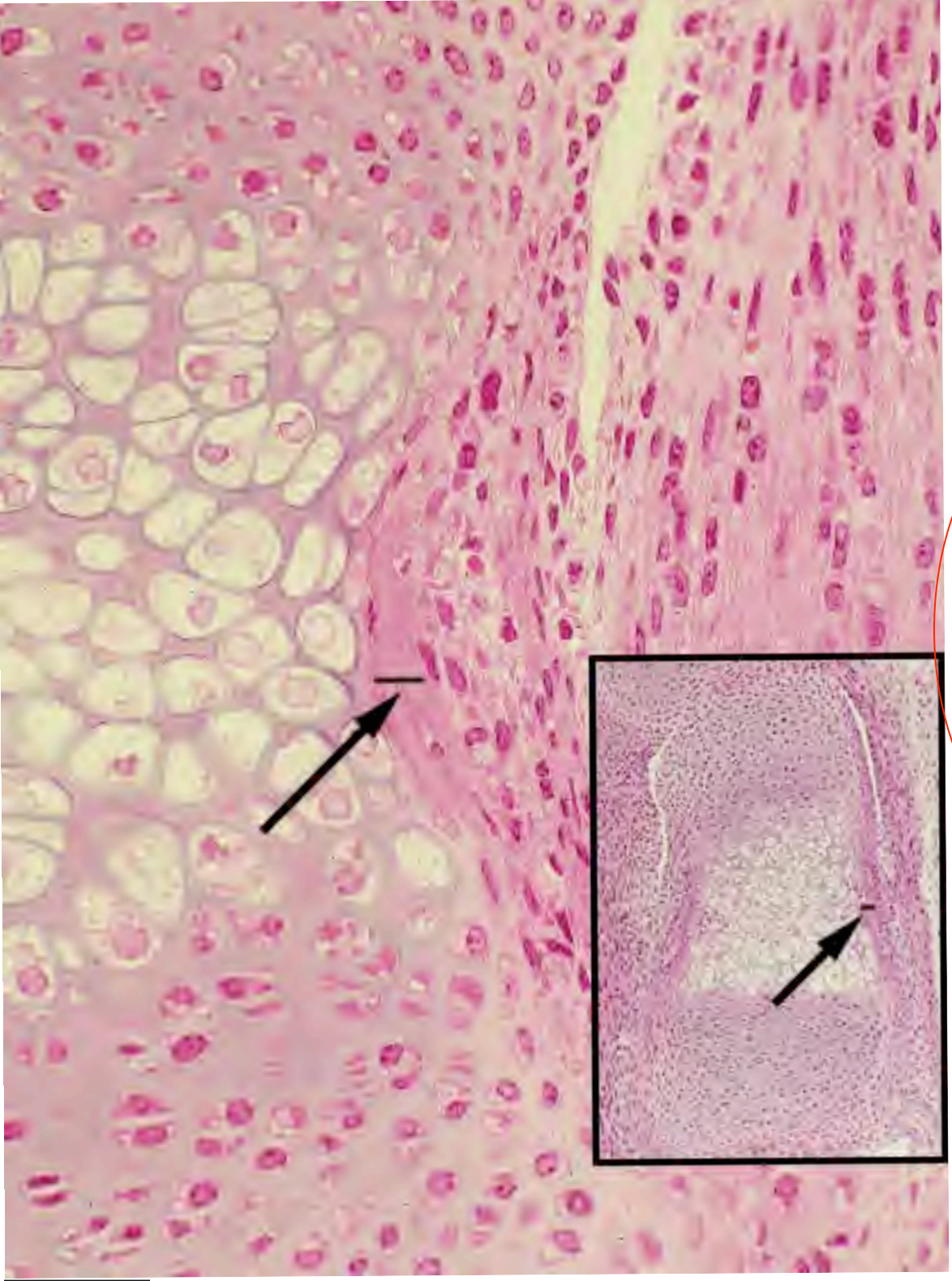
Endochondral Bone Formation

Hyaline cartilage remains:

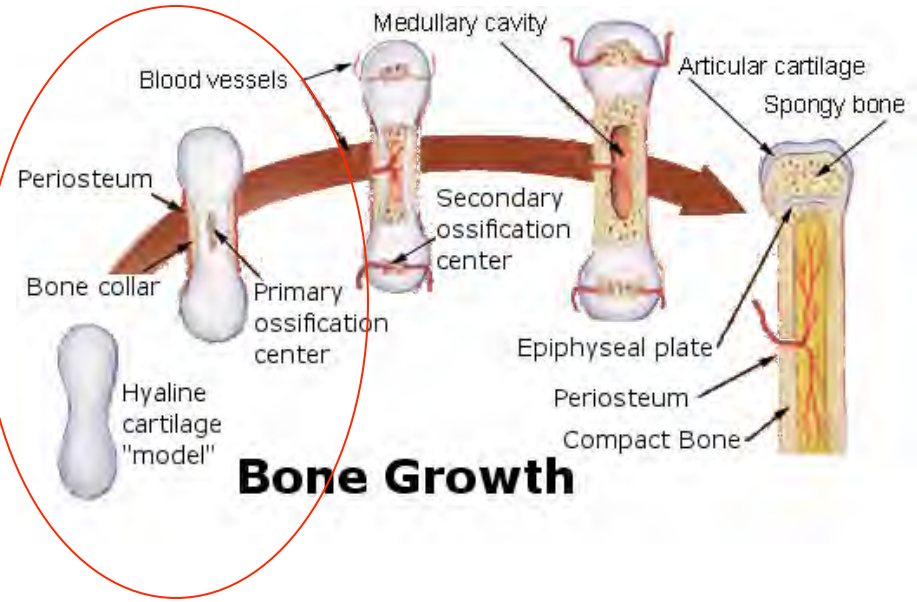
1. **articular surface**
2. **epiphyseal (growth) plate**



Formation of Bone Collar



PD-INEL Source Undetermined



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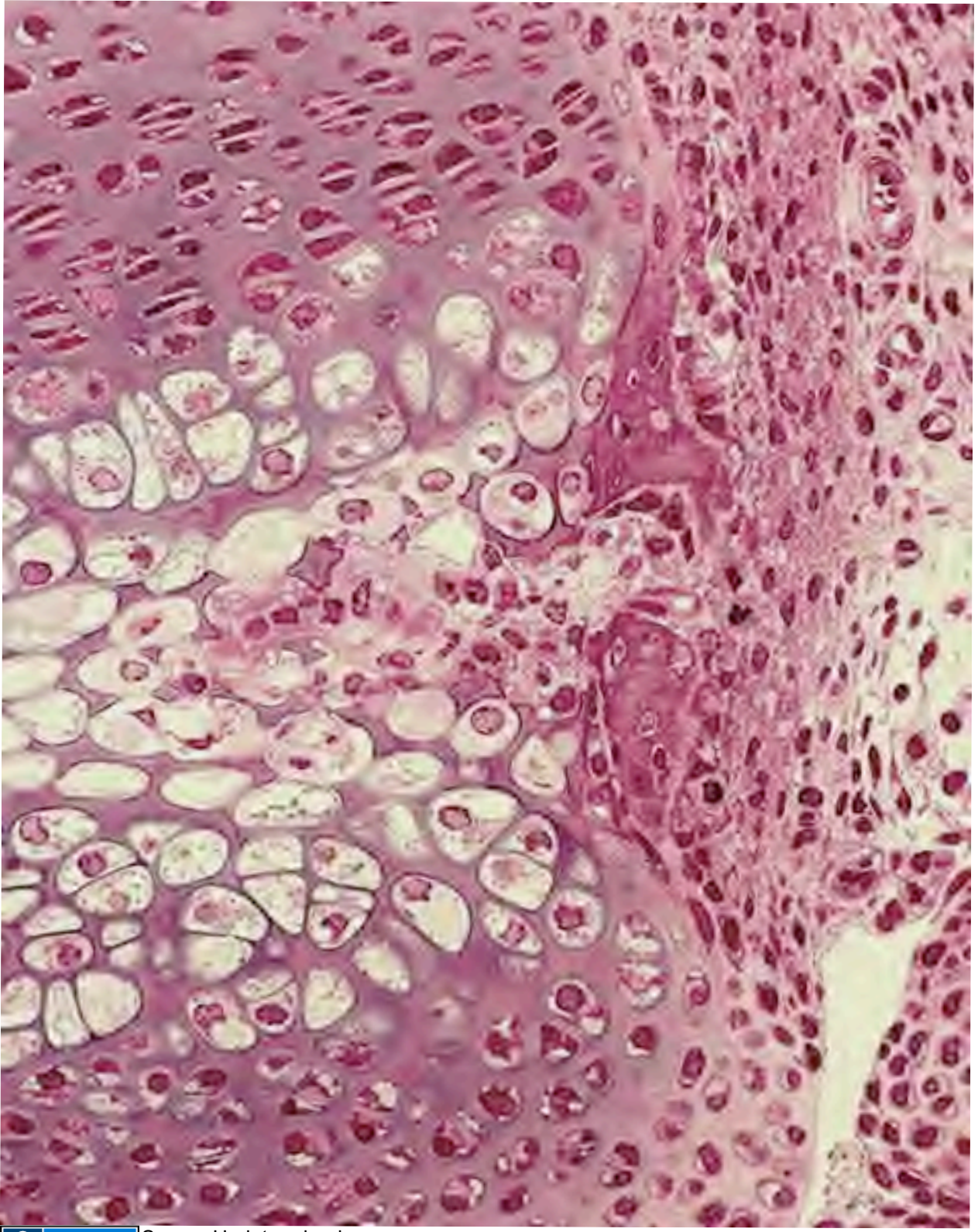

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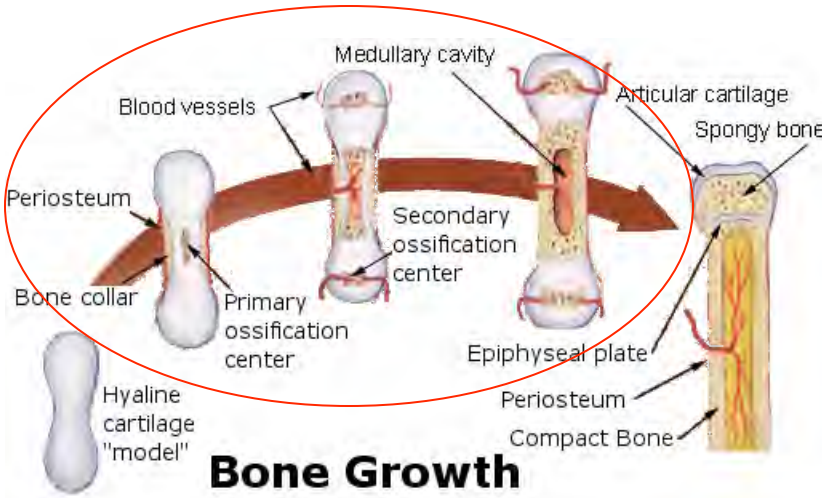
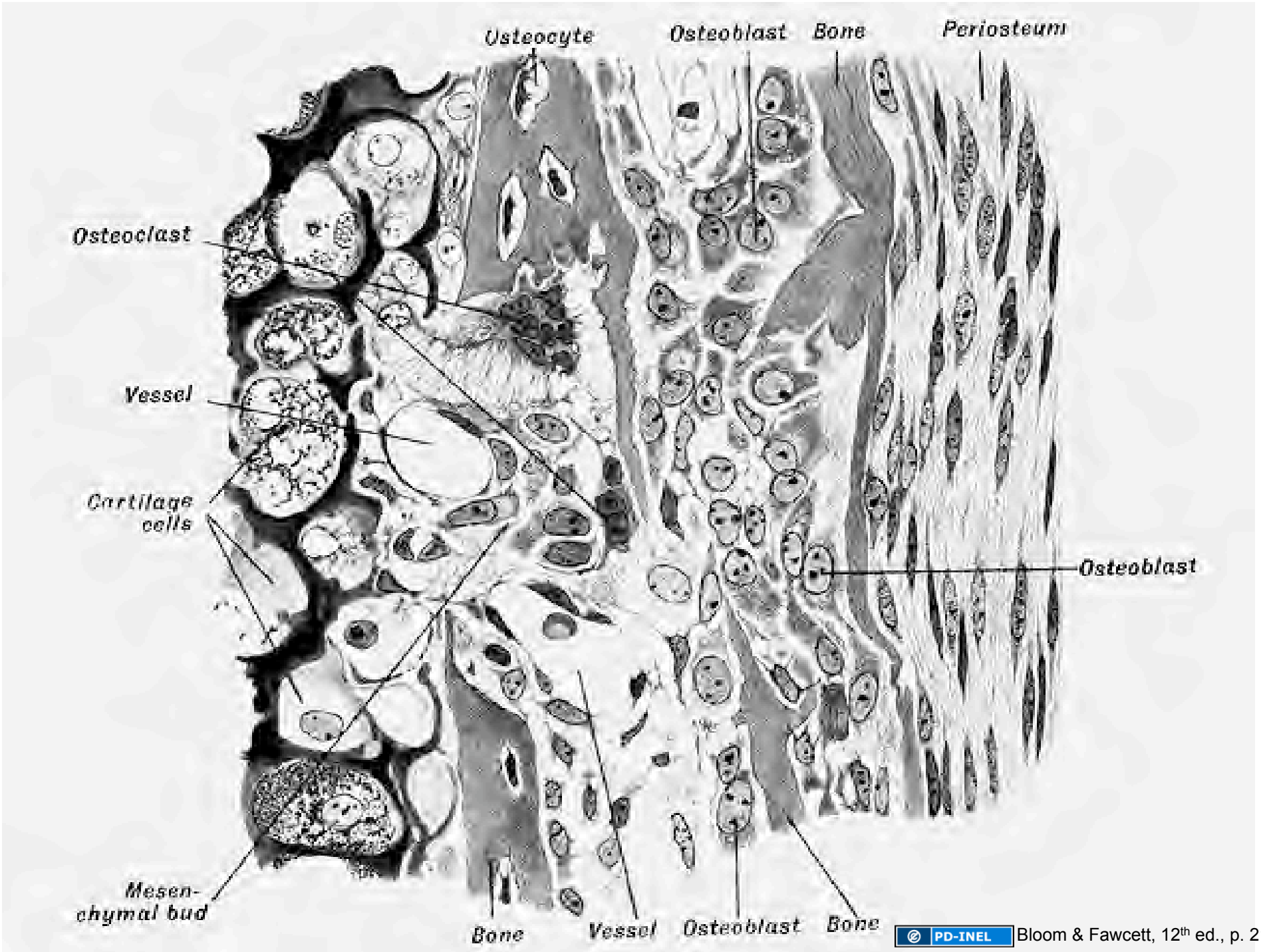
Periosteal Bud



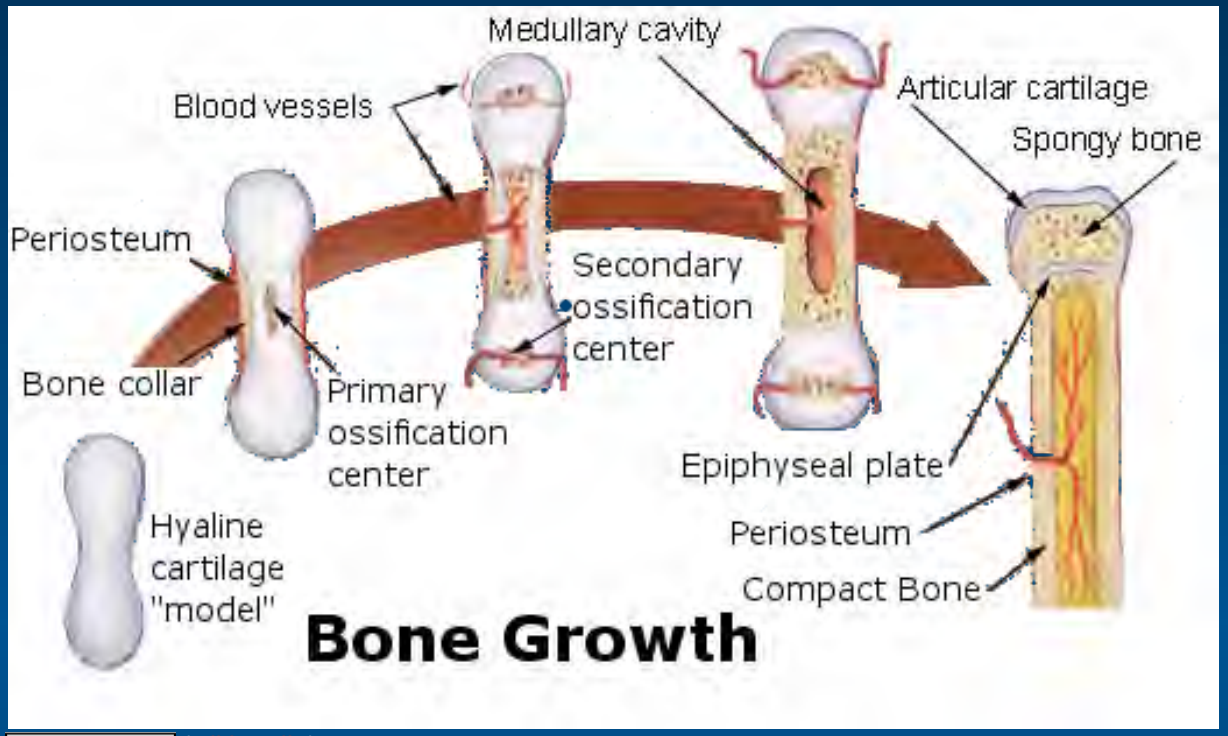
PD-GOV (wikimedia)

Periosteal Bud



 Bloom & Fawcett, 12th ed., p. 217

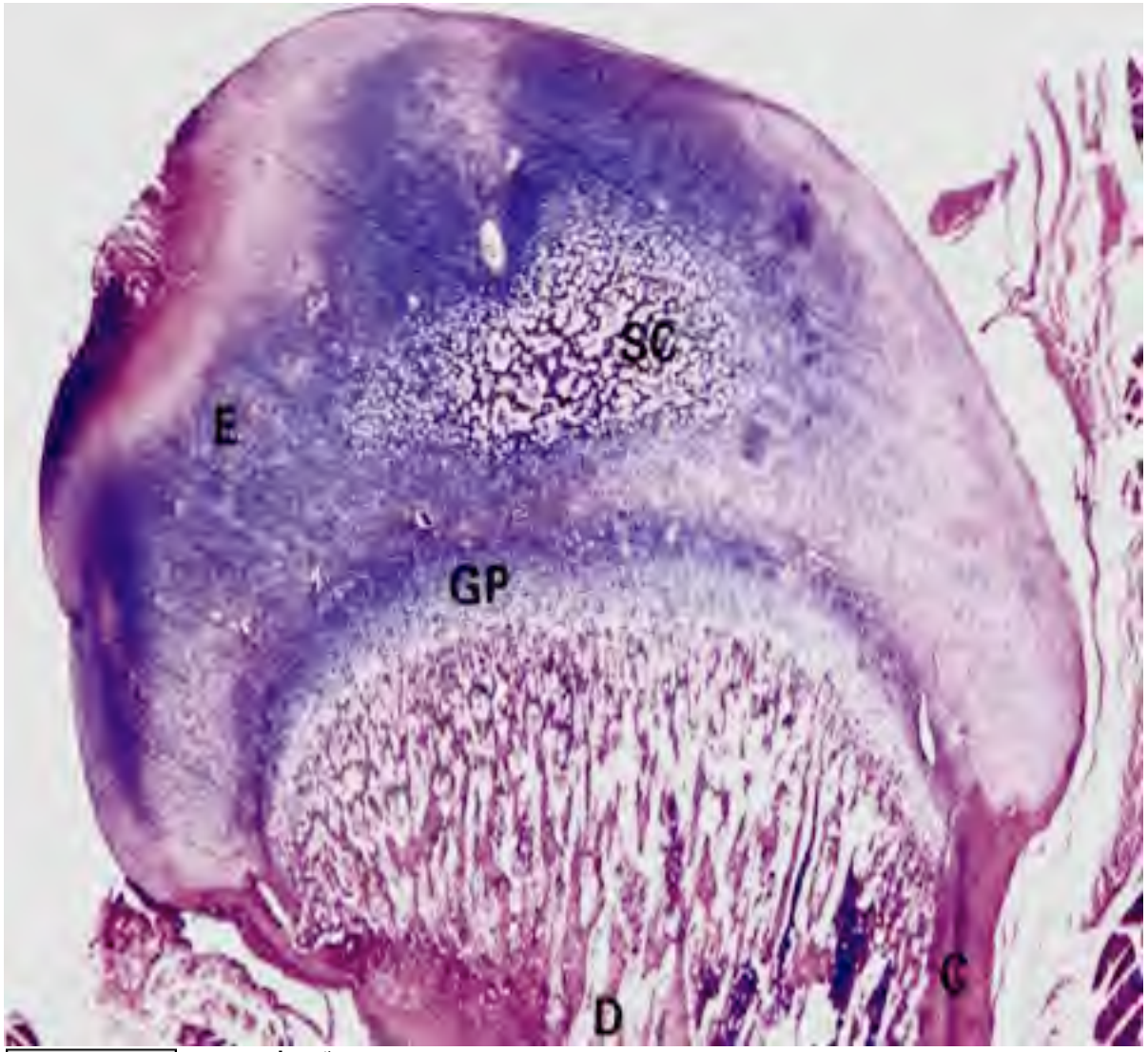
Growth in Diameter of Long Bones



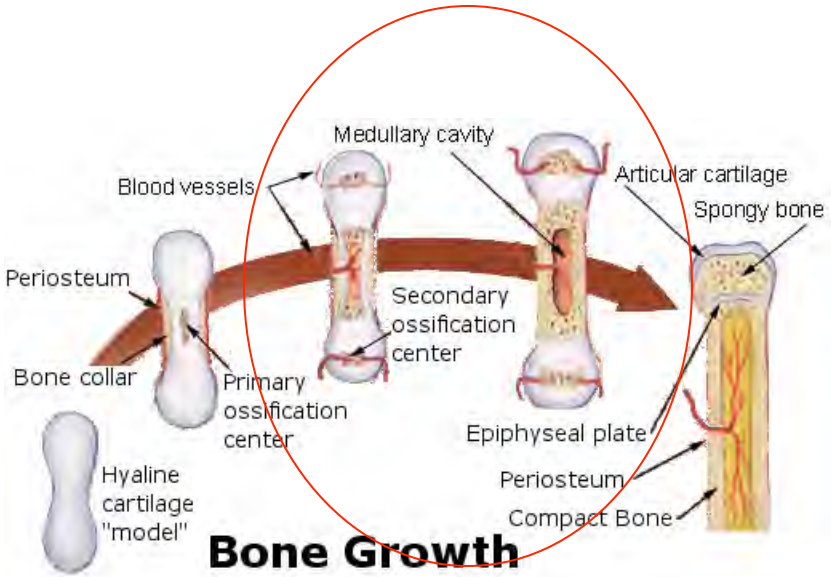
The bone shaft increases in diameter by appositional growth.

- New bone is deposited on the outer surface of the diaphysis by successive generations of osteoblasts arising from osteogenic cells of the periosteum.
- To compensate this growth and prevent bone from becoming too thick and heavy, older bone on the inner surface of the shaft is resorbed by osteoclasts so as to widen the marrow cavity.

Epiphyseal Plate and Secondary Ossification Center

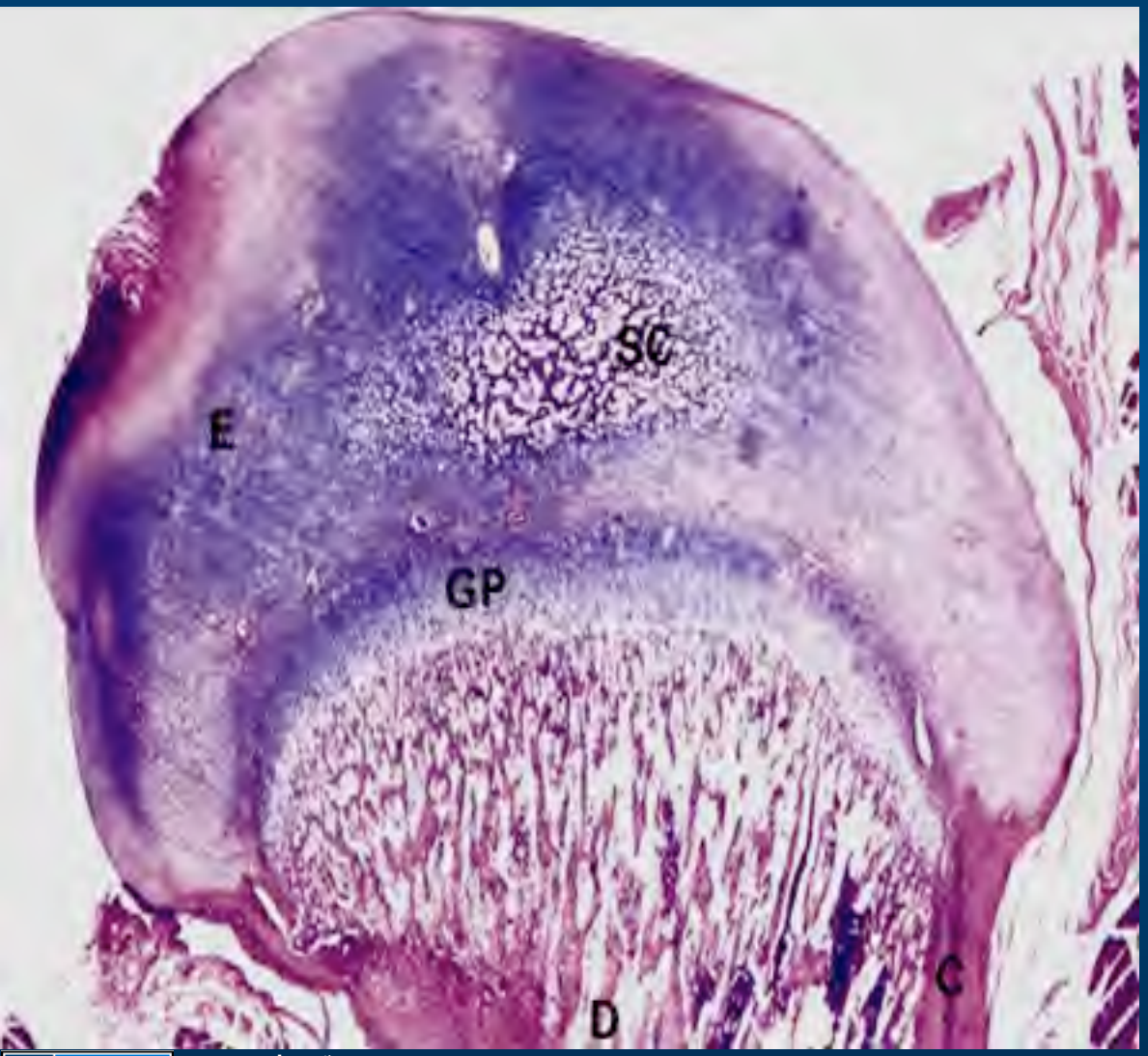


PD-INEL Wheater's 5th ed., p. 199

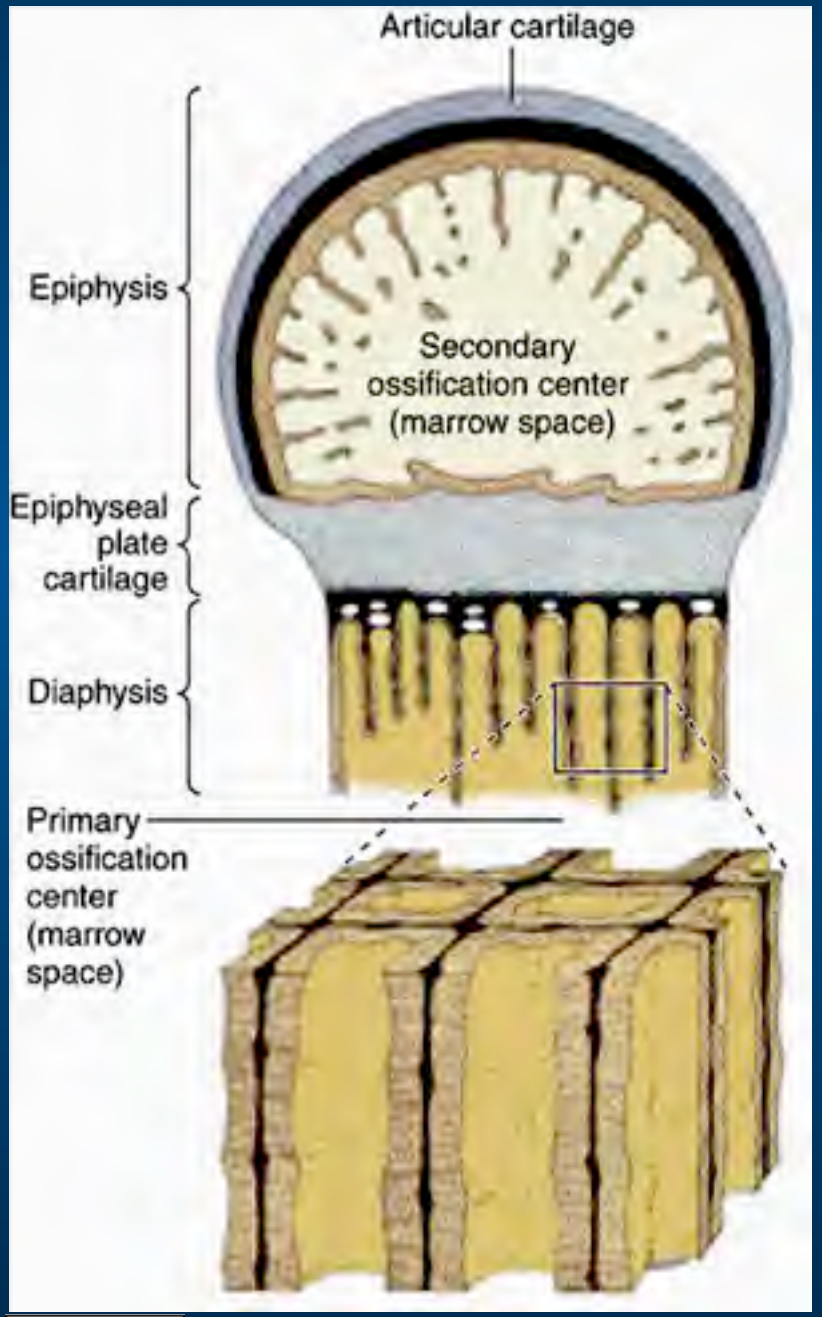


PD-GOV wikimedia

Epiphyseal Plate and Growth in Length of Long Bones

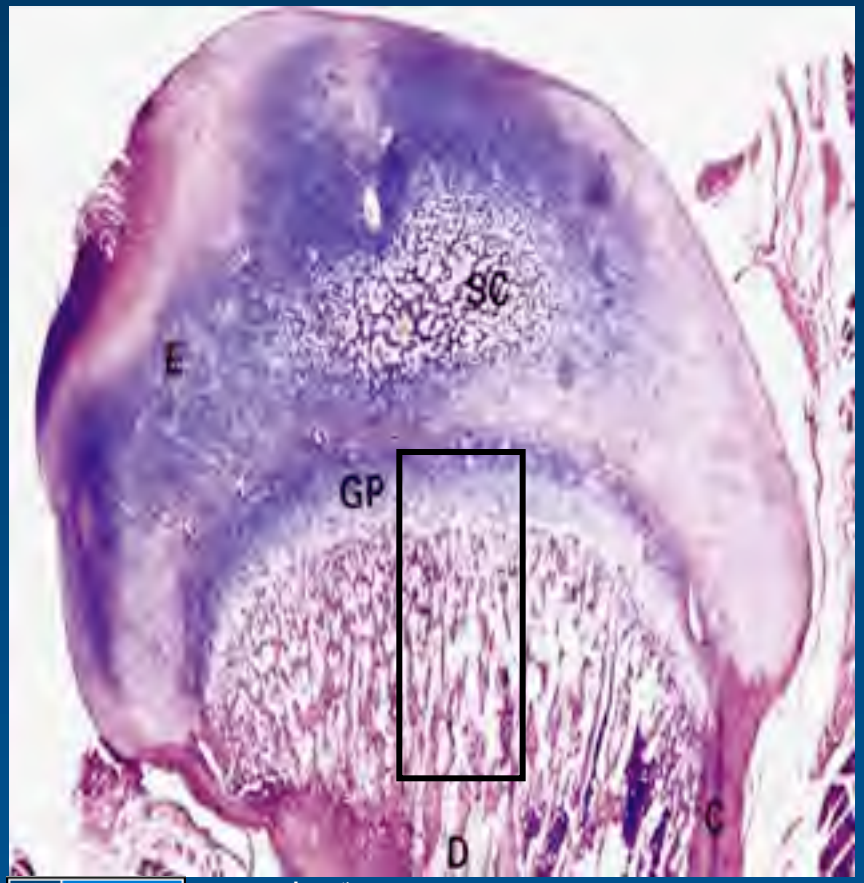


PD-INEL Wheater' s 5th ed., p. 199

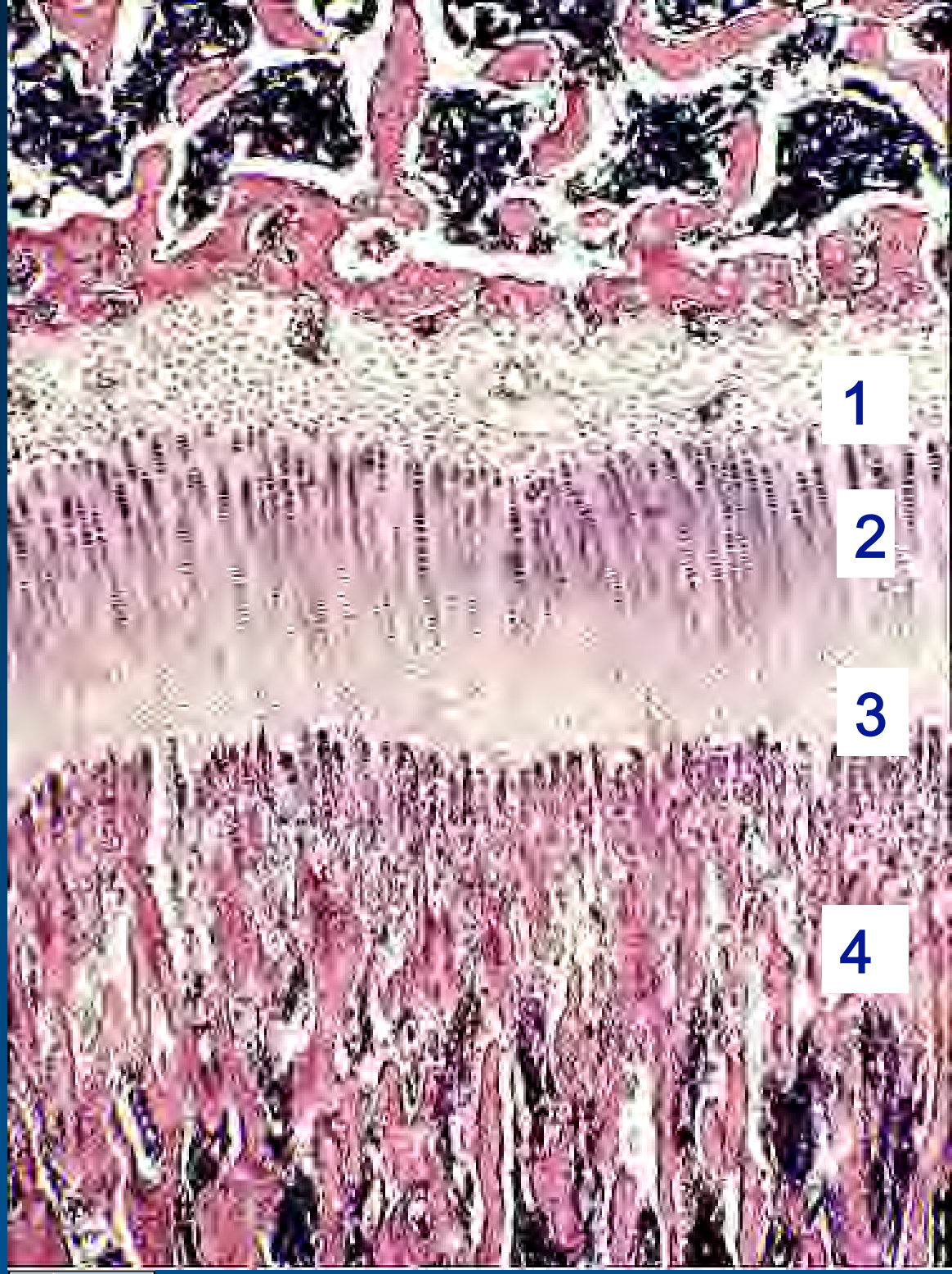


PD-INEL Junqueira & Carneiro, 10th ed., p. 150

Secondary Ossification Center, Epiphyseal Plate and Metaphysis

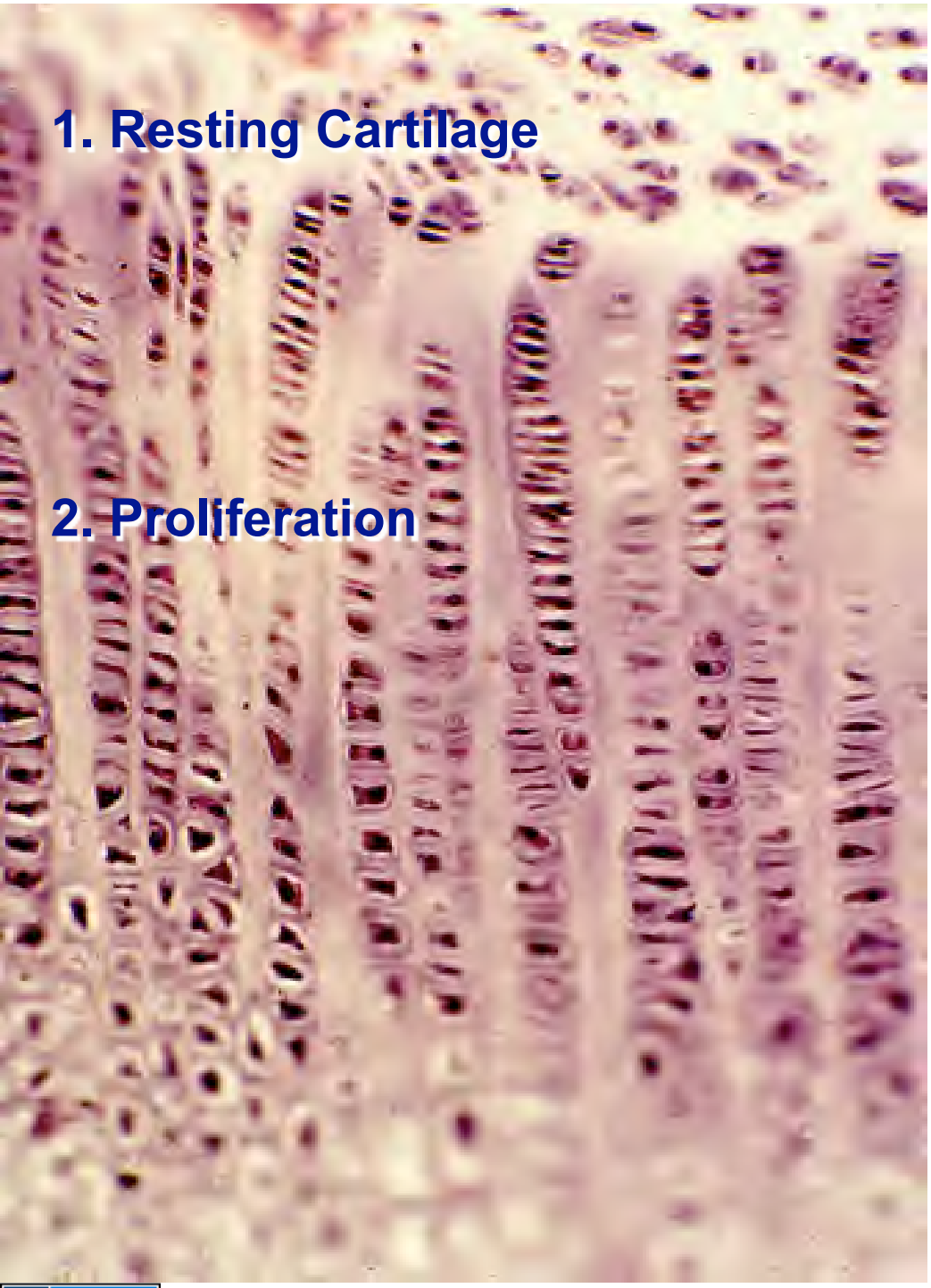


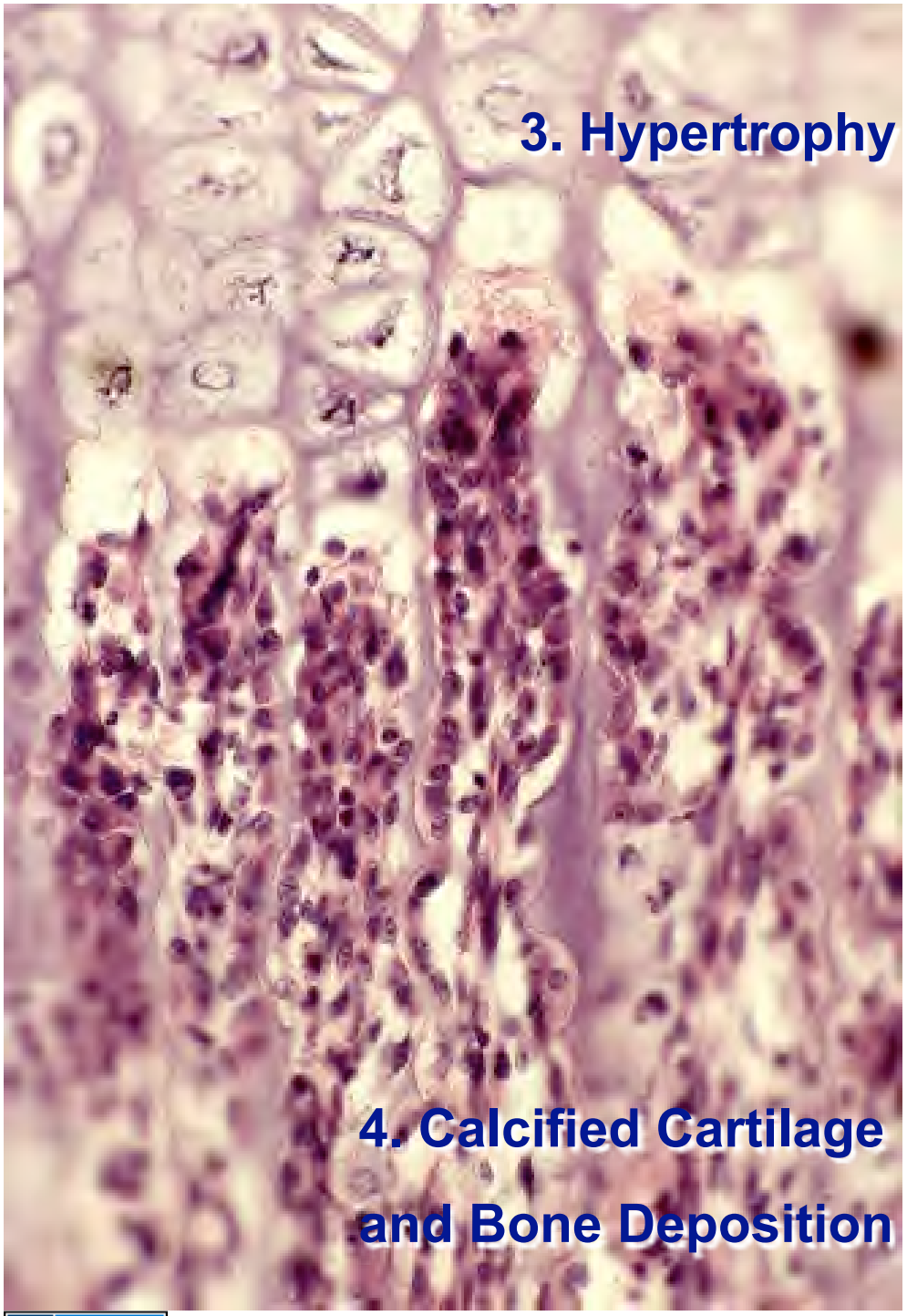
PD-INEL Wheater' s 5th ed., p. 199

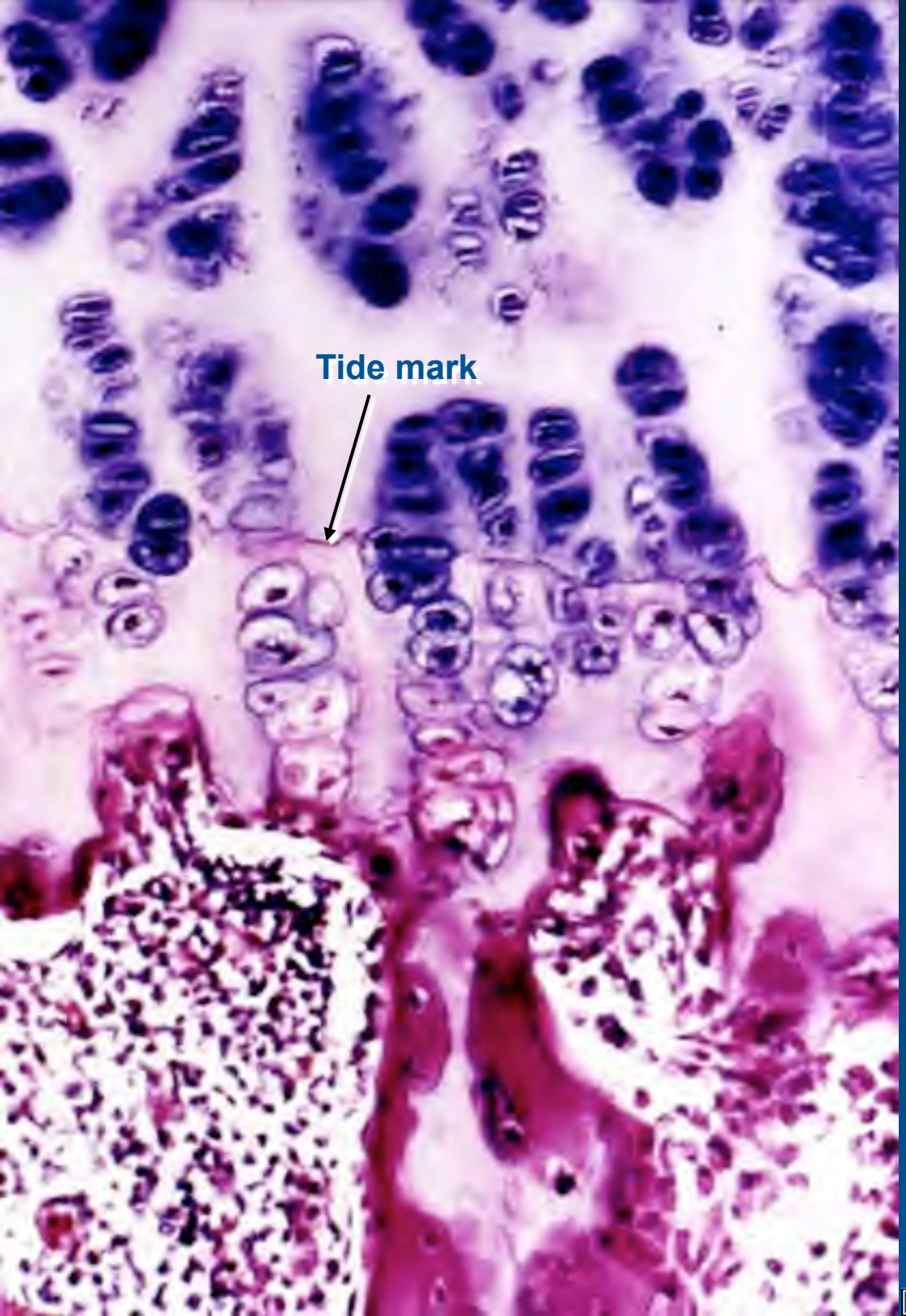


PD-INEL Source Undetermined

Epiphyseal Plate: Zone of







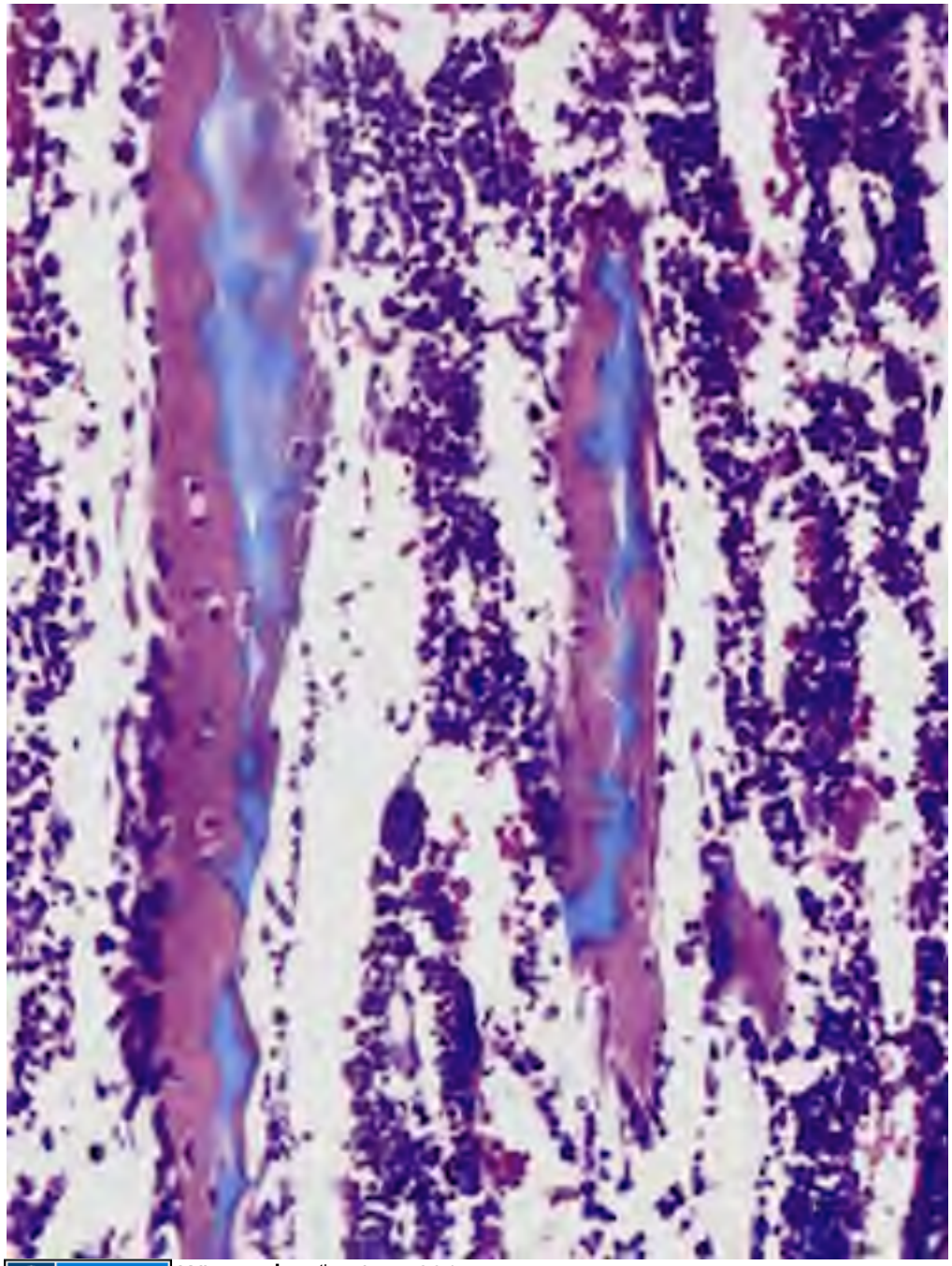
Zone of:

Proliferation

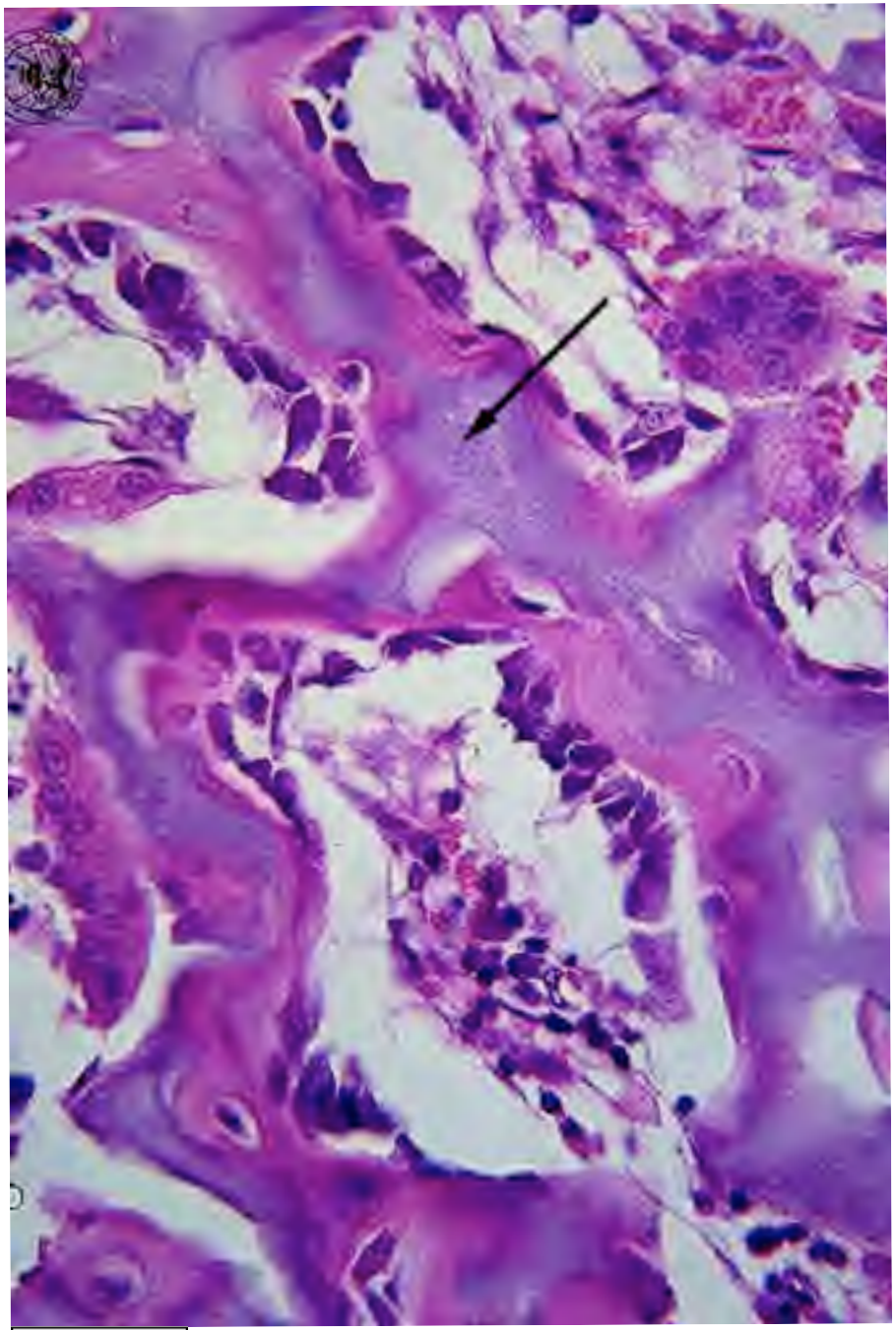
Hypertrophy

Calcification and Bone deposition

Calcified Cartilage and Bone Deposition

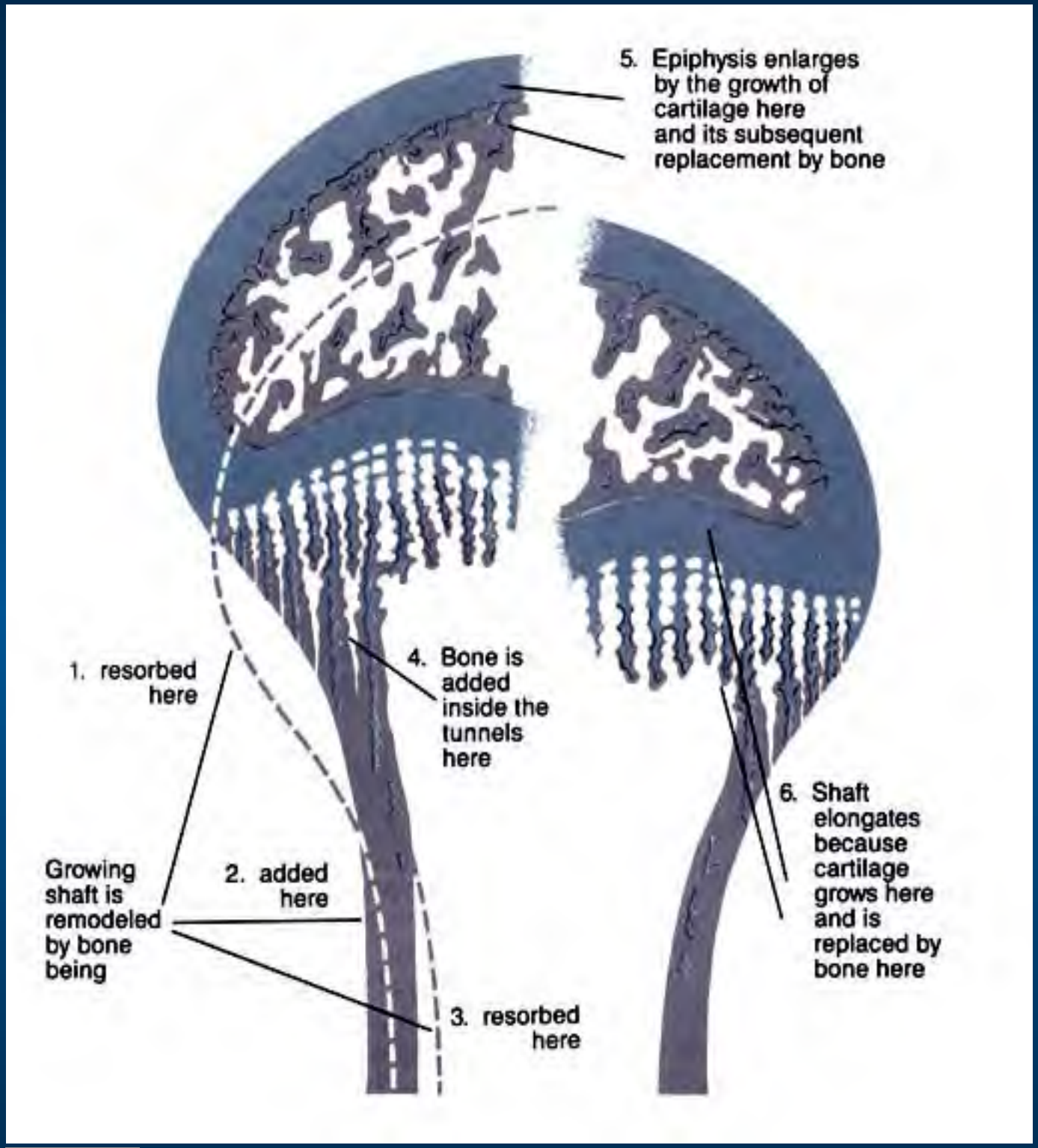


PD-INEL Wheater's 5th ed., p. 201



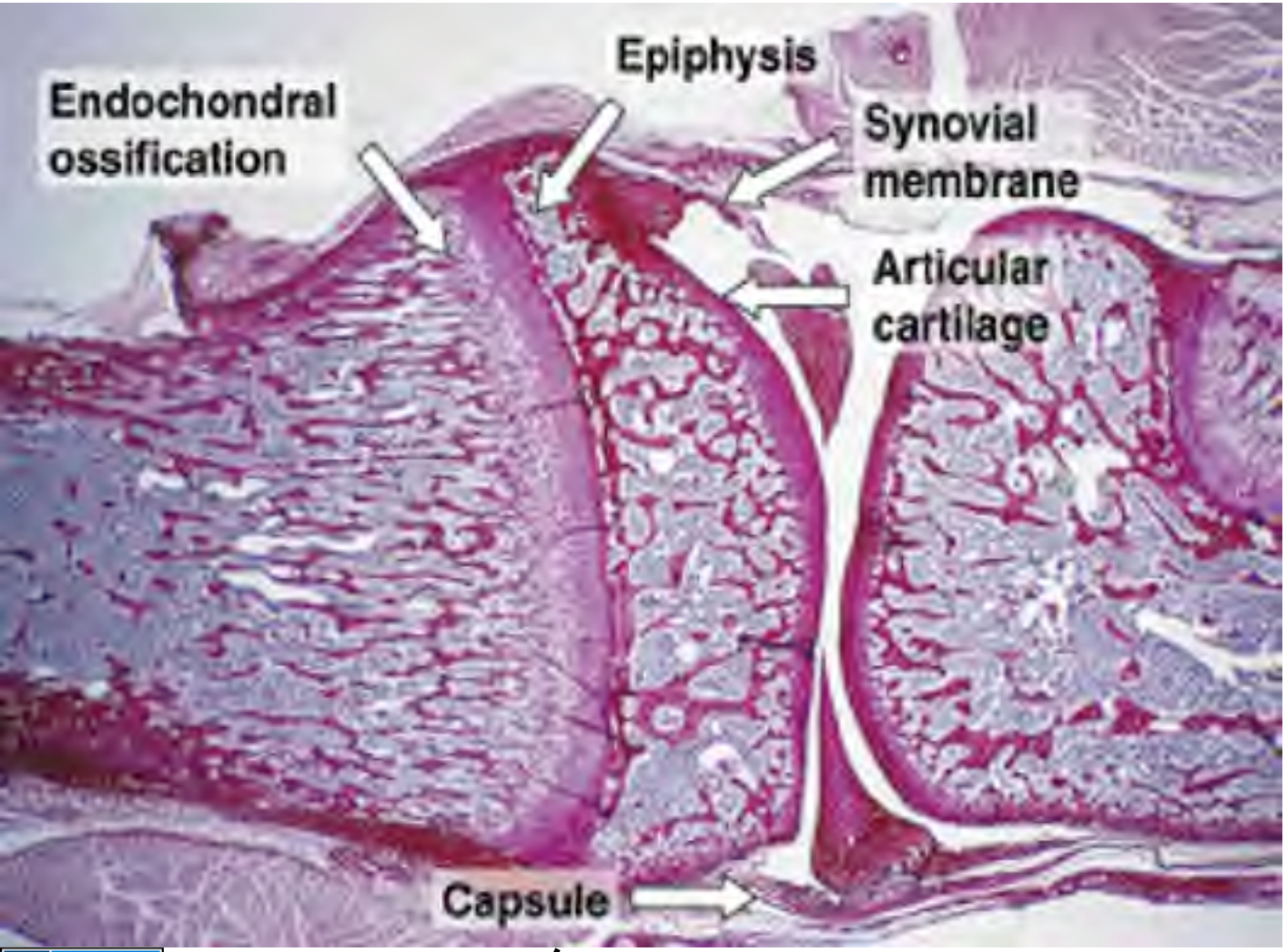
PD-INEL Source Undetermined

Bone Growth in Length and Diameter

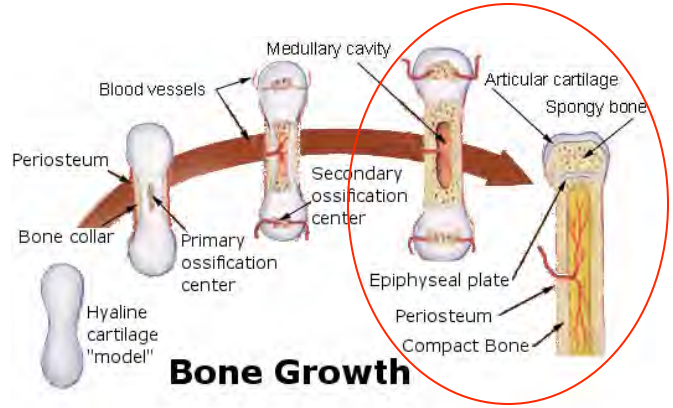


 Ham's Histology 9th ed., p. 303

Mature Bone

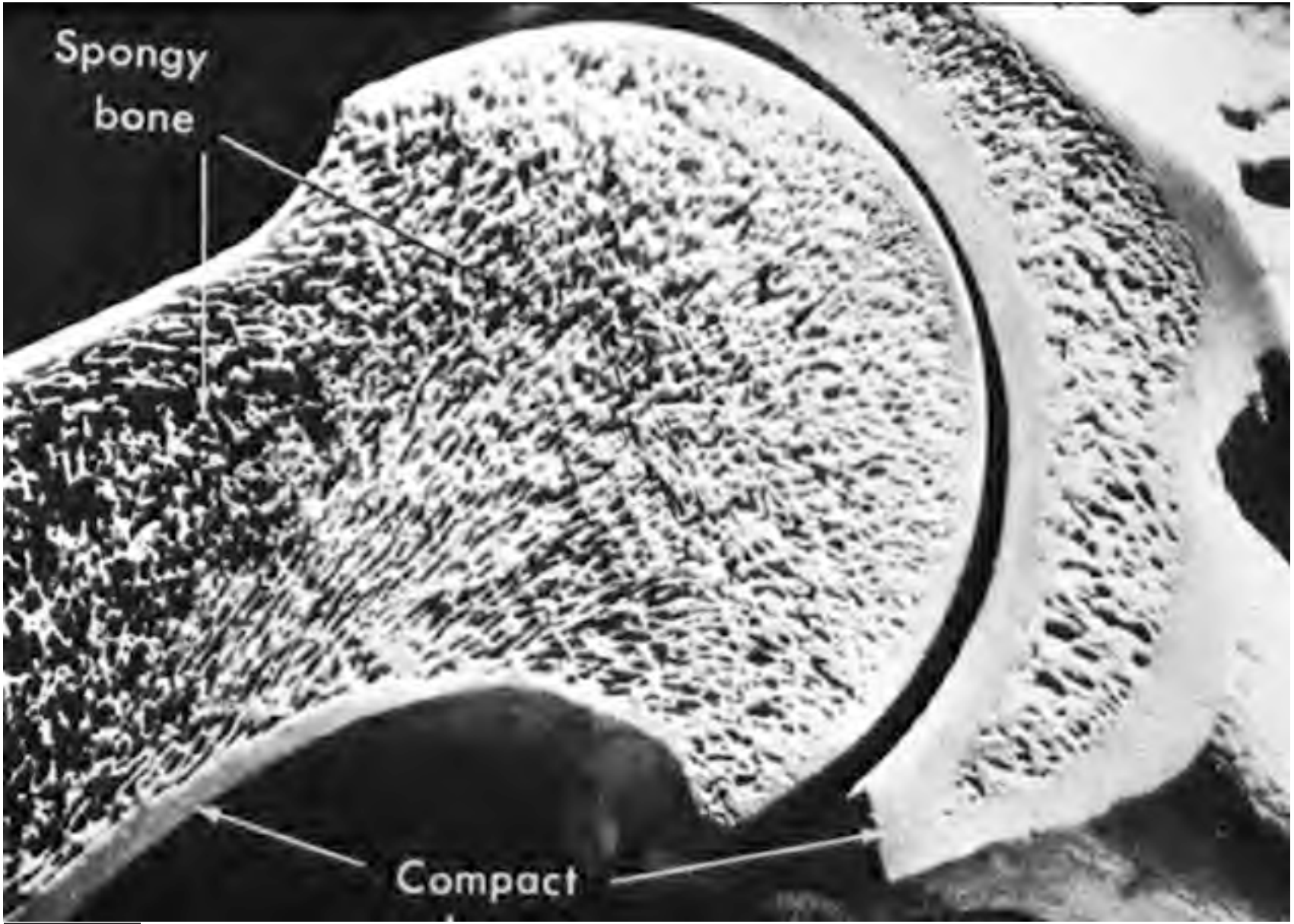


PD-INEL Junqueira & Carneiro, 10th ed., p. 156



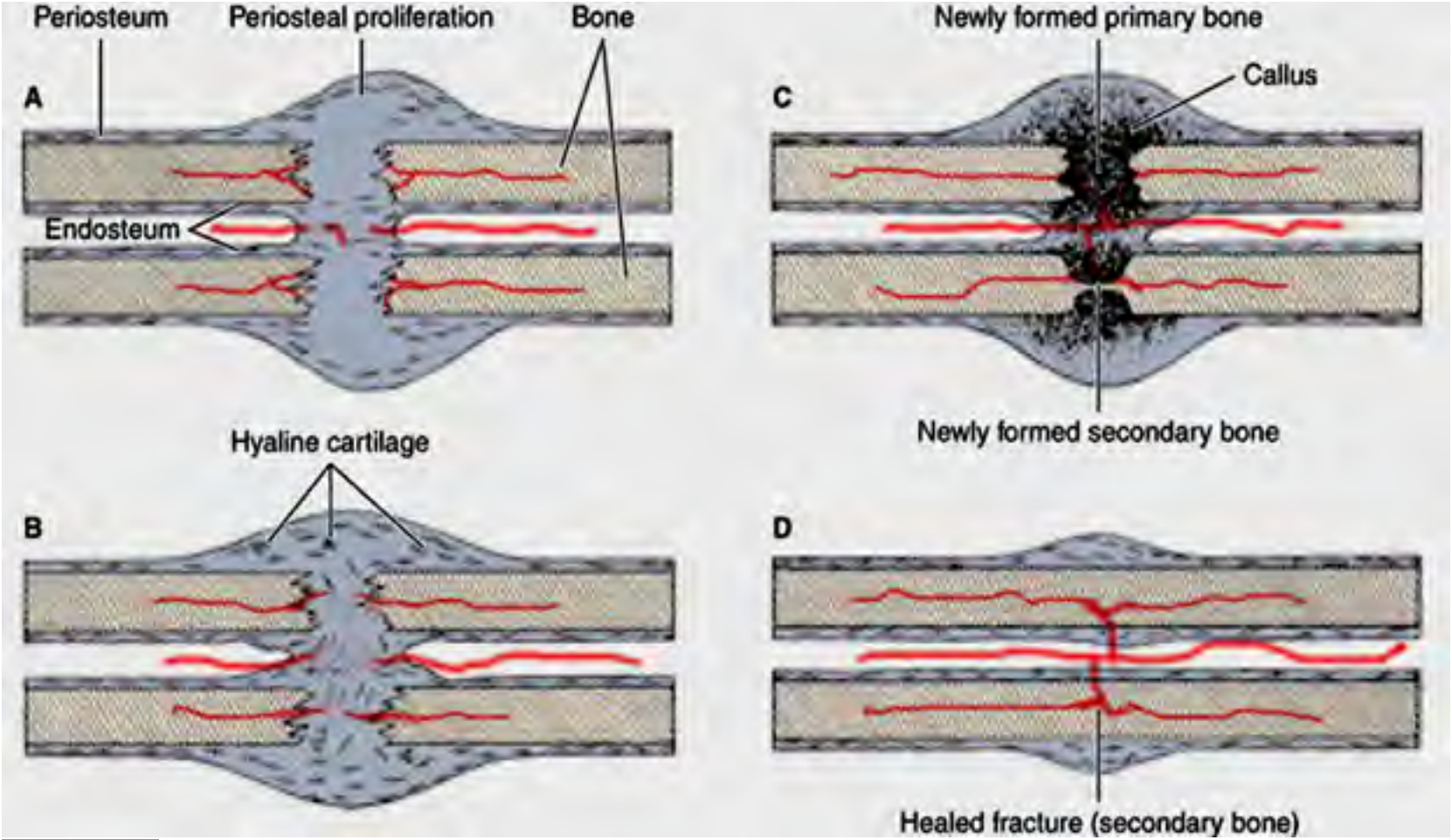
PD-GOV wikimedia

Mature (adult) Bone



PD-INEL Bloom & Fawcett, 12th ed., p. 195

Repair of Fractured Bone



PD-INEL Modified from Junqueira & Carneiro 10th ed., p. 154

Bone Remodeling

Bone remodeling occurs continuously.

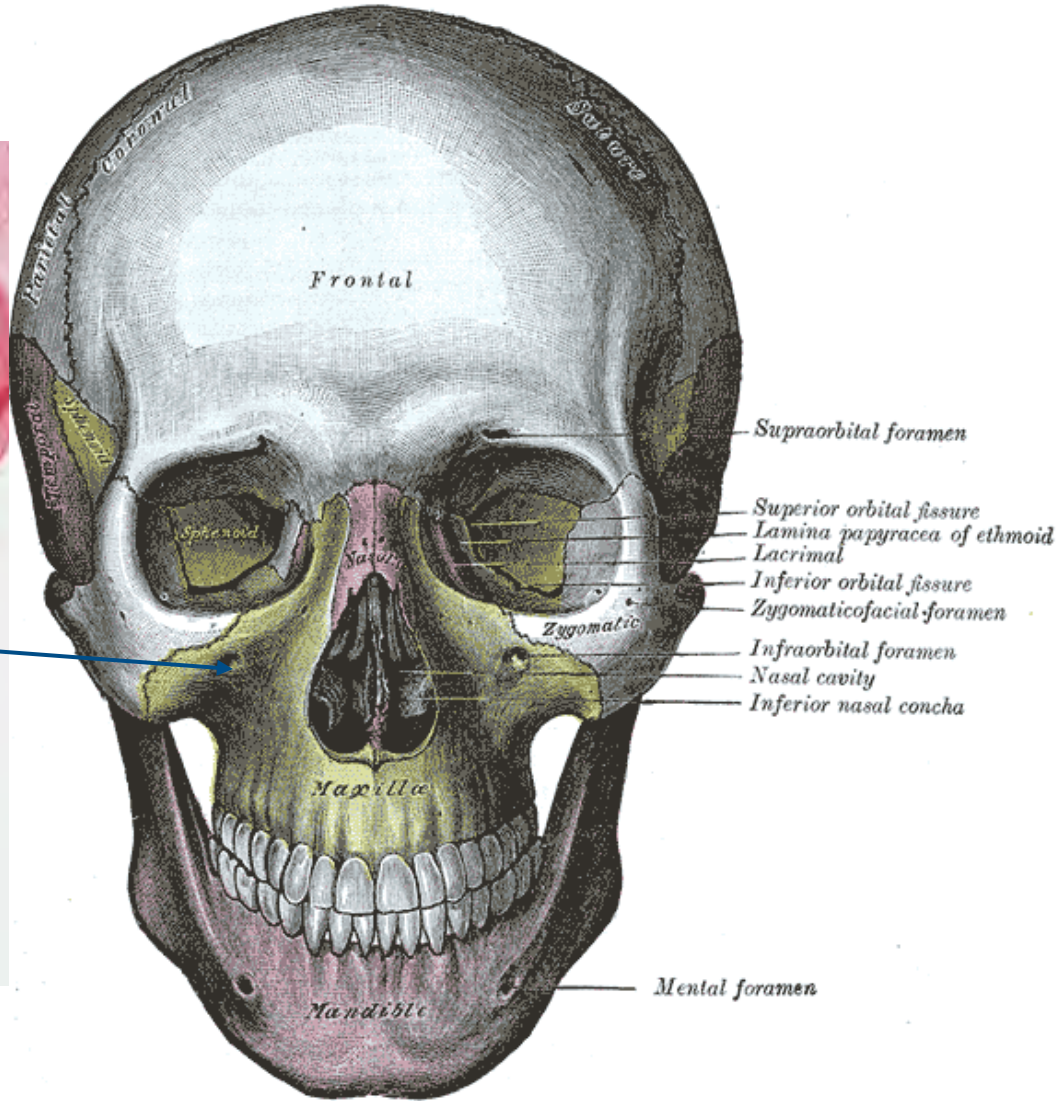
It is the process whereby bone is being resorbed by osteoclasts and is then replaced by new bone deposited by ostoblasts. The activity of the two cell types is coupled and balanced to maintain the normal internal structure and shape of a bone.

Remodeling:

- Structural remodeling during bone growth.
- Internal remodeling to replace worn out bone.
- Compensatory remodeling in responses to prevailing stresses, injury or changes in metabolic activities.

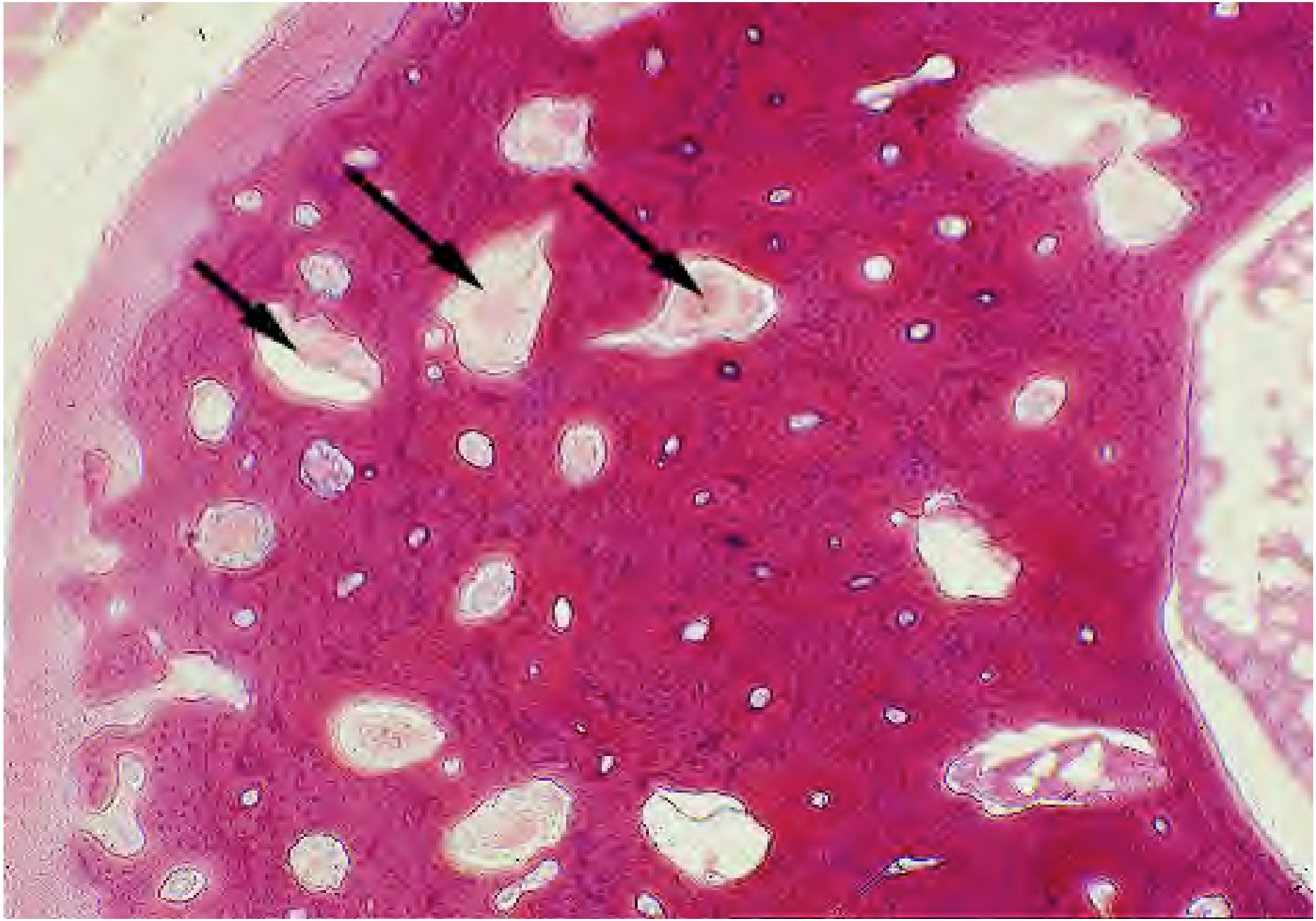
Intramembranous ossification of facial (maxillary) bone

PD-INEL Michigan Medical School Histology Slide Collection

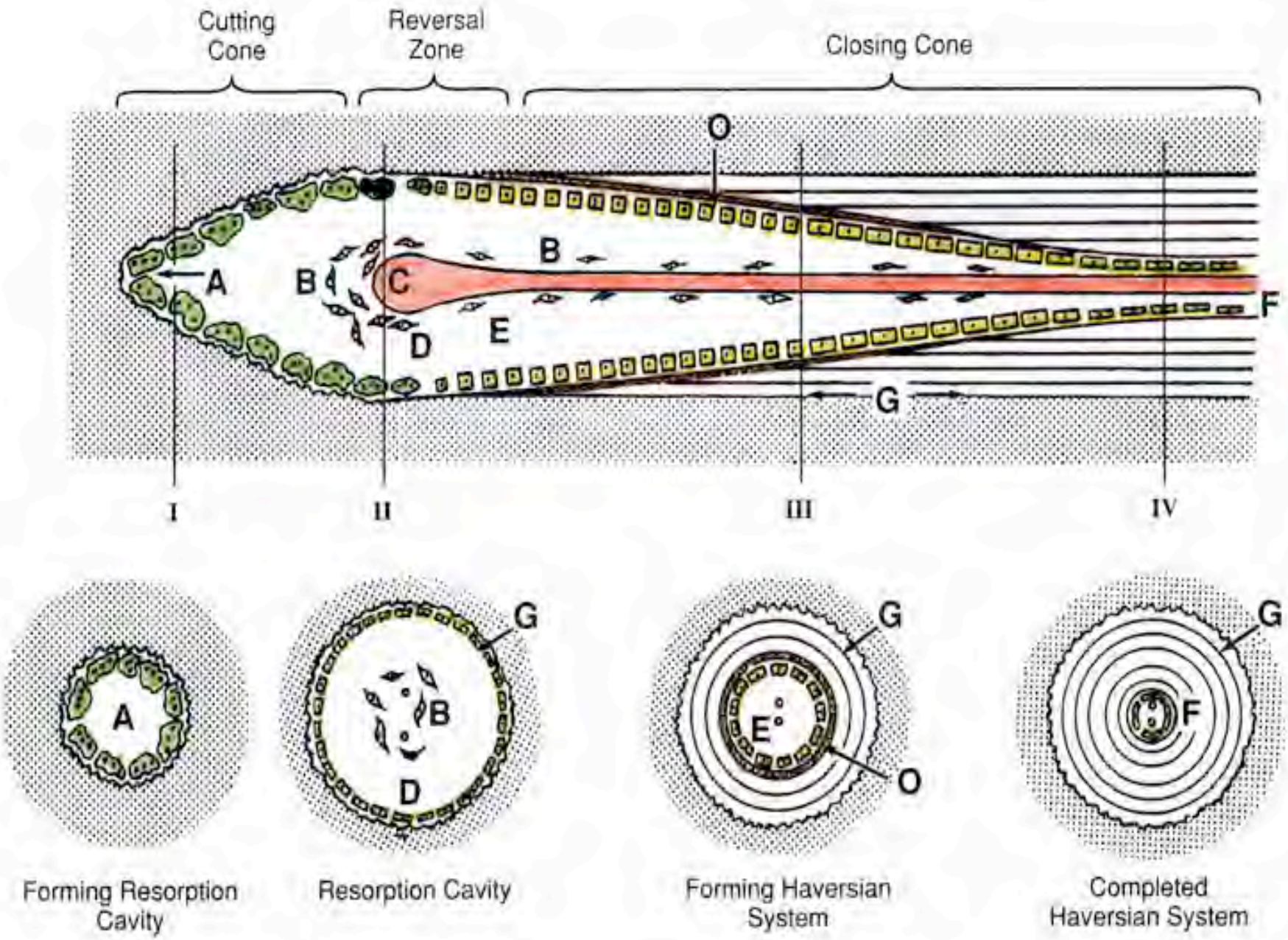


PD-EXP Gray's Anatomy (wikimedia)

Bone Remodeling
Erosion (resorption) Tunnel

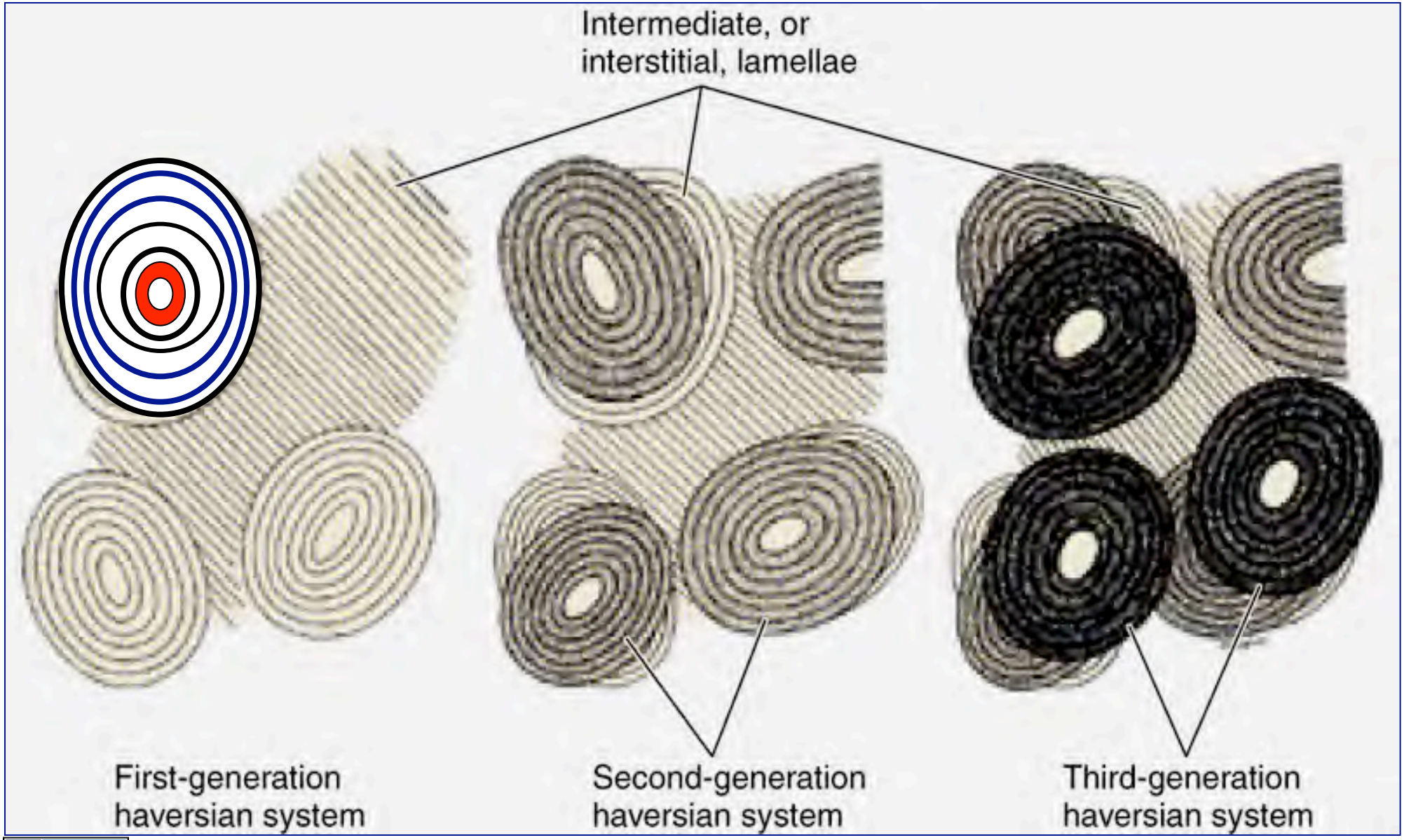


Resorption tunnel



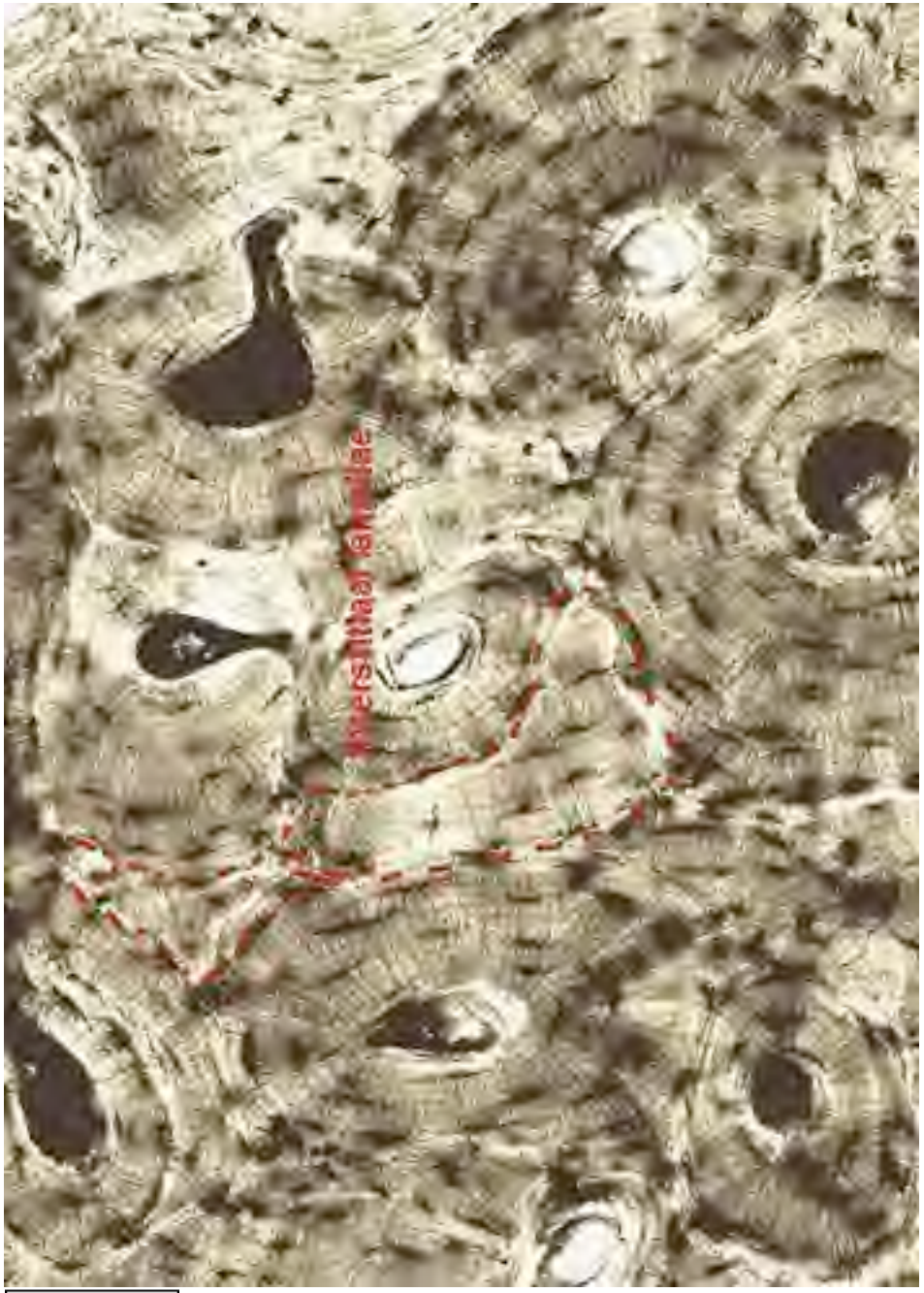
 Weiss, 6th ed., p. 243

Bone Remodeling



 Modified from Junqueira & Carneiro 10th ed., p. 147

Osteons (os) and Interstitial lamellae (il)



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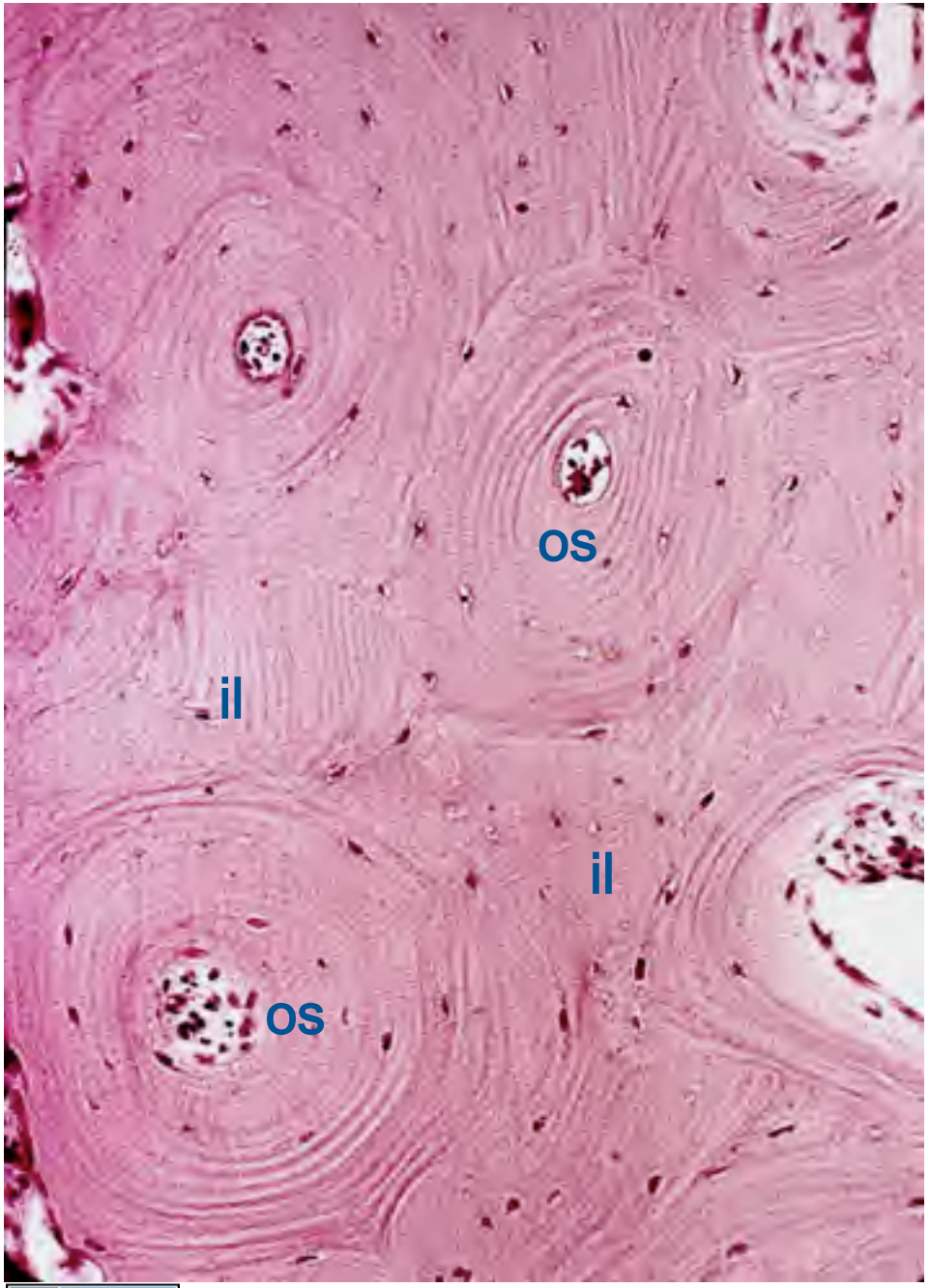

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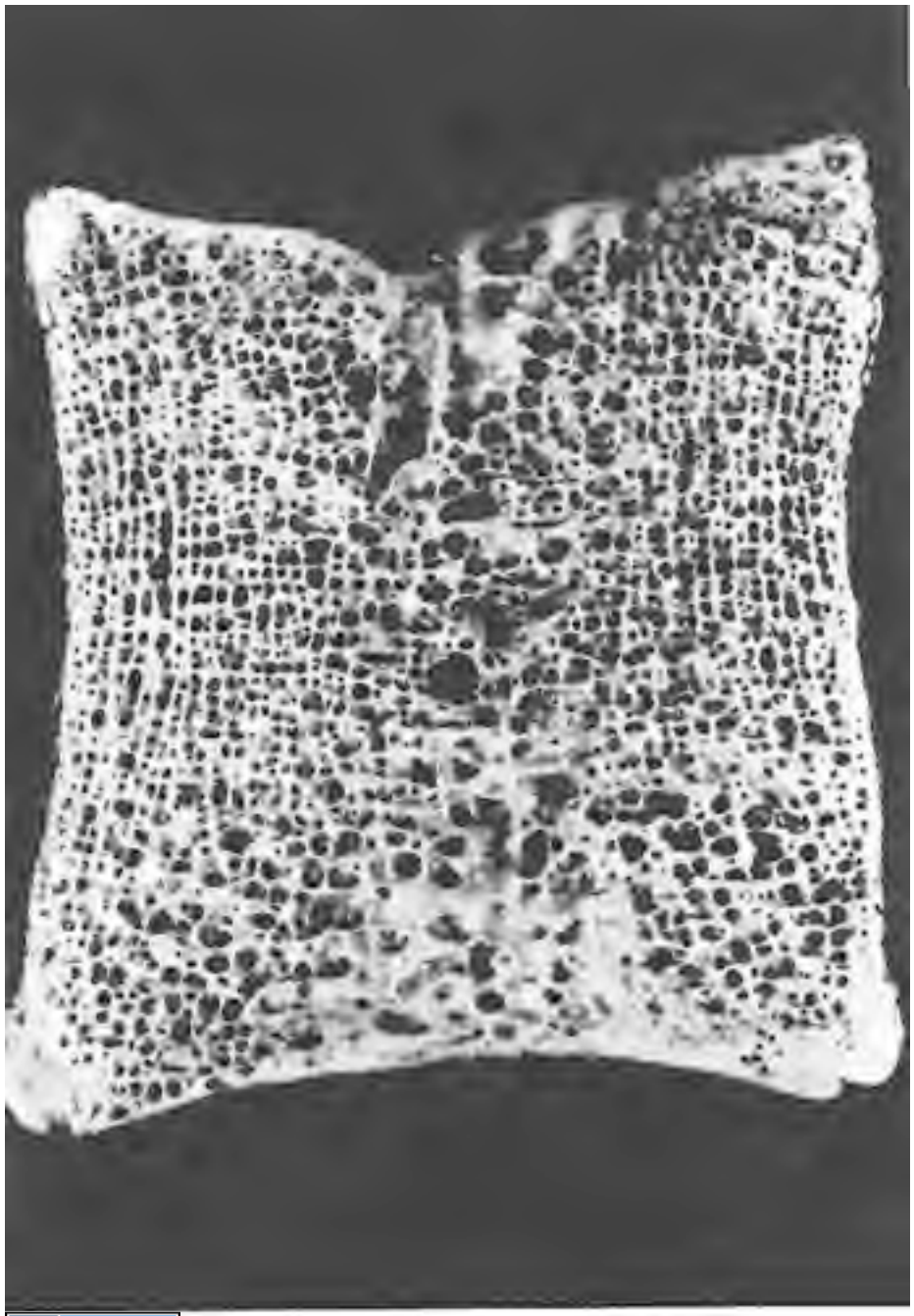
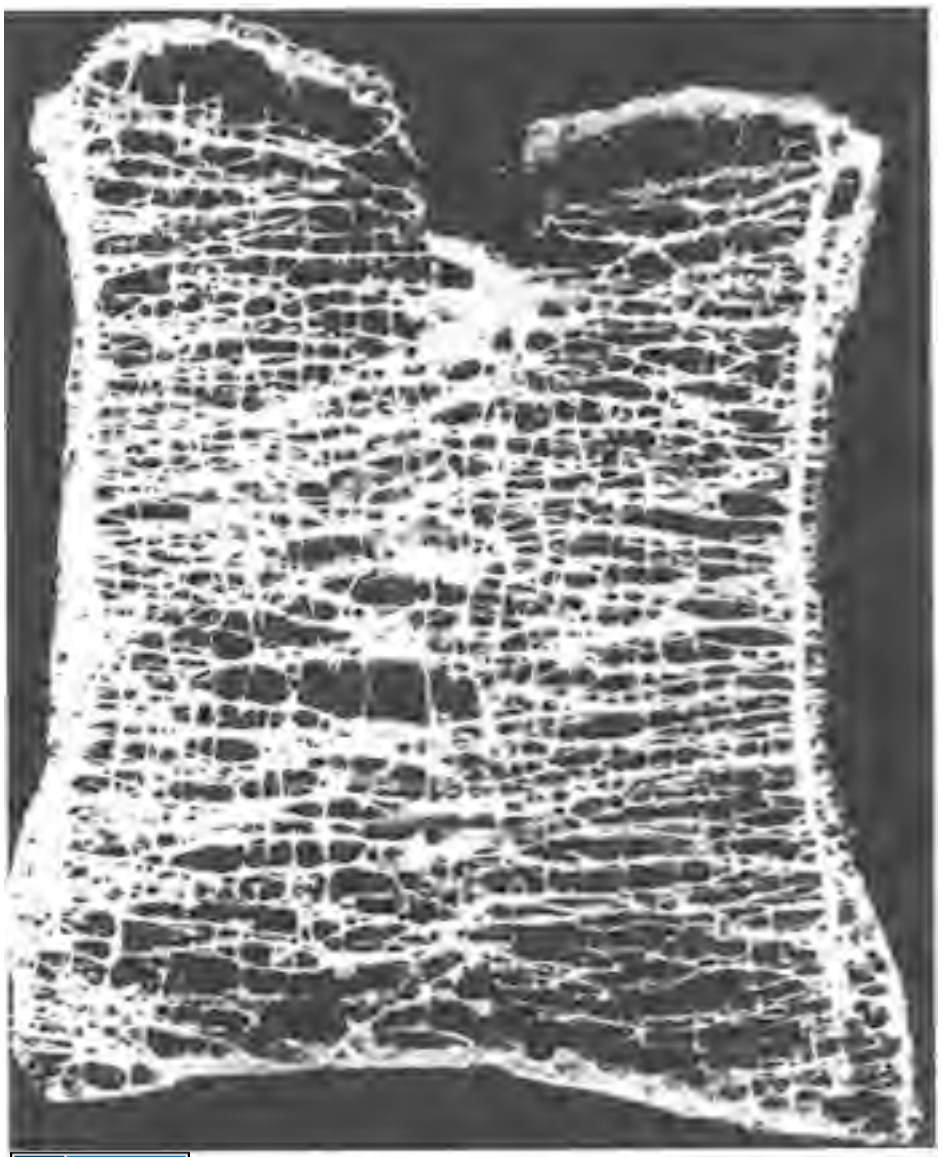
Age-related Bone Loss

Osteoporosis



PD-INEL Weiss, 5th ed., p. 245



PD-INEL Weiss, 5th ed., p. 245

Bone Resorption > Deposition

Nutritional Effects on Bone

Scurvy: Insufficient level of dietary vitamin C leading to inadequate hydroxylation of proline of collagen (unable to form triple-helix).

Rickets: In the absence of an adequate level of vitamin D, ossification of epiphyseal cartilage is disturbed, leading to formation of a mixture of uncalcified cartilage and poorly calcified bone matrix in the metaphysis.

Osteomalacia (adult rickets): Accumulation of an excessive amount of uncalcified osteoid due to a prolonged deficiency of calcium and vitamin D.

Regulation of Blood Calcium Level

When the blood level of calcium falls:

secretion of parathyroid hormone is increased.

The hormone acts on osteoblasts to suppress their bone deposition and induce the secretion of osteoclast-stimulating factor.

Activated osteoclasts resorb bone, releasing calcium into the blood to restore the normal level.

When the blood level of calcium increases:

secretion of parathyroid hormone is suppressed.

Osteoblasts continue deposition of bone.

secretion of calcitonin (a thyroid hormone) is increased. **Calcitonin acts directly on the osteoclasts to inhibit bone resorption.**

Bone formation and remodeling
Learning objectives - 1

- Be able to describe, as well as recognize in section, the process of **intramembranous bone formation**, including the process whereby cancellous bone is converted into compact bone.
- Be able to recognize osteoblasts, osteocytes and osteoclasts and know their role in the process of intramembranous bone formation and conversion of cancellous bone to compact bone.
- Be able to recognize mature and immature (mottled or woven) bone.
- Understand the process of **endochondral bone formation** and know how a cartilage model is broken down and replaced by bone (e.g. formation of a bony collar, chondrocyte death, invasion of an osteogenic bud from the periosteum, etc.).
- Understand how the diameter of a long bone increases.

Bone formation and remodeling
Learning objectives - 2

- Understand how the epiphyseal growth mechanism results in elongation of a long bone.
- Be able to recognize the different zones of a cartilage growth plate and describe the processes of osteogenesis taking place in each zone (e.g. zone of resting cartilage, proliferation, hypertrophy, calcification and ossification).
- Be able to describe the process and types of **bone remodeling** and to recognize cells and structures involved in the process.
- Be able to describe how **fracture repair** resembles the process of endochondral bone formation.

Additional Source Information

for more information see: http://open.umich.edu/wiki/CitationPolicy

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Slide 6: Michigan Medical School Histology Slide Collection; Kierszenbaum, p. 115
Slide 7: Kierszenbaum, p. 115
Slide 8: Weiss, 6th ed., p. 222; Source Undetermined
Slide 9: Michigan Medical School Histology Slide Collection; Weiss 6th Ed. P. 219
Slide 12: Kierszenbaum p.125
Slide 13: Kierszenbaum p. 122
Slide 14: Junqueira & Carneiro, 10th ed., p. 148
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Slide 19: Weiss, 6th ed., p. 225
Slide 20: Bloom & Fawcett, 12th ed., p. 205
Slide 21: Wheater's 5th ed., p. 190
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Slide 38: Sources Undetermined
Slide 39: Source Undetermined
Slide 40: Wheater's 5th ed., p. 201; Source Undetermined
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Slide 50: Sources Undetermined
Slide 51: Weiss, 5th ed., p. 245