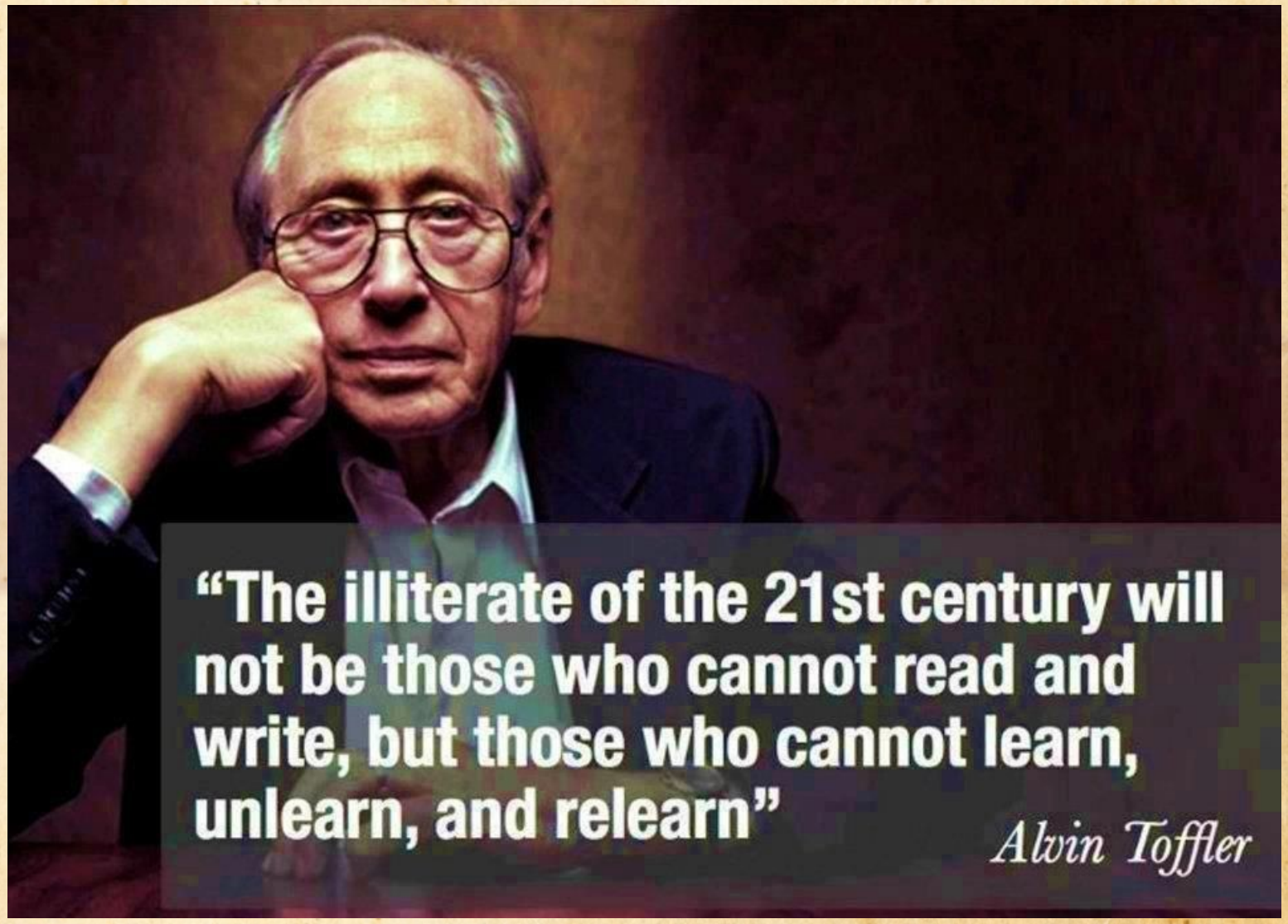
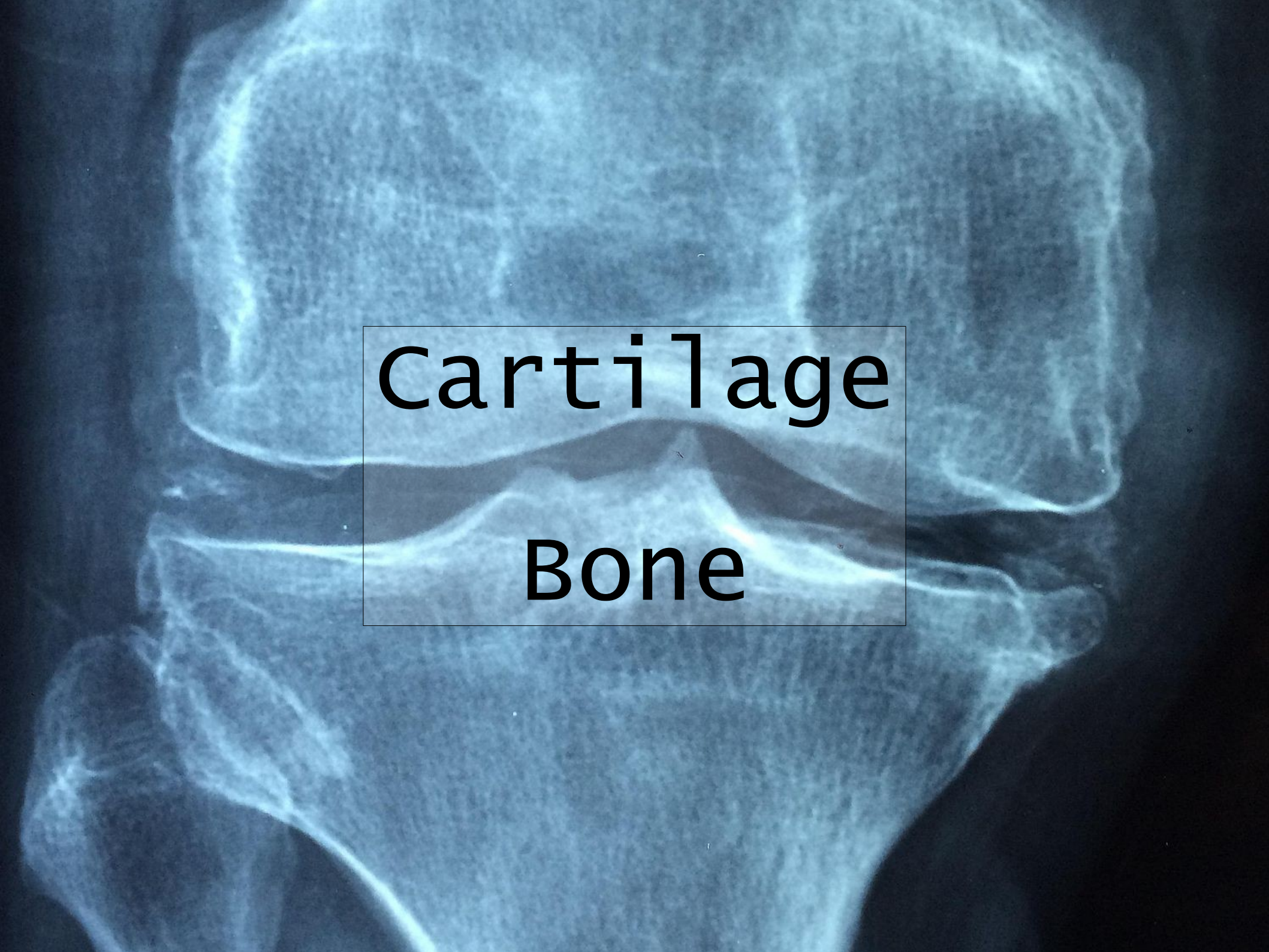
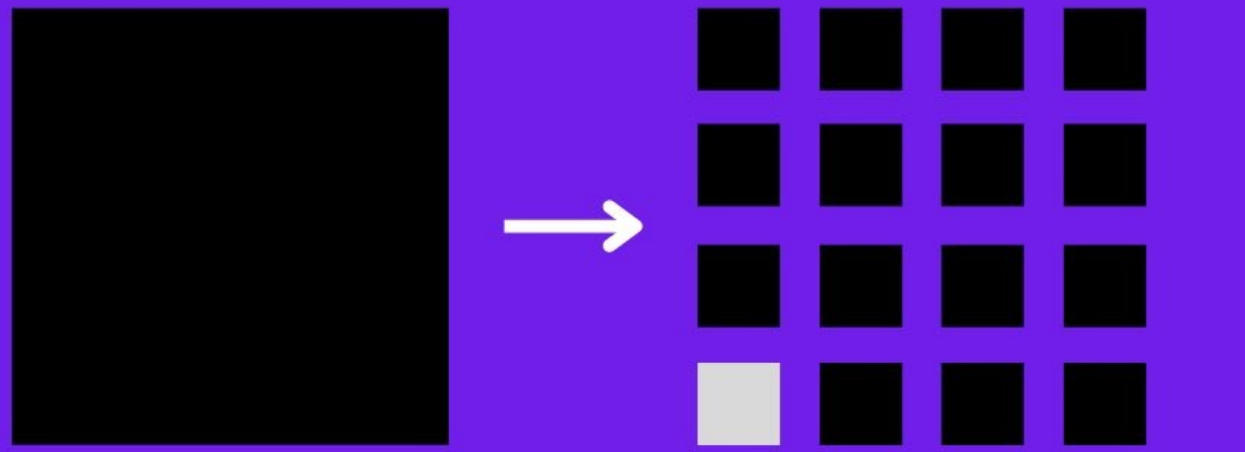

“The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn”
Alvin Toffler


Cartilage
Bone


GOALS THAT
FEEL IMPOSSIBLE
SMALL STEP YOU
CAN TAKE TODAY

Cartilage

Cartilage

- Avascular – no blood vessels
- Smooth – even-textured
- Elastic – can bend

Functions

- Smooth surface – bone articulation
- Bone formation
- Structural support – rings in trachea

Components

- Small number chondrocytes
- Deposit matrix
- Fibers
- Collagen
- Elastic
- Tensile strenght
- Majority ECM
- Traps water – resilience

Mature chondrocytes

- Secrete
- Maintain
- ECM

Avascular

- No blood vessels
- Diffusion of nutrients
- Heals poorly
- Epithelia?

3 Types

- Hyaline cartilage
- Type II collagen
- Elastic cartilage
- Type II collagen and Elastic fibres
- Fibrocartilage
- Type I & Type II collagen

Hyaline cartilage

- Glassy appearance
- Highly hydrated
- Articular surfaces
- Structural support
- Rings in trachea
- Epiphyseal plates

Articulating surface

Articulating surface

- No perichondrium
- Limit ability to grow

Trachea

- Outer layer dense irregular CT – perichondrium
- Outer fibrous
- Inner chondrogenic layer
- Spindle-shaped cells
- Differentiate into chondroblasts
- Migrate into matrix
- Produce cartilage matrix
- Mature into chondrocytes

Chondrocytes

- Within small cavities – lacunae
- Clusters 2 to 4 cells

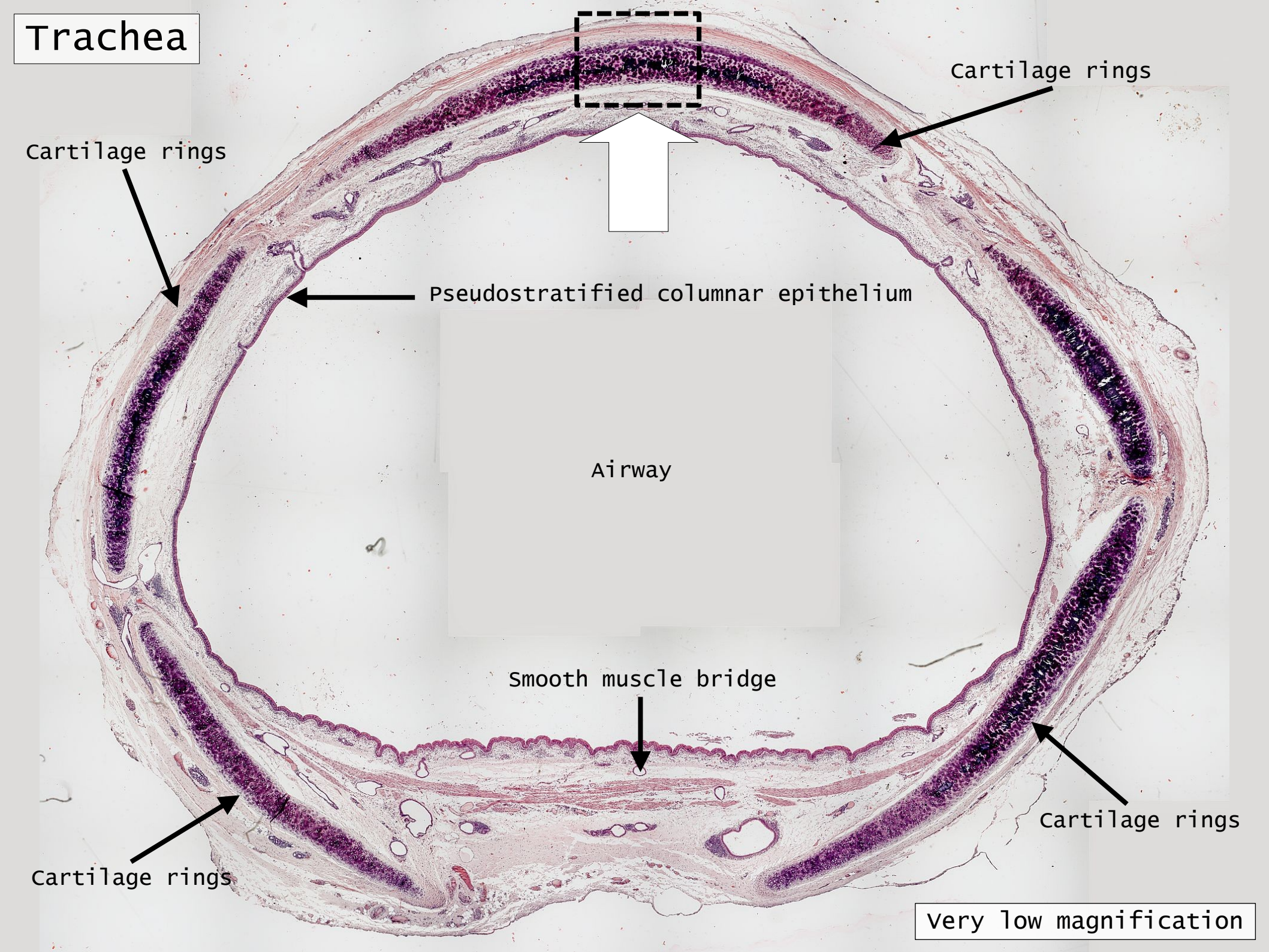
Extracellular matrix

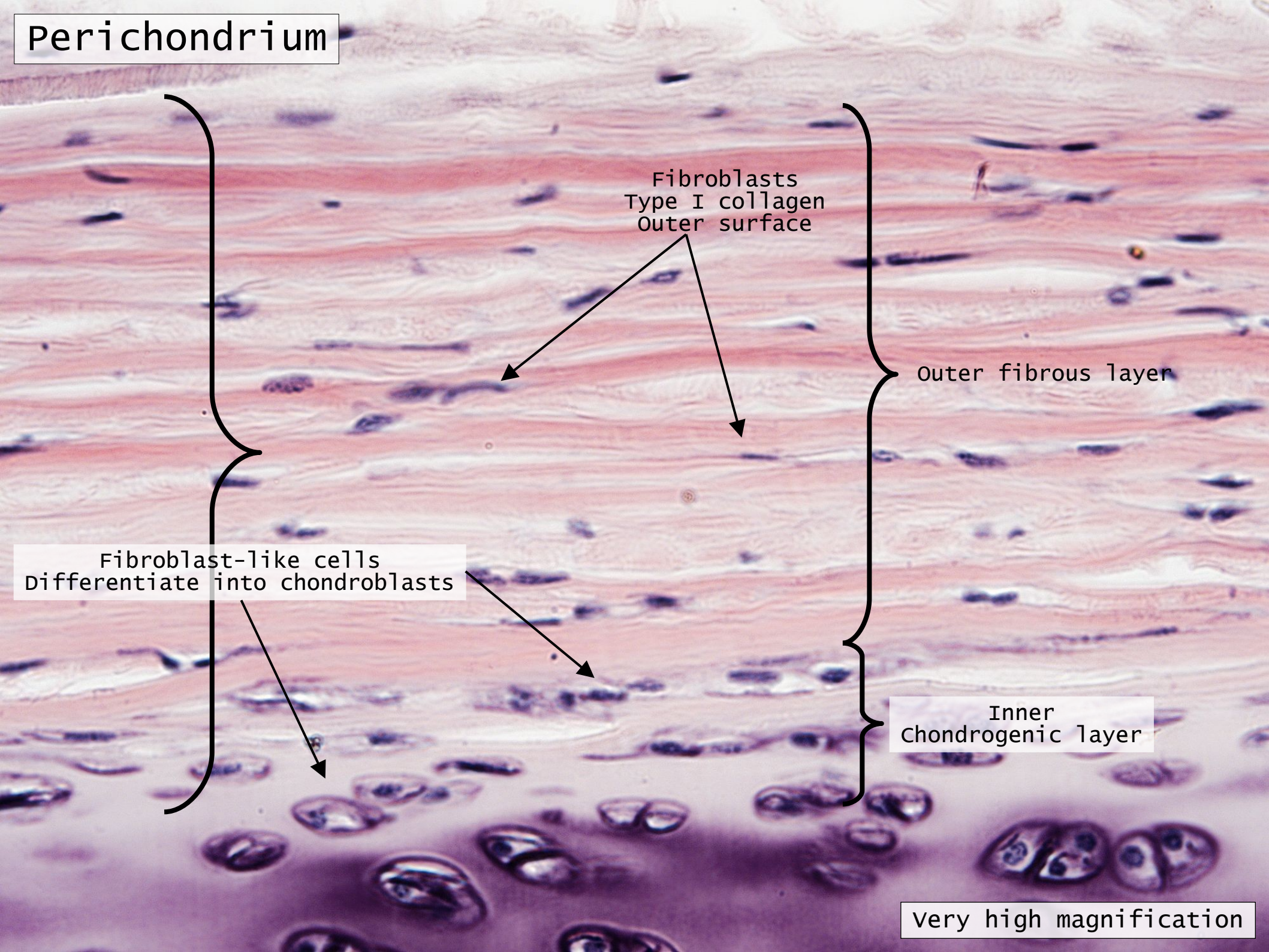
- Glassy appearance
- Type II collagen
- Proteoglycan
- Amorphous ground substance

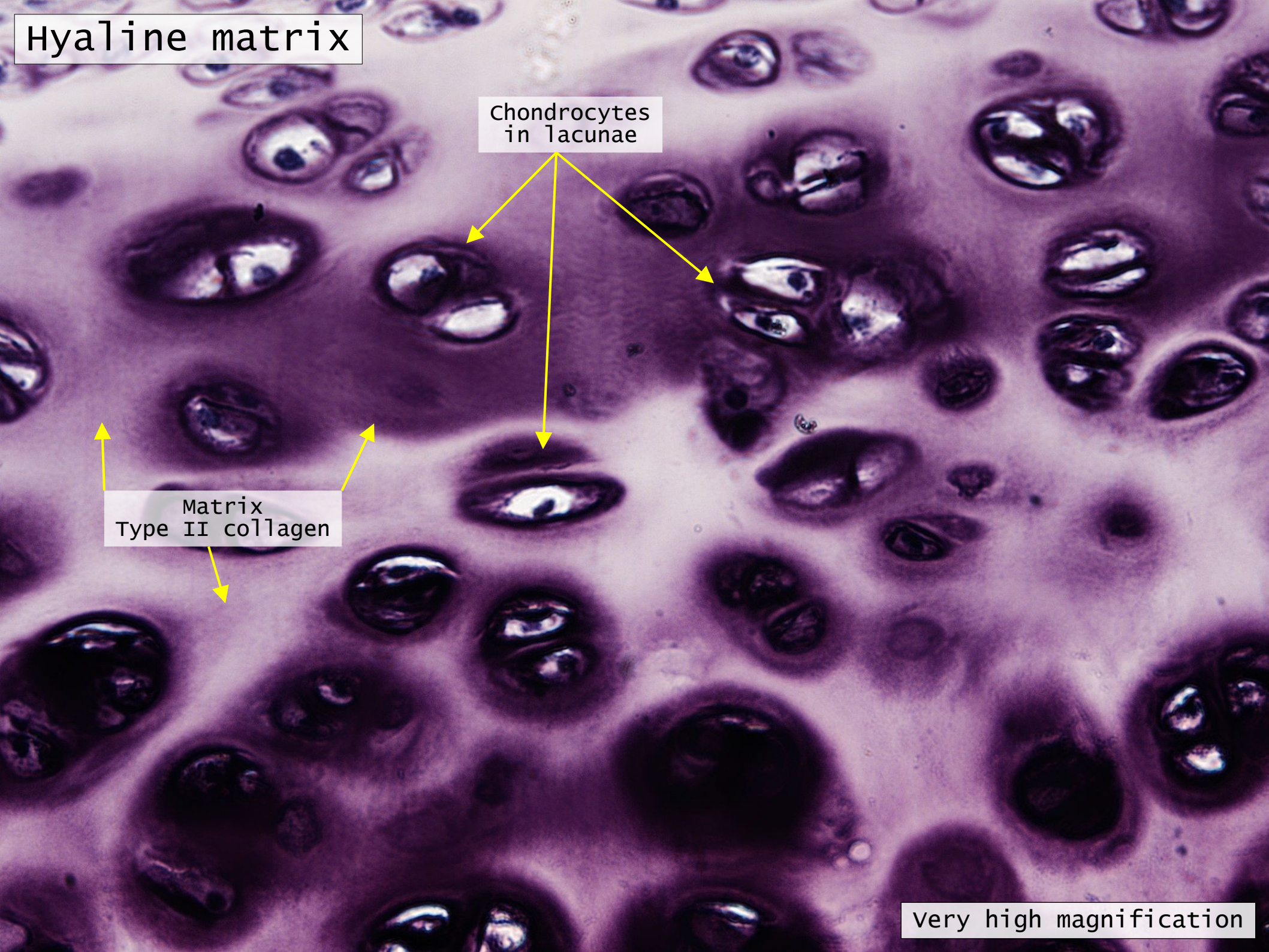
Hyaline Cartilage

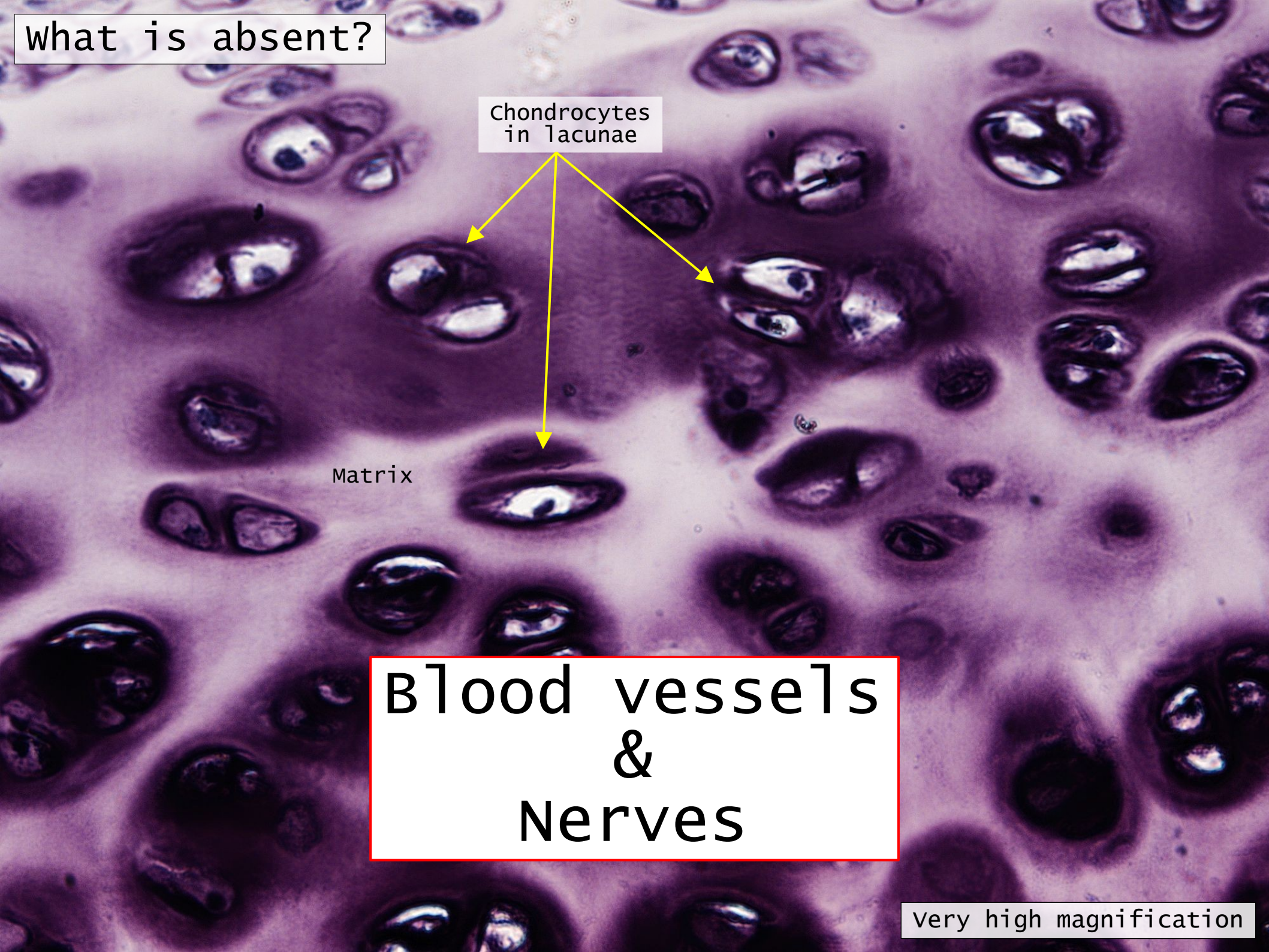
Trachea

Slide 73


Trachea
Cartilage rings
Cartilage rings
Pseudostratified columnar epithelium
Airway
Smooth muscle bridge
Cartilage rings
Cartilage rings
Very low magnification


Perichondrium
Fibroblasts
Type I collagen
Outer surface
Outer fibrous layer
Fibroblast-like cells
Differentiate into chondroblasts
Inner
Chondrogenic layer
Very high magnification


Hyaline matrix
Chondrocytes in lacunae
Matrix Type II collagen
Very high magnification


What is absent?
Chondrocytes in lacunae
Matrix
Blood vessels & Nerves
Very high magnification

Elastic cartilage

- Dense network branching elastic fibers
- More flexible
- Bend and move to function
- Ear
- Epiglottis
- Auditory tubes

Elastic cartilage

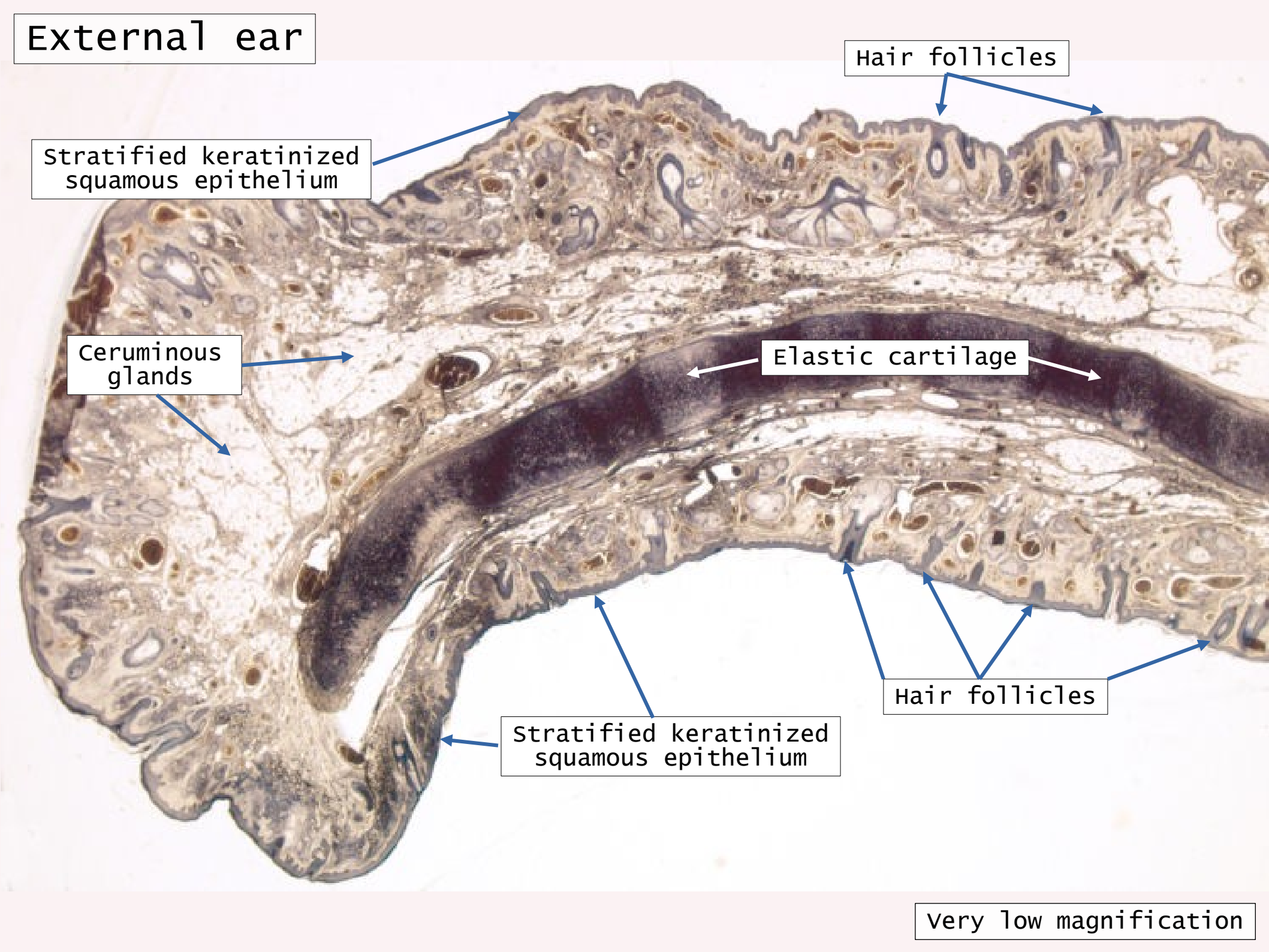
- Similar to hyaline
- ECM dense network elastic fibers
- Elastic fibers – flexible and elastic characteristics
- Cartilage matrix
- Chondrocytes in lacunae
- Perichondrium

Elastic Cartilage

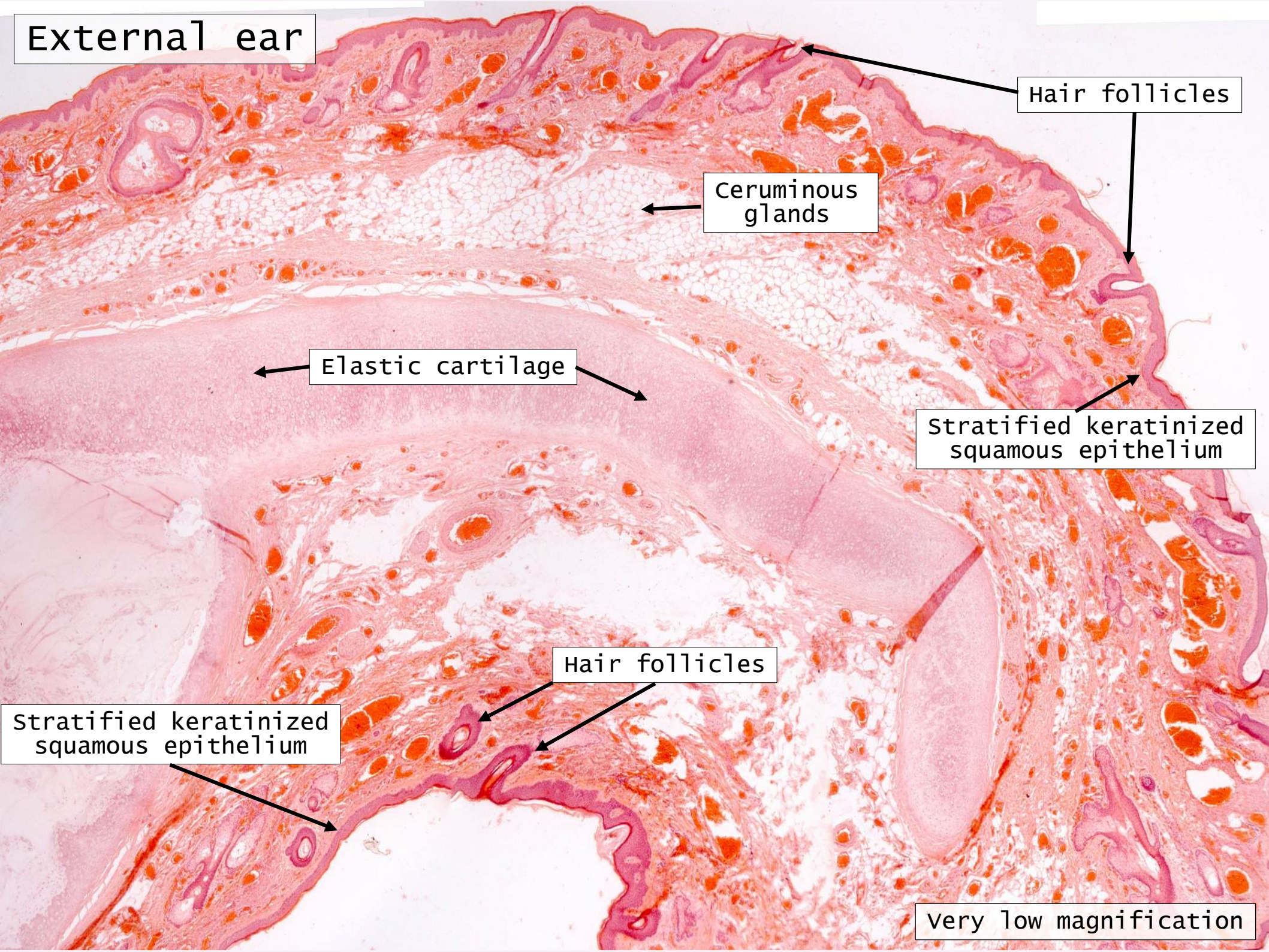
Ear

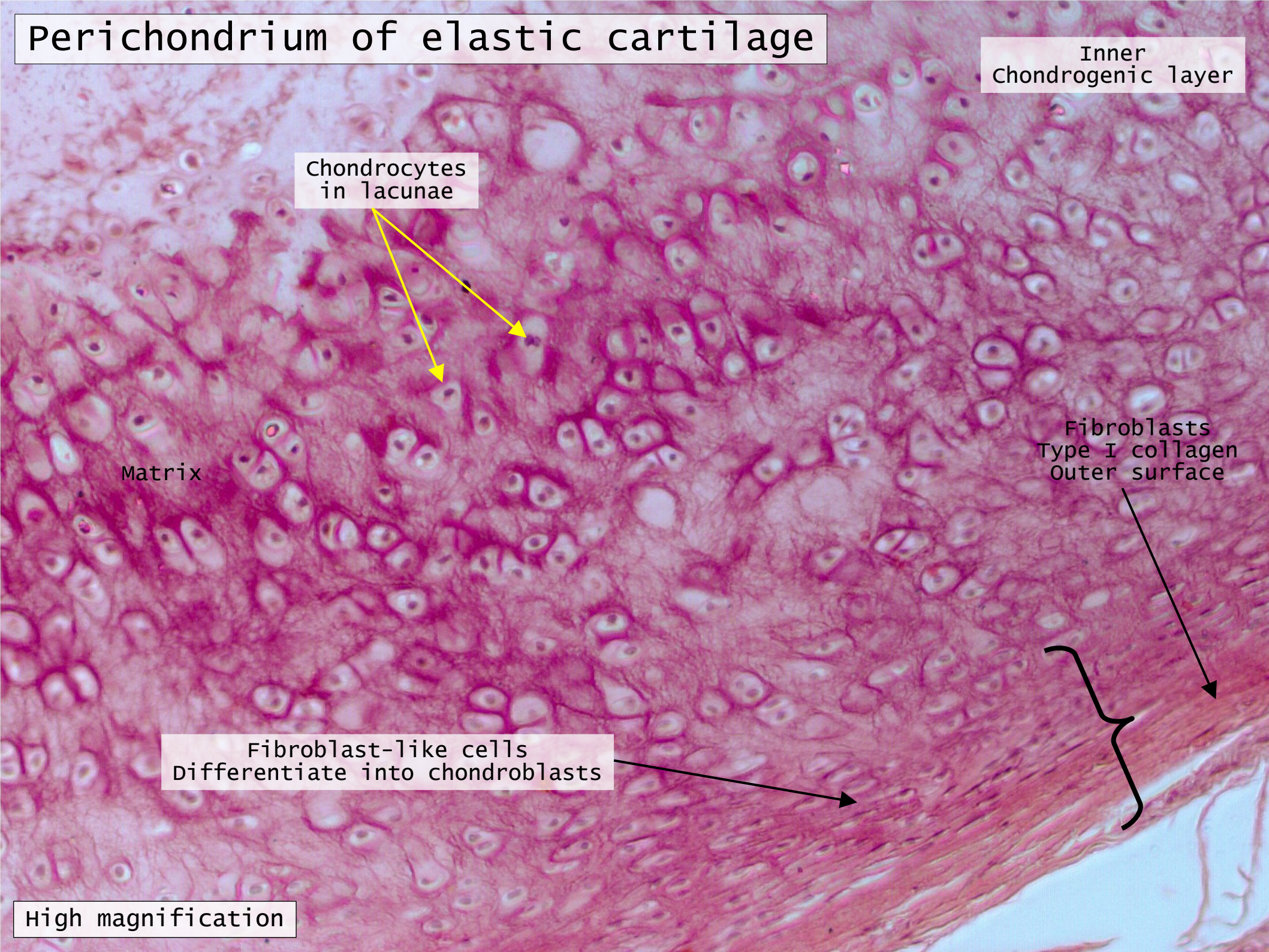
Slide 9

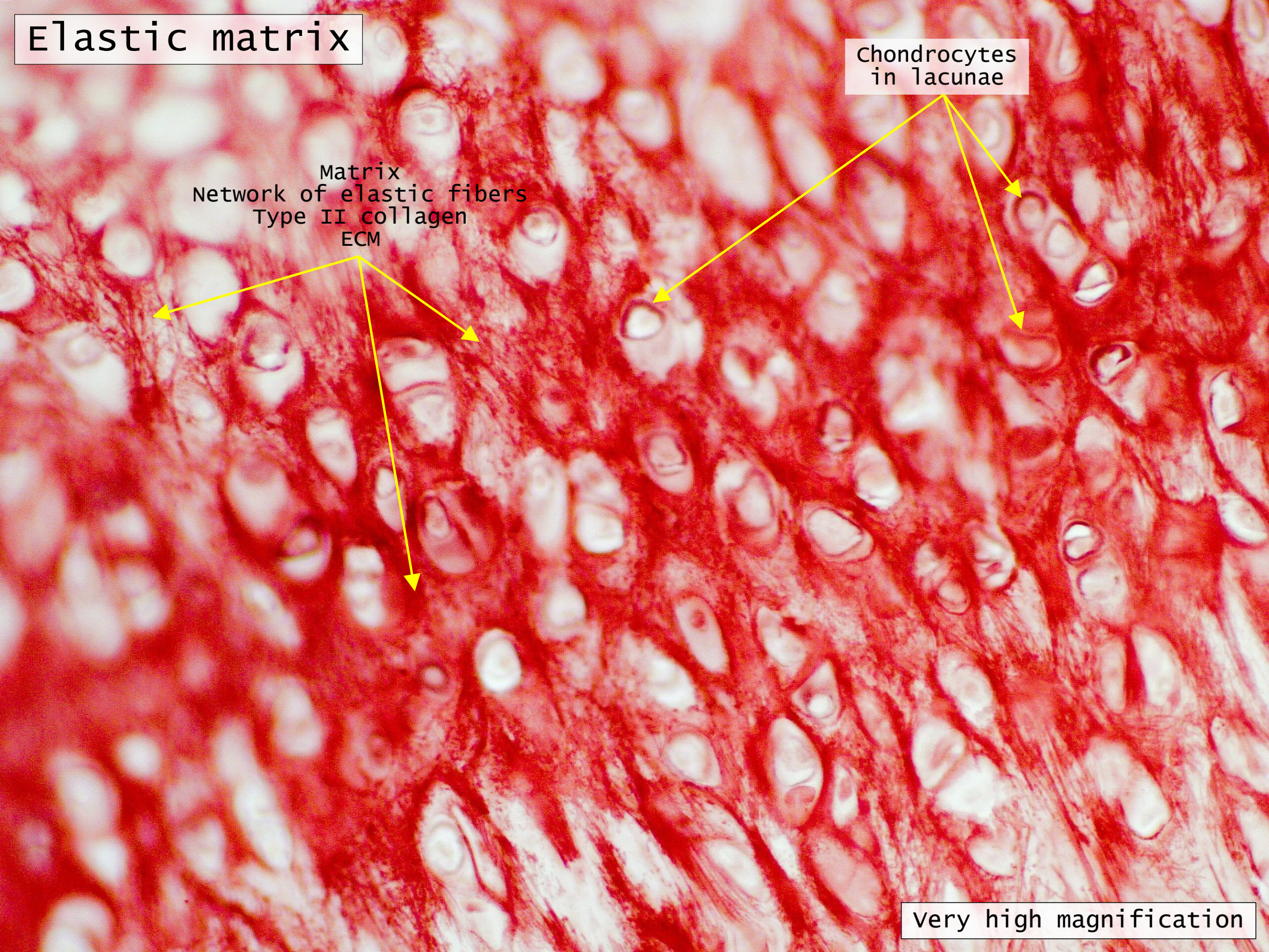
External ear

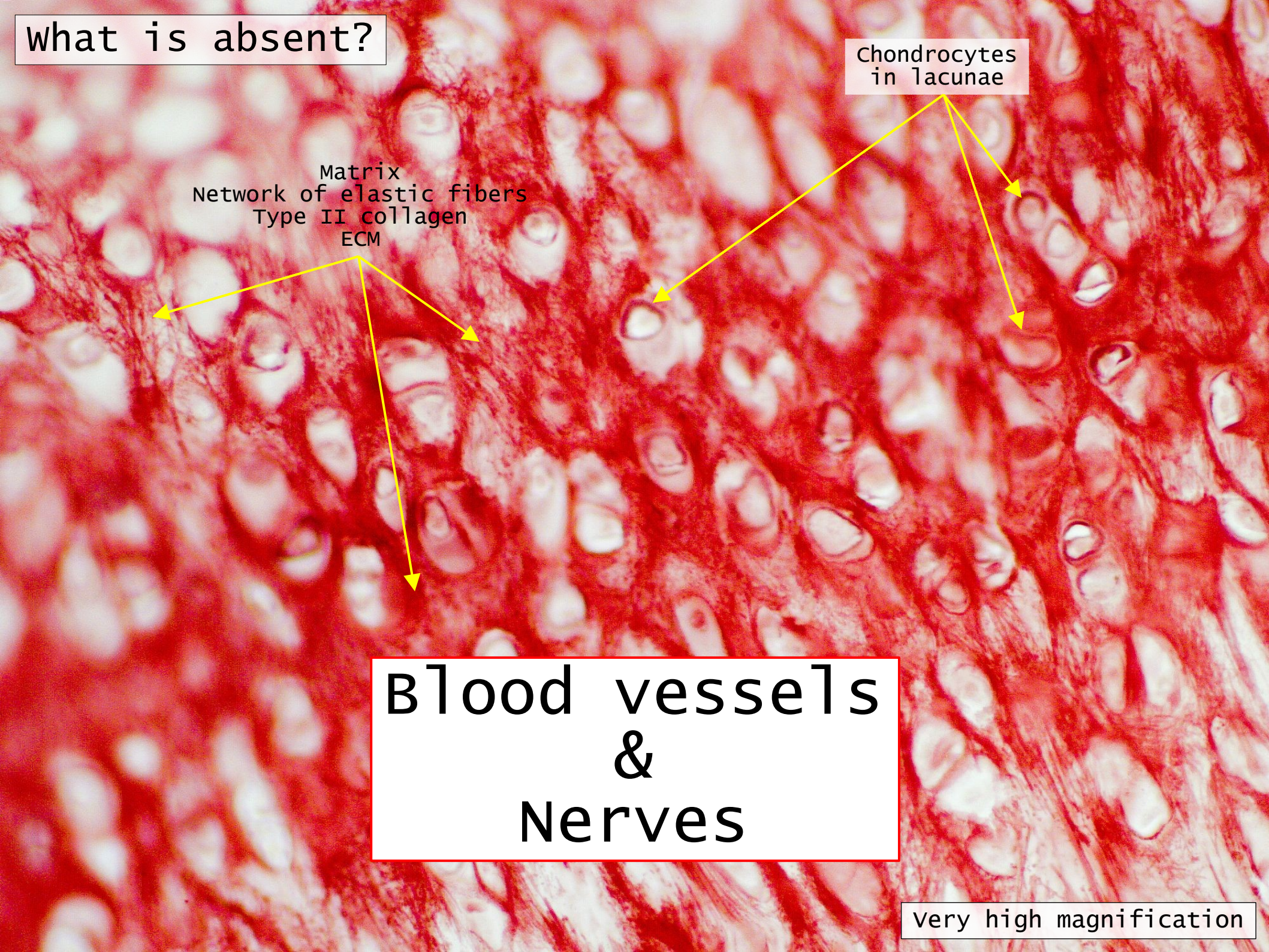


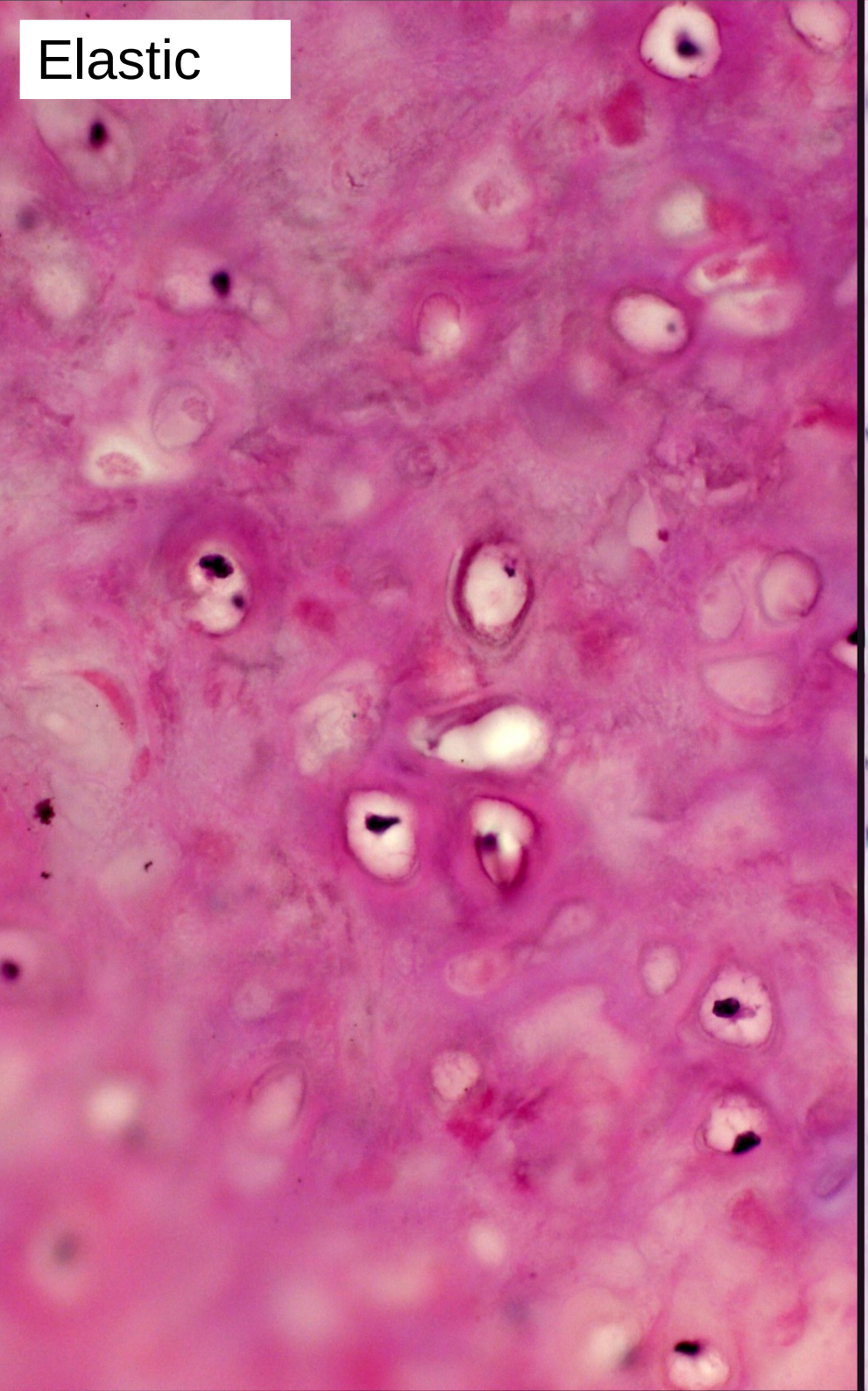
Very low magnification

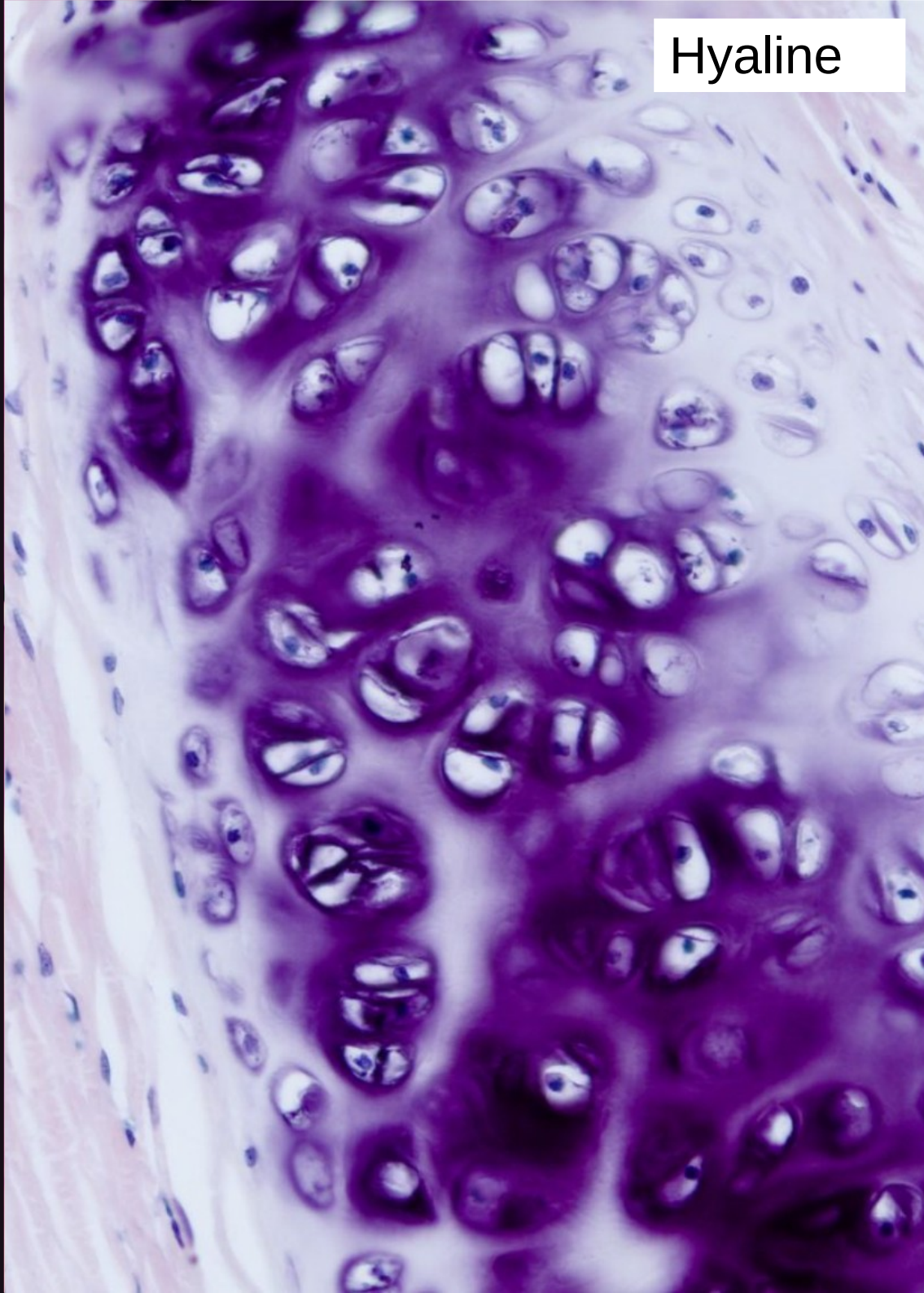

External ear
Hair follicles
Ceruminous glands
Elastic cartilage
Stratified keratinized squamous epithelium
Hair follicles
Stratified keratinized squamous epithelium
Very low magnification


Perichondrium of elastic cartilage
Inner
Chondrogenic layer
Chondrocytes
in lacunae
Matrix
Fibroblasts
Type I collagen
Outer surface
Fibroblast-like cells
Differentiate into chondroblasts
High magnification


Elastic matrix
Chondrocytes
in lacunae
Matrix
Network of elastic fibers
Type II collagen
ECM
Very high magnification


What is absent?
Chondrocytes in lacunae
Matrix
Network of elastic fibers
Type II collagen
ECM
Blood vessels
&
Nerves
Very high magnification


Elastic


Hyaline

Fibrocartilage

- Dense connective tissue
  - Collagen fibers
- Bands ECM
- Tendon to bone
- Intervertebral discs
- Menisci

Fibrocartilage

- Mixture of features from hyaline and dense CT
- No perichondrium
- Alternating layers
  - Cartilage matrix
  - Dense CT with collagen type I
- Fibers aligned with functional stress
- Chondrocytes within lacunae
  - Round nuclei in lacunae
- Fibroblasts in the fibrous areas
  - Long thin nuclei
  - Not clearly discernable

Alternating layers

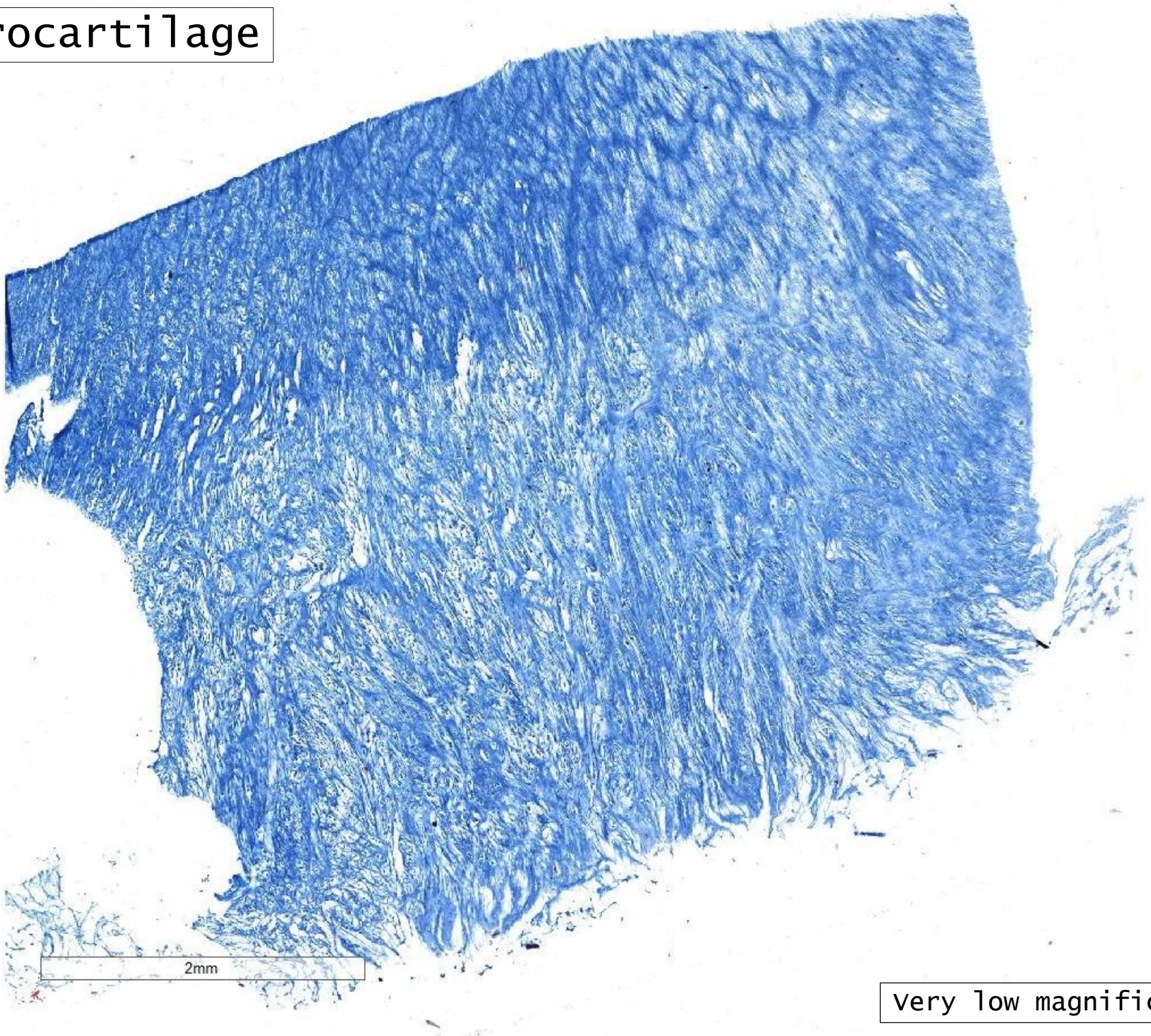
- Cartilage matrix
- Dense CT
- Combine
  - Tensile strength of collagen fibers
  - Resistance to compression of cartilage

Fibrocartilage

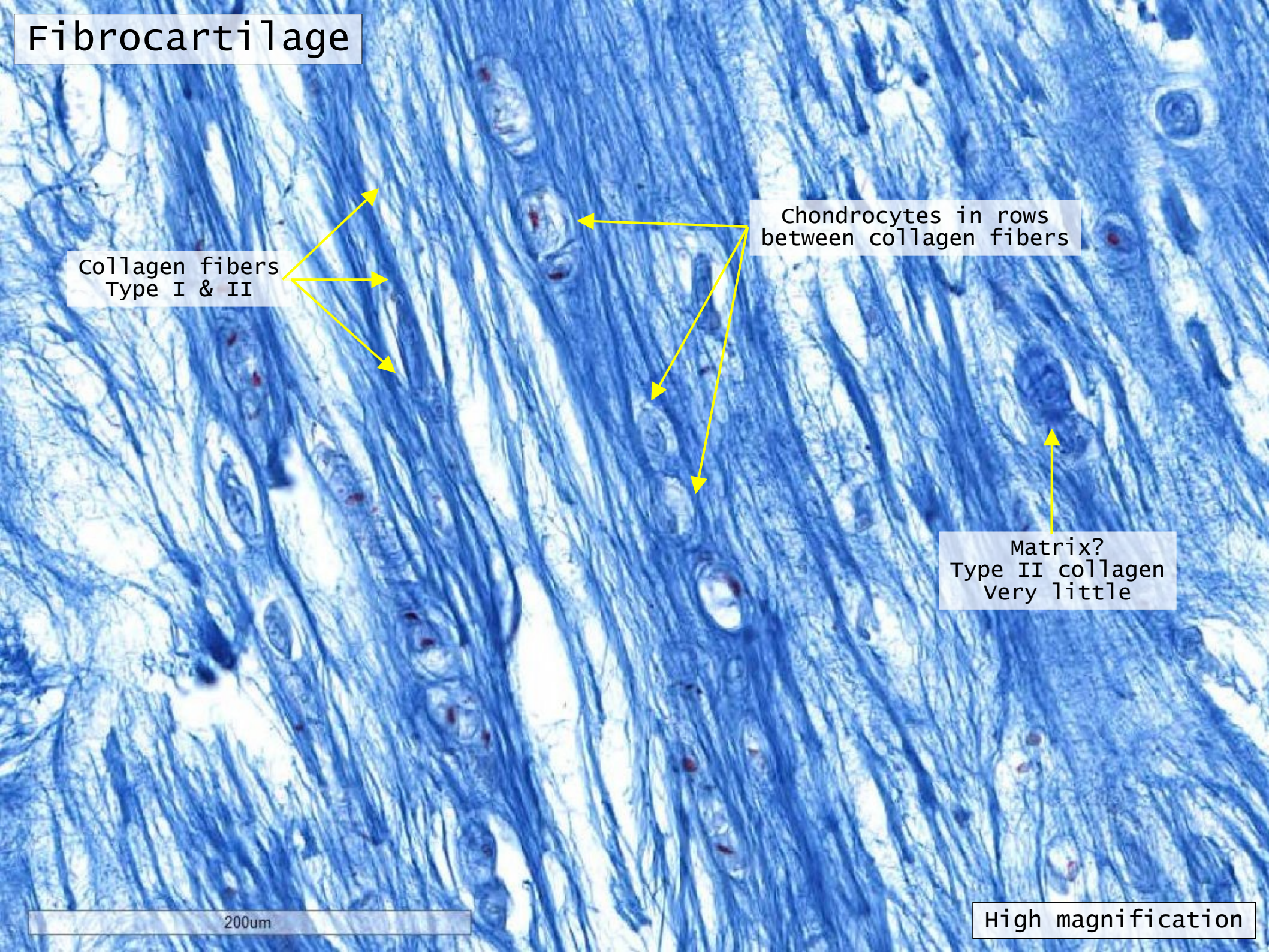
Tendon

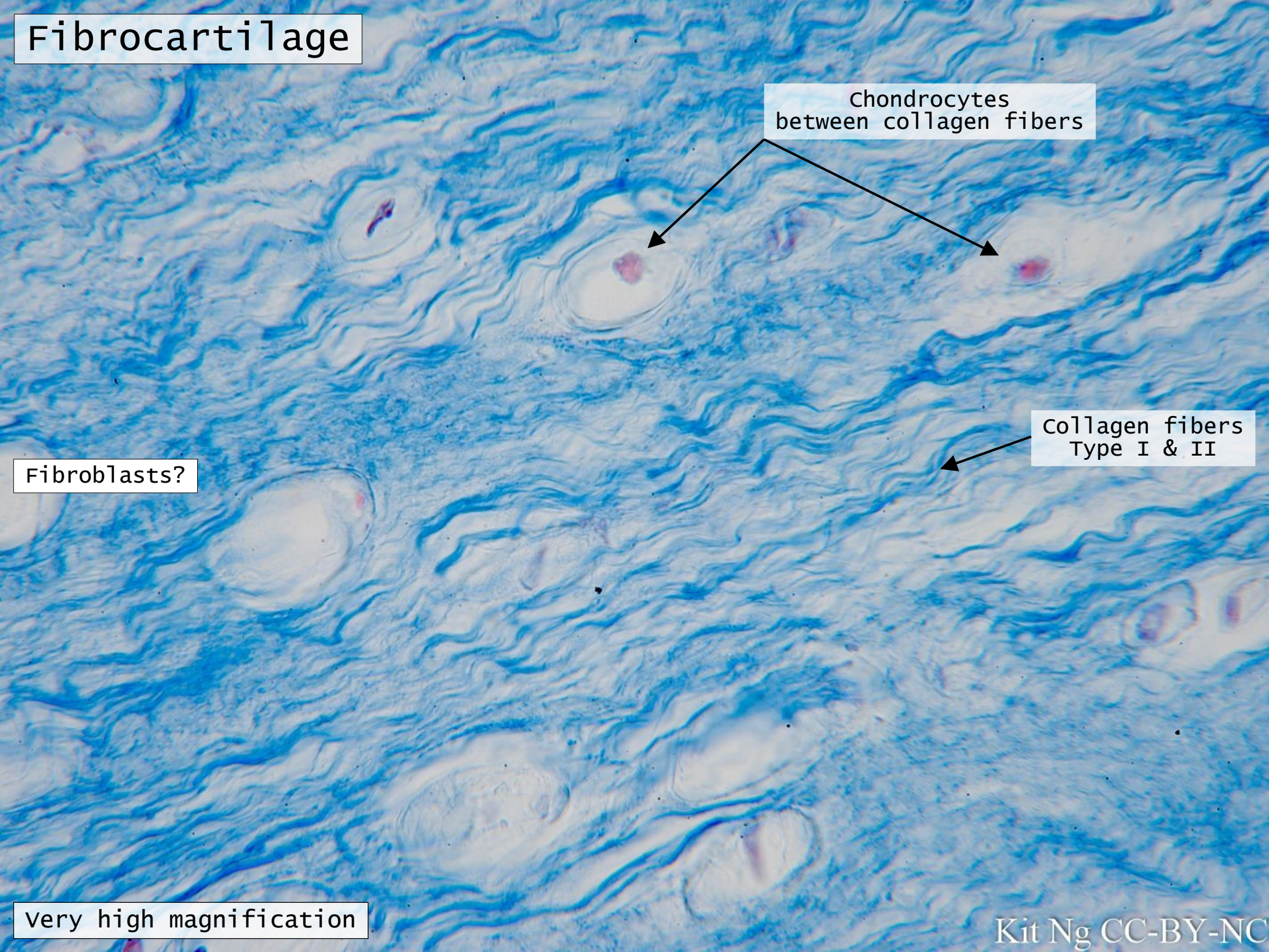
Slide 10

Fibrocartilage

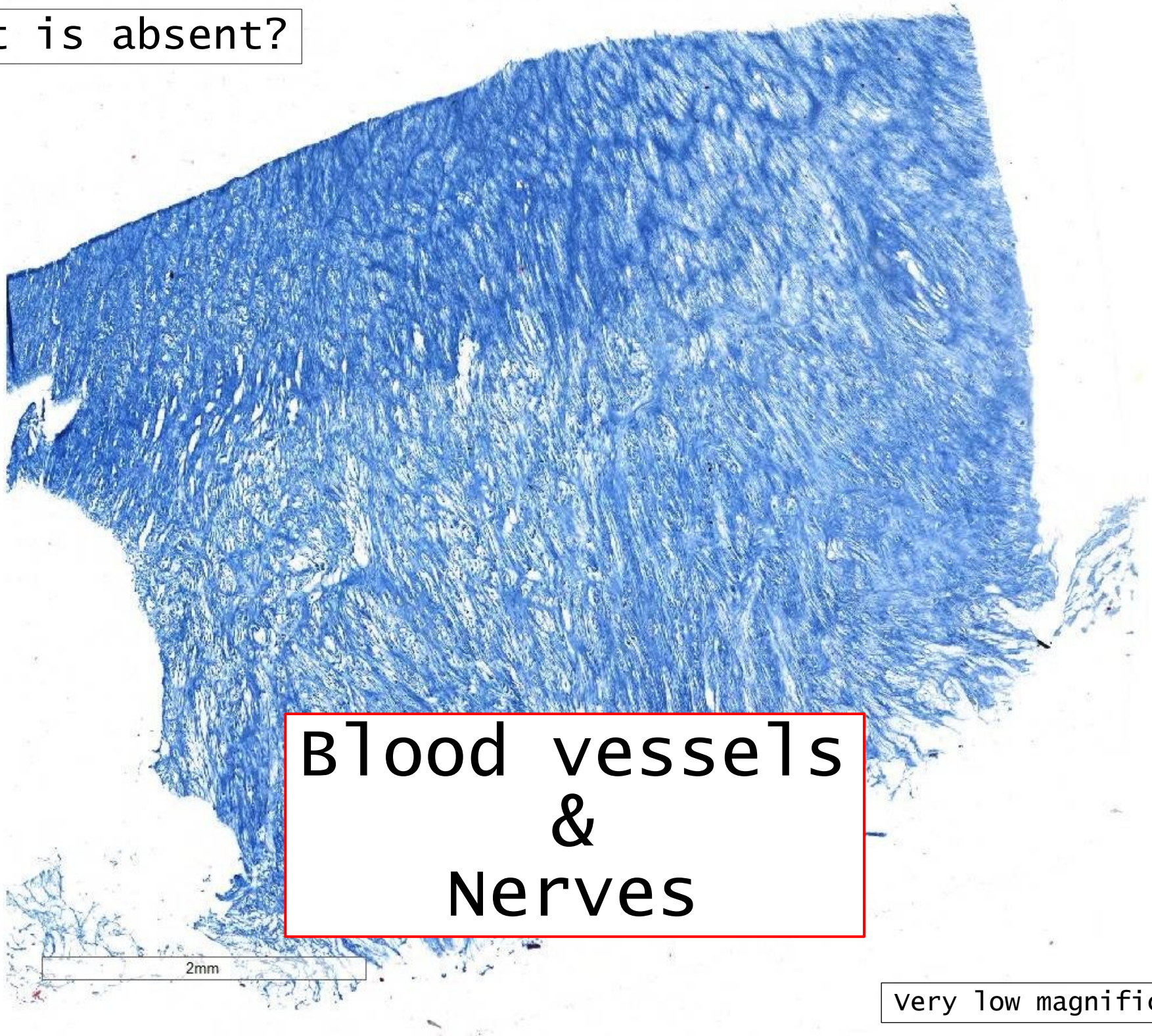


Very low magnification


Fibrocartilage
Collagen fibers
Type I & II
Chondrocytes in rows
between collagen fibers
Matrix?
Type II collagen
Very little
200um
High magnification



What is absent?



Blood vessels
&
Nerves

Very low magnification

No blood vessels

- Low healing potential
- Nutrients?
- Epithelia?

Summary

- 3 types of cartilage
- Hyaline
- Elastic
- Fibrocartilage

Hyaline

- ECM with glassy appearance
- Articular surfaces – long bones
- Structures – trachea
- Articular hyaline has no perichondrium

Elastic cartilage

- Firm and flexible
- External ear & epiglottis
- Dense network elastic fibers
- Always perichondrium

Fibrocartilage

- Intervertebral discs & knee
- Combines hyaline cartilage & dense CT
- Contains type I collagen & fibroblasts
- No perichondrium

Bone

- Support and protection
- Hard & rigid – mineralization of ECM – bone matrix
- Reservoir for calcium
- Rich blood supply

Cells

- Osteocytes
- Osteoblasts
- Osteoclasts

Osteocytes

- In cavities (lacunae)
- Between layers of bone matrix
- Nutrition
- Mechano-sensory

Osteoblasts

- On surface of bone
- Inside bone matrix
- Synthesizing matrix
- Mediating mineralisation of matrix

Osteoclasts

- Large multinucleated
- Remove calcified bone matrix
- Turnover
- Remodelling

Two types of bone

- Compact bone
  - Cortical bone
  - Closer to surface
  - Dense
- Spongy bone
  - Also cancellous or trabecular bone
  - Deeper
  - Interconnecting cavities

Two forms

- Layered or lamellar bone
  - Matrix arranged in sheets
  - Compact bone
- Woven bone
  - Collagen fibers arranged randomly
  - Developing & fractured

Long bones

- Outer edge
- Compact bone outside
- Spongy bone inside

Flat bones

- Compact bone both sides
- Spongy bone inside

Compact bone

- Cylindrical units
- Osteons
- Aligned long axis of bone
- Concentric rings of bone – lamellae
- Around central channel

Spongy bone

- "Beams"
- Spicules of bone
- Interconnected spaces
- Contains bone marrow

Osteoclasts

- Inside bone marrow
- In resorption cavity on surface of bone matrix
- Multiple nuclei within osteoclast
- Megakaryocyte – single multilobed nucleus

Osteon

- Structural unit of bone
- Also called Haversian system

Osteon

- Concentric lamellae (layers)
- Around central canal
- Haversian canal
- Contains blood vessels & nerves
- Osteoblasts on surface of canal

Haversian lamellae

- Concentric around canal
- Lacunae
- Osteocytes within lacunae
- Canaliculi

Osteoblasts

- Large spindle or cuboidal cells
- Basophilic
- Single nucleus

Bone

- Two main types
- Denser cortical bone
- Lamellae of collagen matrix
- Trabecular bone
- Random arrangement of collagen fibers
- Three main cell types
- Osteocytes in lacunae with canaliculi
- Osteoblasts on surfaces
- Osteoclasts large multinucleated on surfaces

Bone

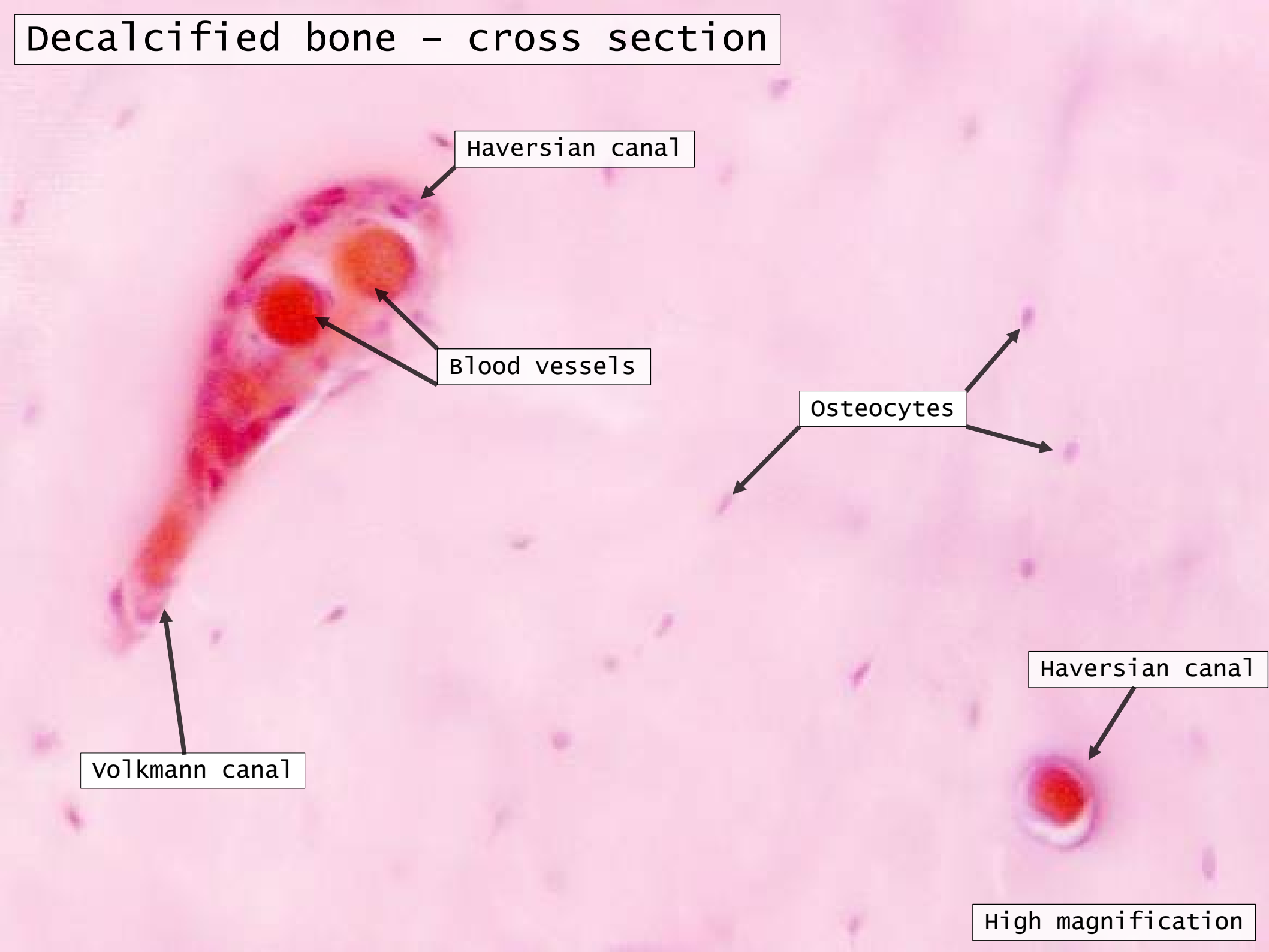
Compact bone (cross section): Slide 12
Compact bone (ground cross section): Slide 13
Compact bone (ground longitudinal section): Slide 14

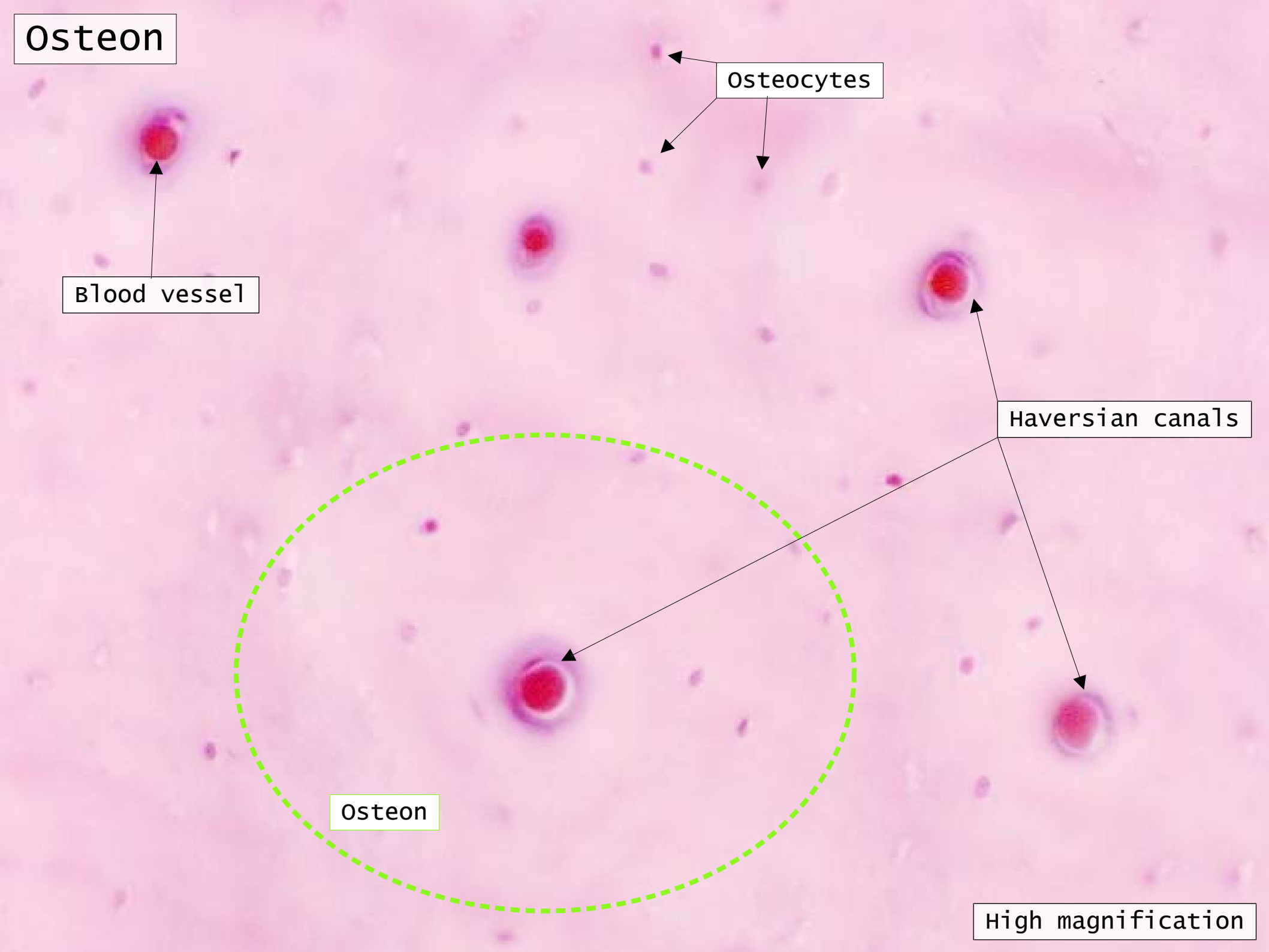
Decalcified bone – cross section

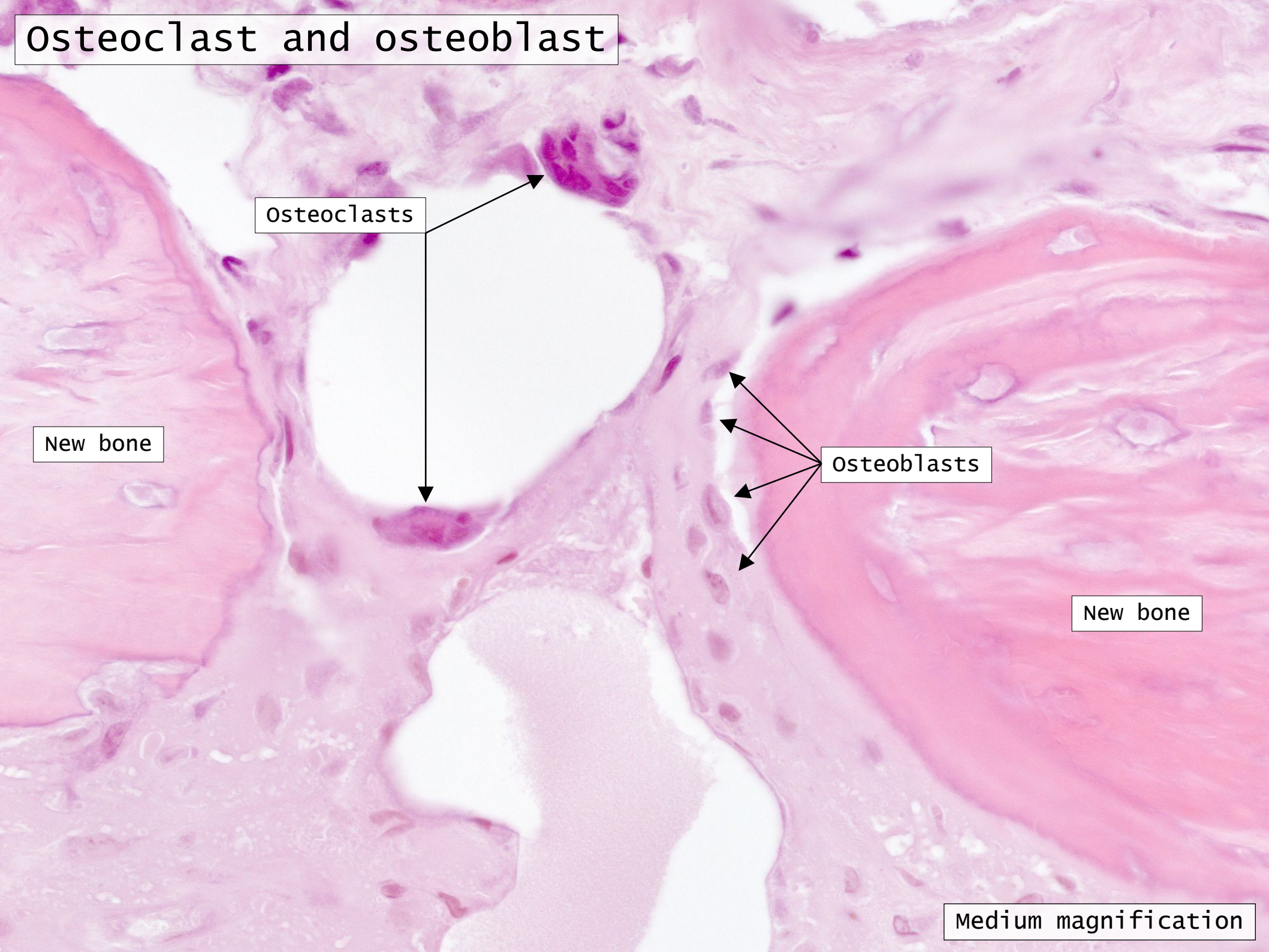
Very low magnification

Decalcified bone – cross section

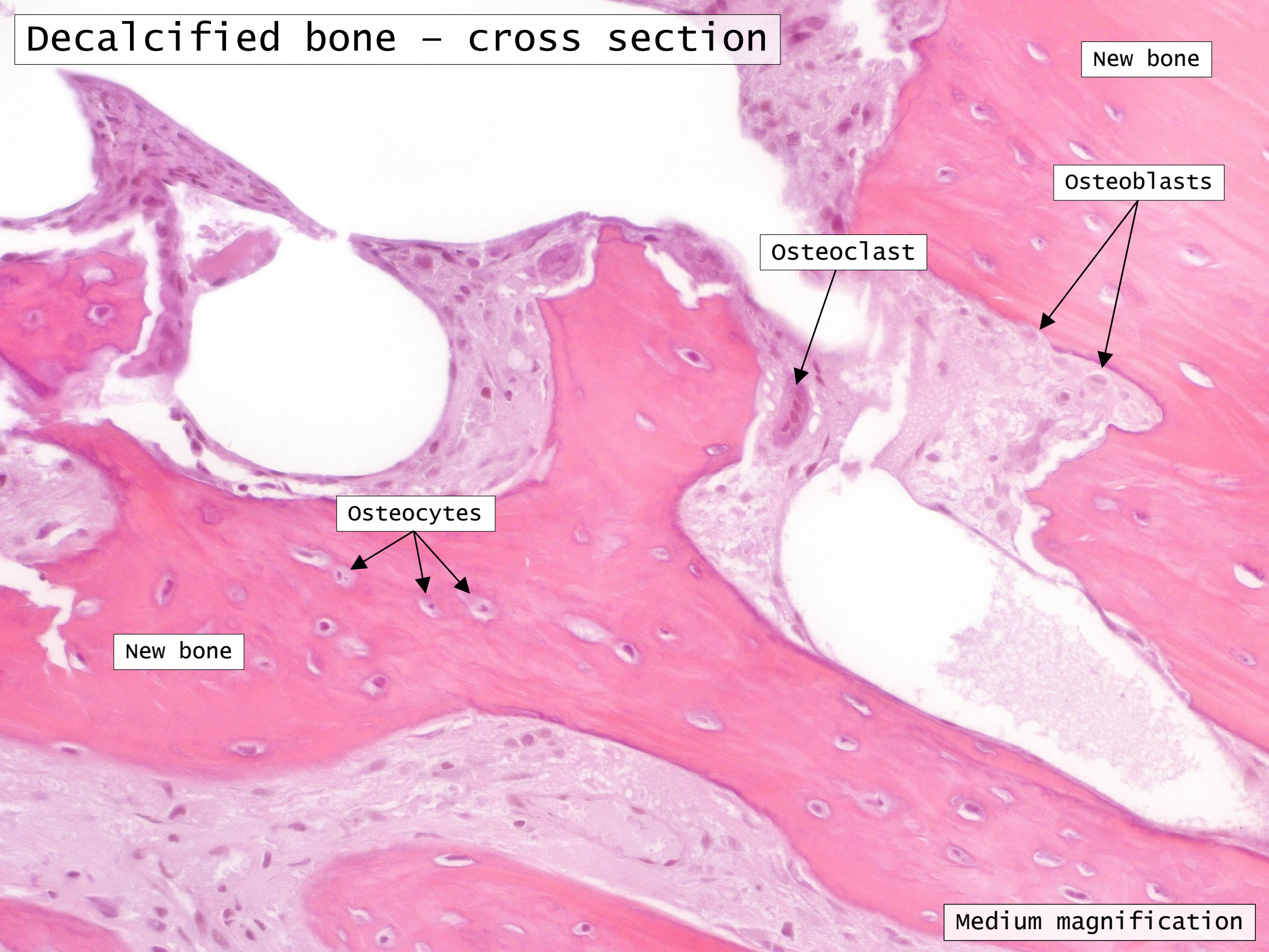
Decalcified bone – cross section

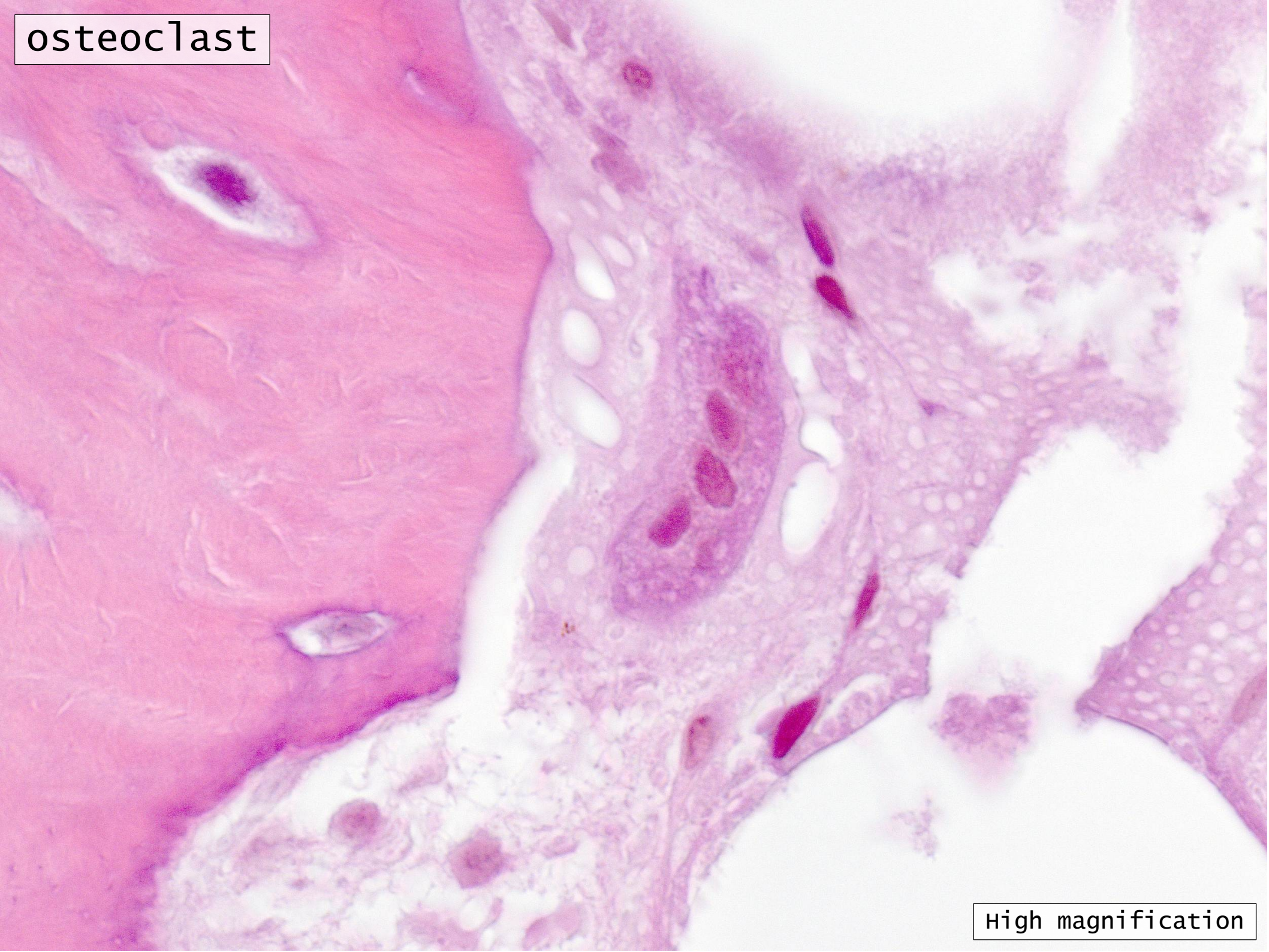


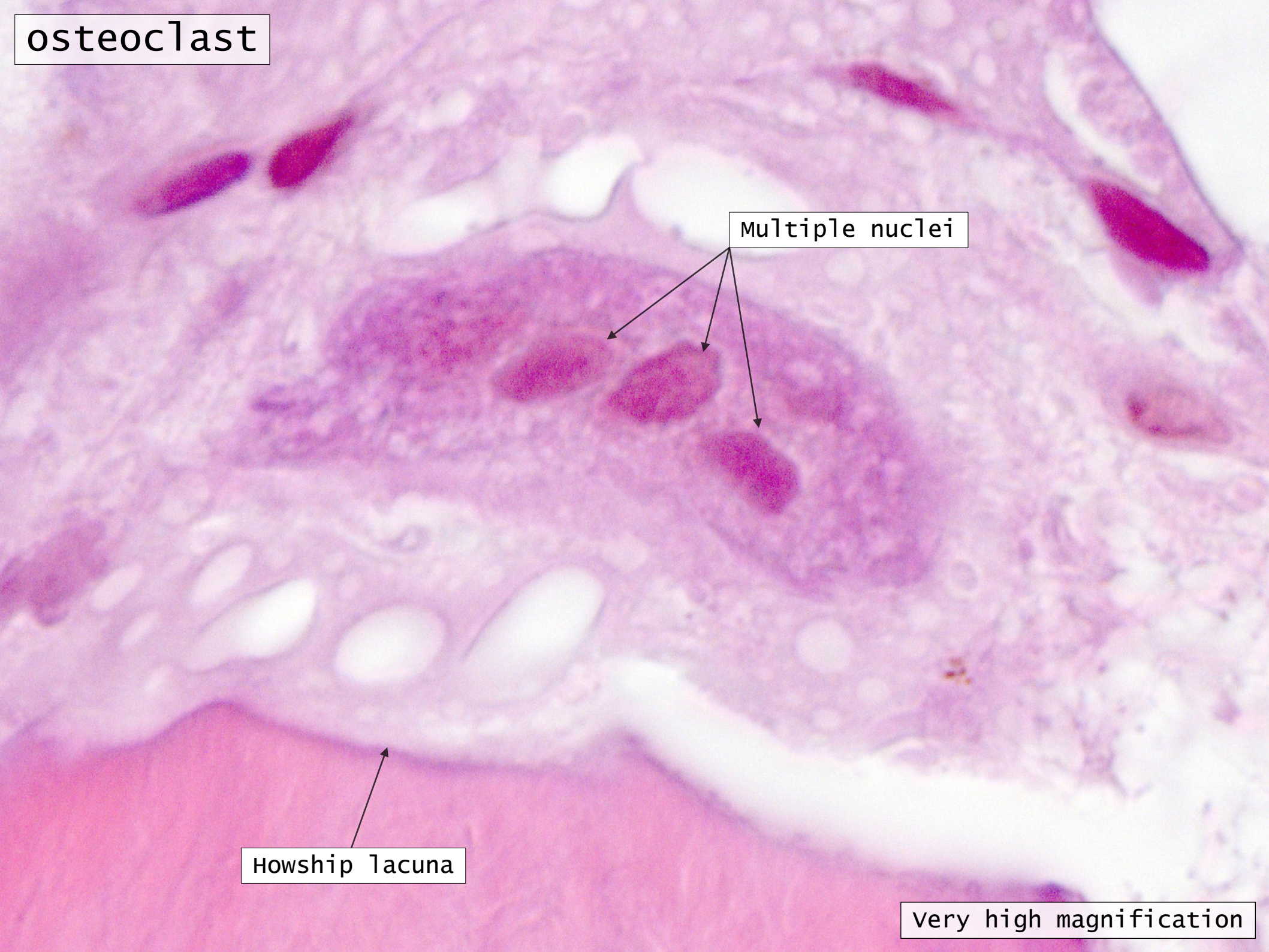

Osteon
Osteocytes
Blood vessel
Haversian canals
Osteon
High magnification


Osteoclast and osteoblast
Osteoclasts
New bone
Osteoblasts
New bone
Medium magnification

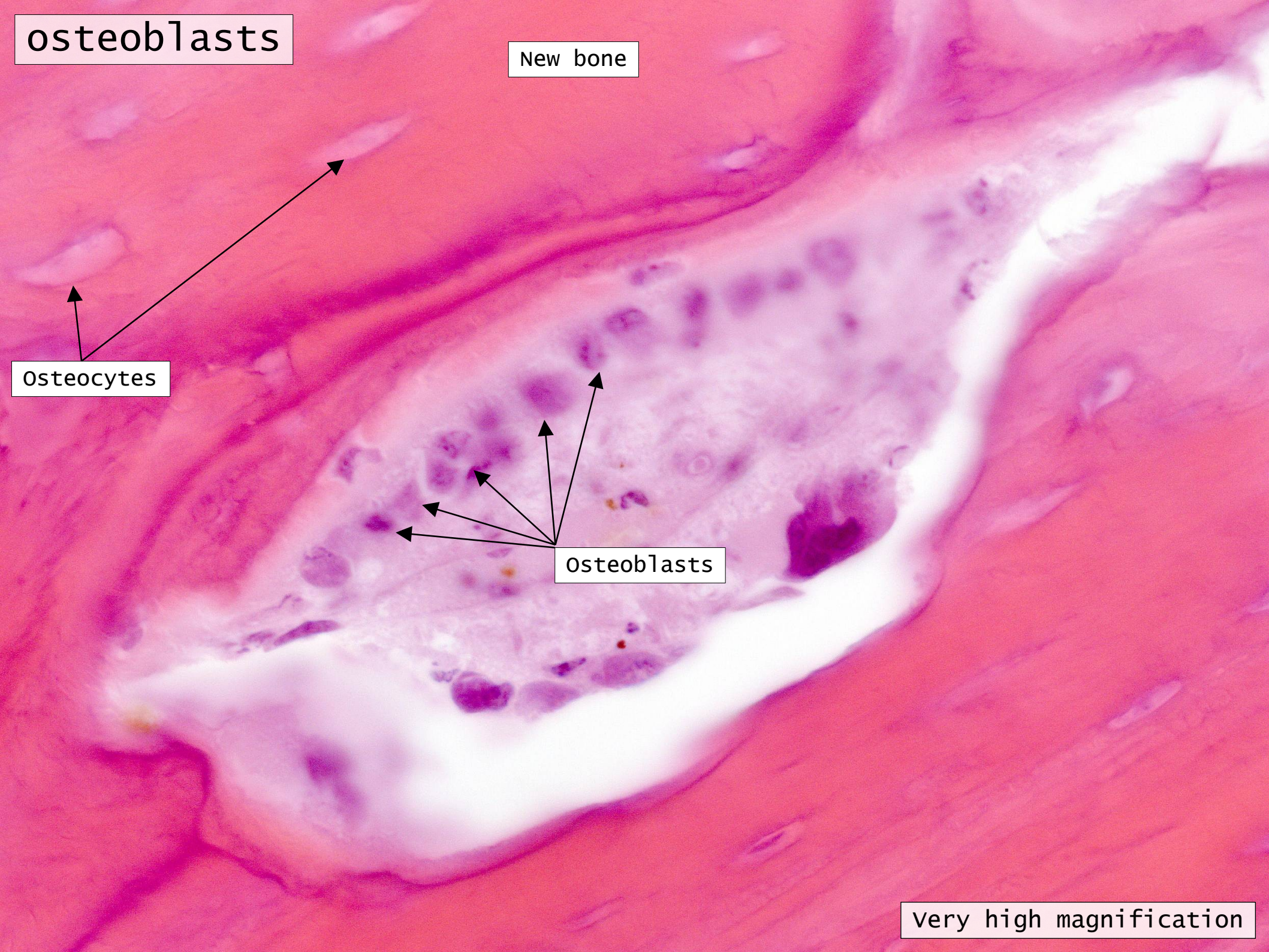
Decalcified bone – cross section



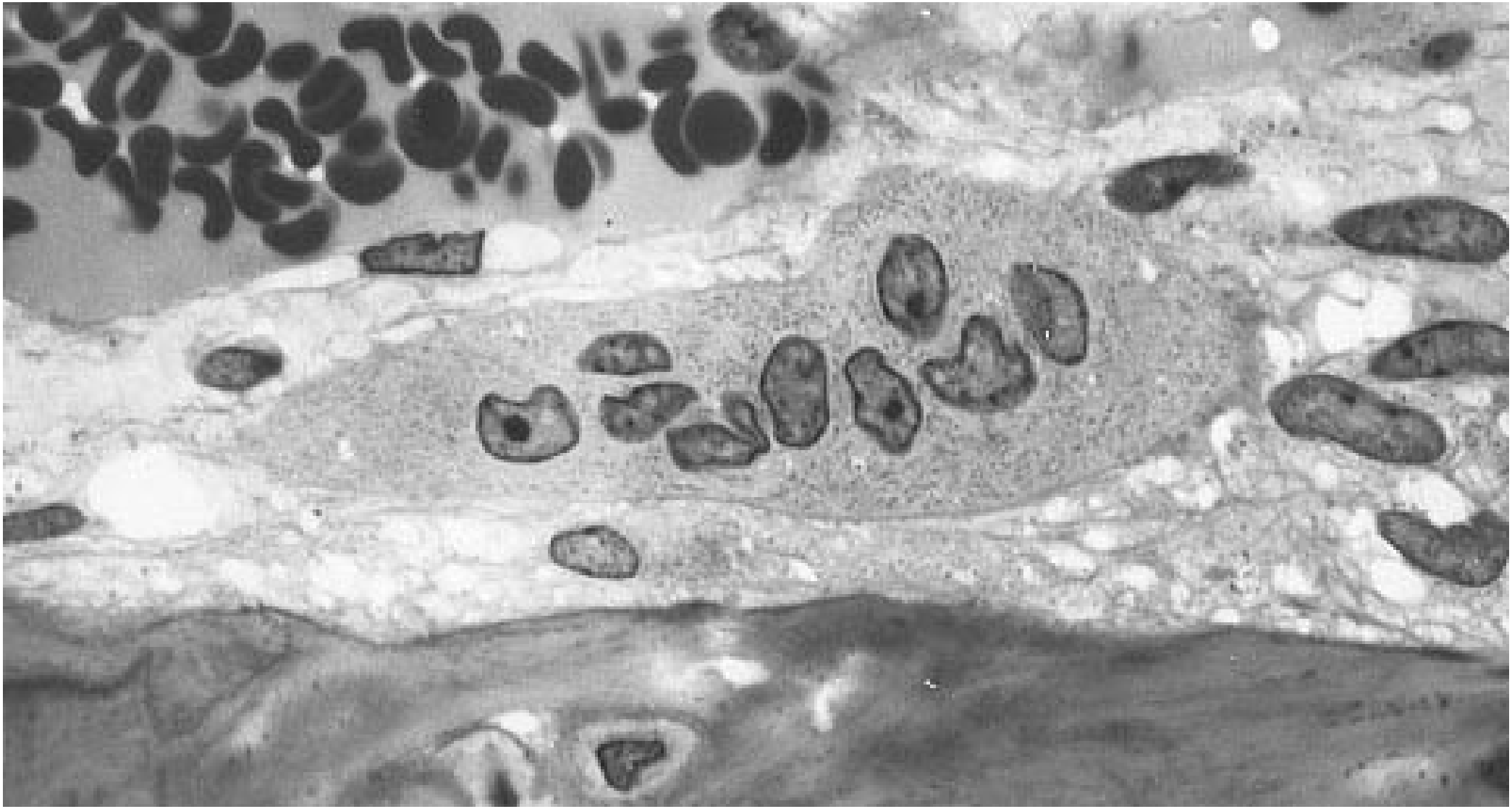

osteoclast
High magnification


osteoclast
Multiple nuclei
Howship lacuna
Very high magnification


osteoblasts
Newly deposited bone matrix
Osteocytes
Row of osteoblasts
High magnification

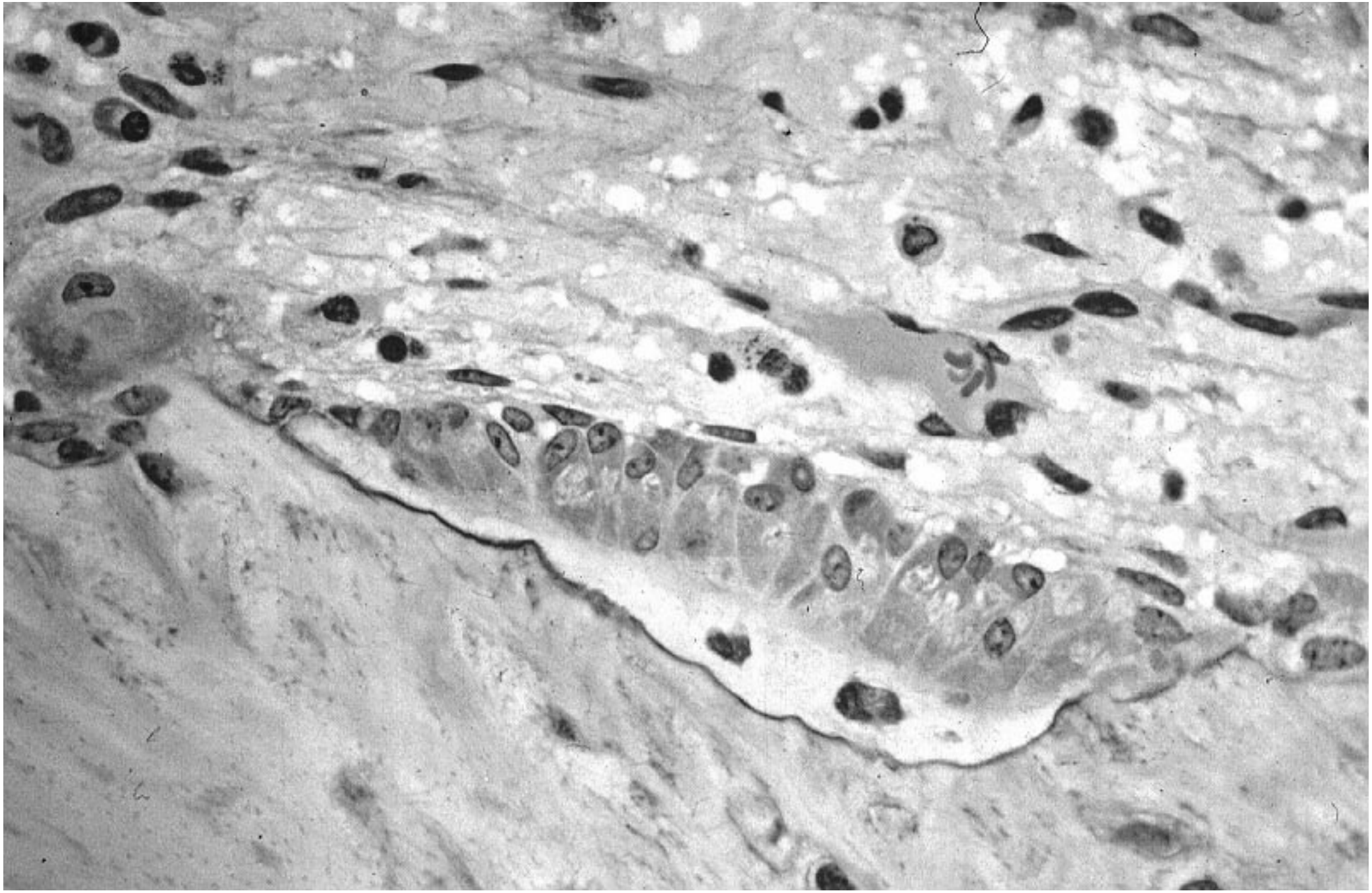

osteoblasts
New bone
Osteocytes
Osteoblasts
Very high magnification

Osteoclast

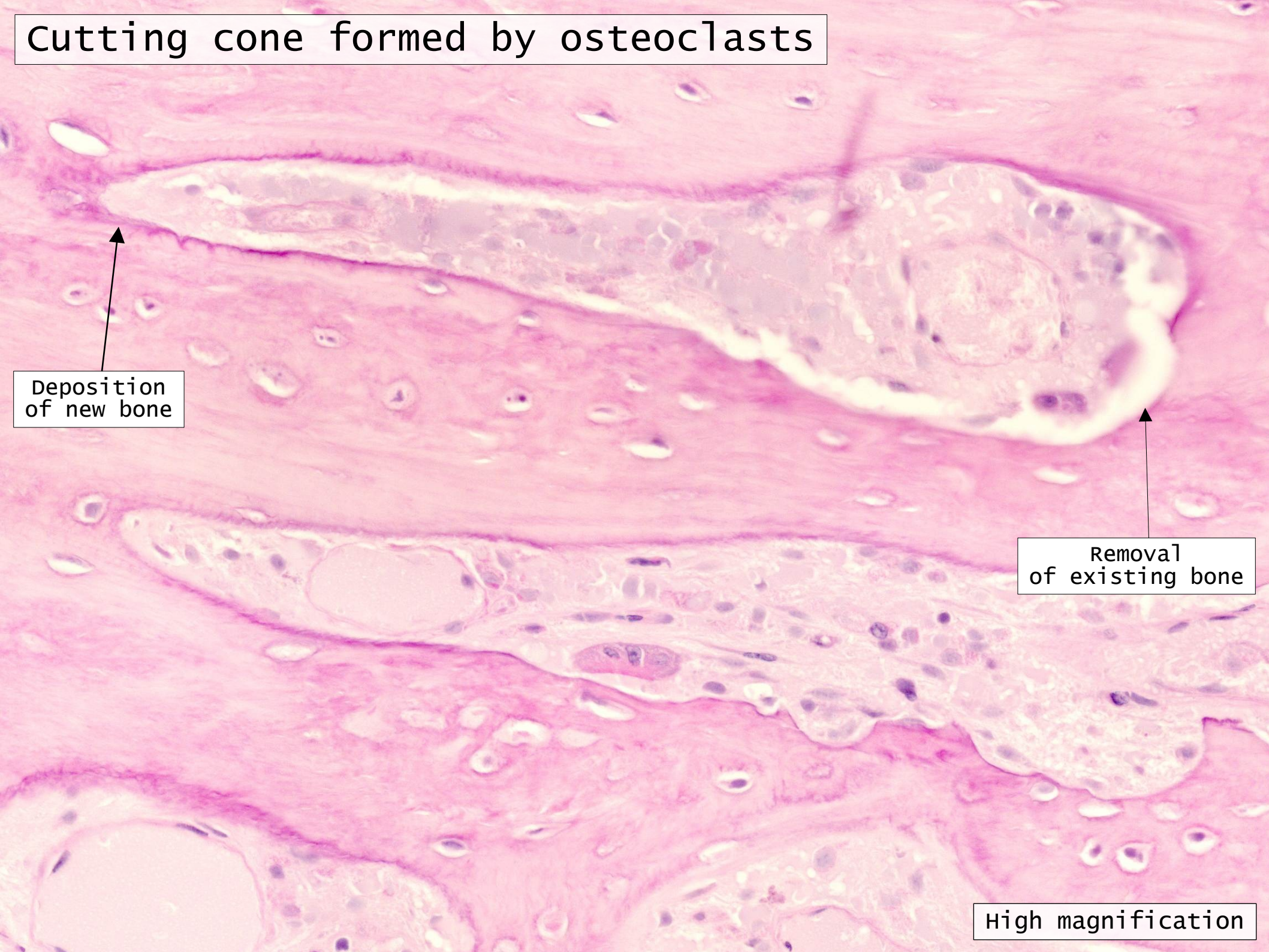


Very high magnification; PD

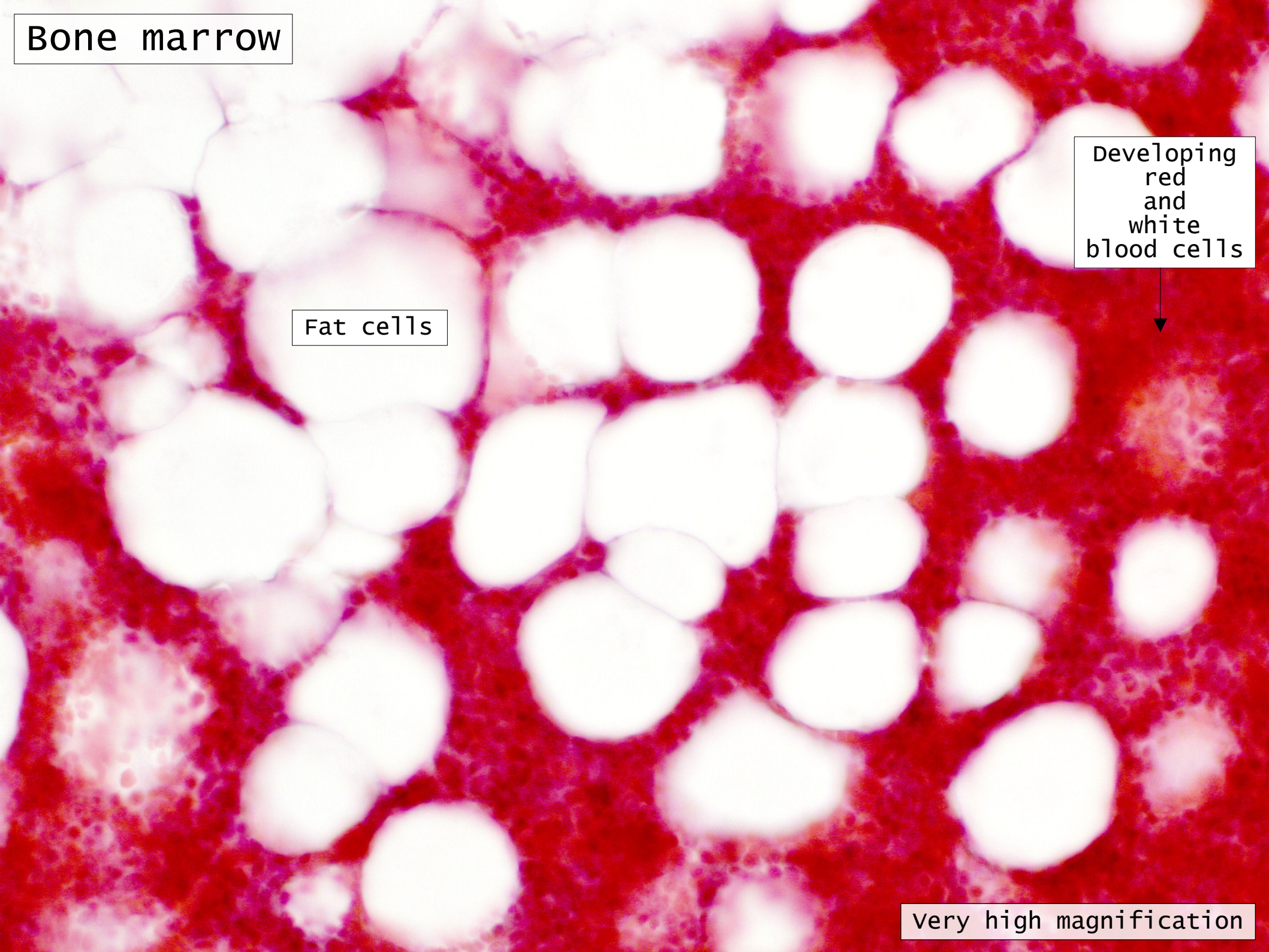
Active osteoblasts



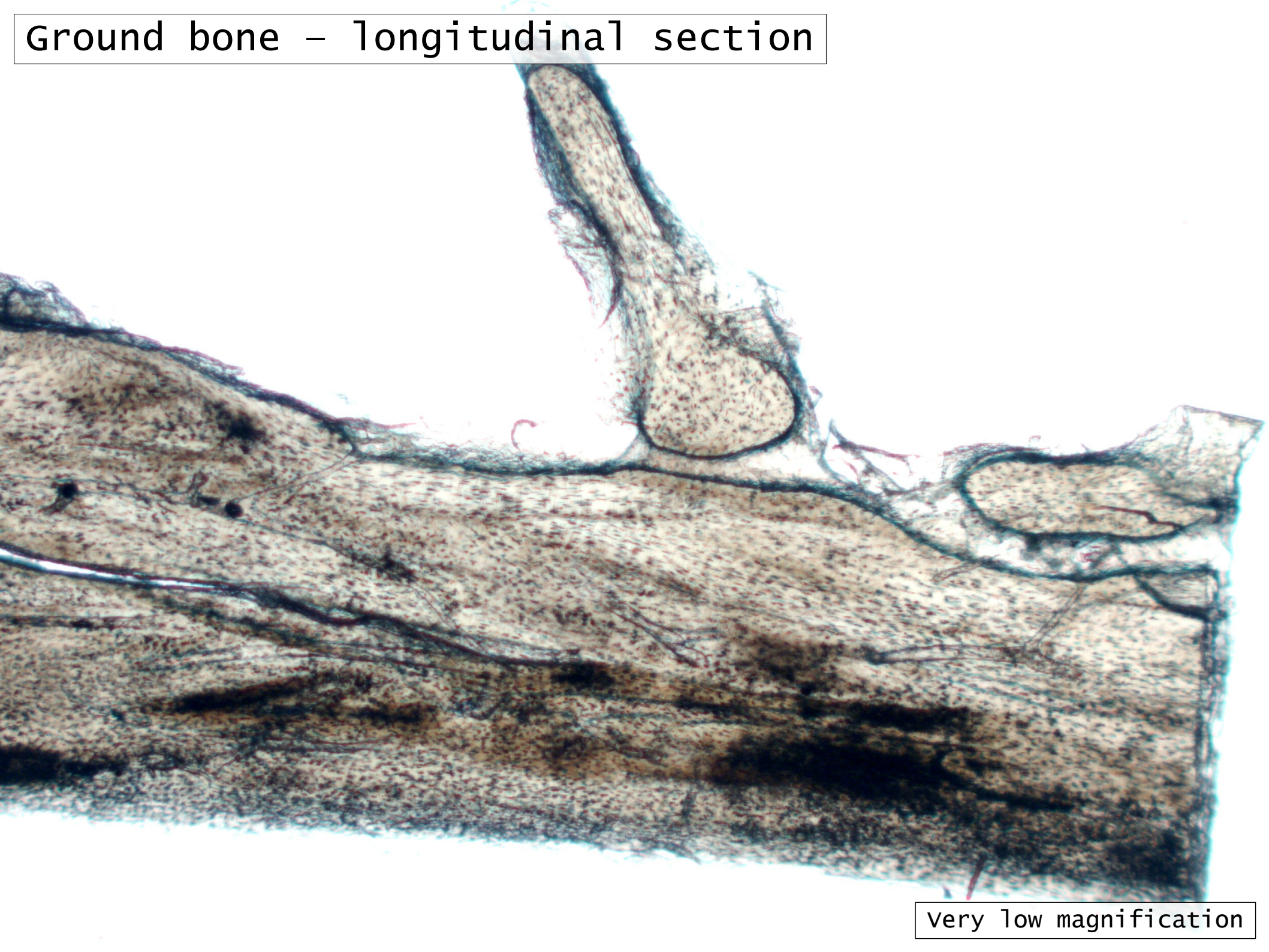
Very high magnification


Cutting cone formed by osteoclasts
Deposition of new bone
Removal of existing bone
High magnification


Blood vessel in bone
Lumen
Nuclei of endothelial cells
High magnification

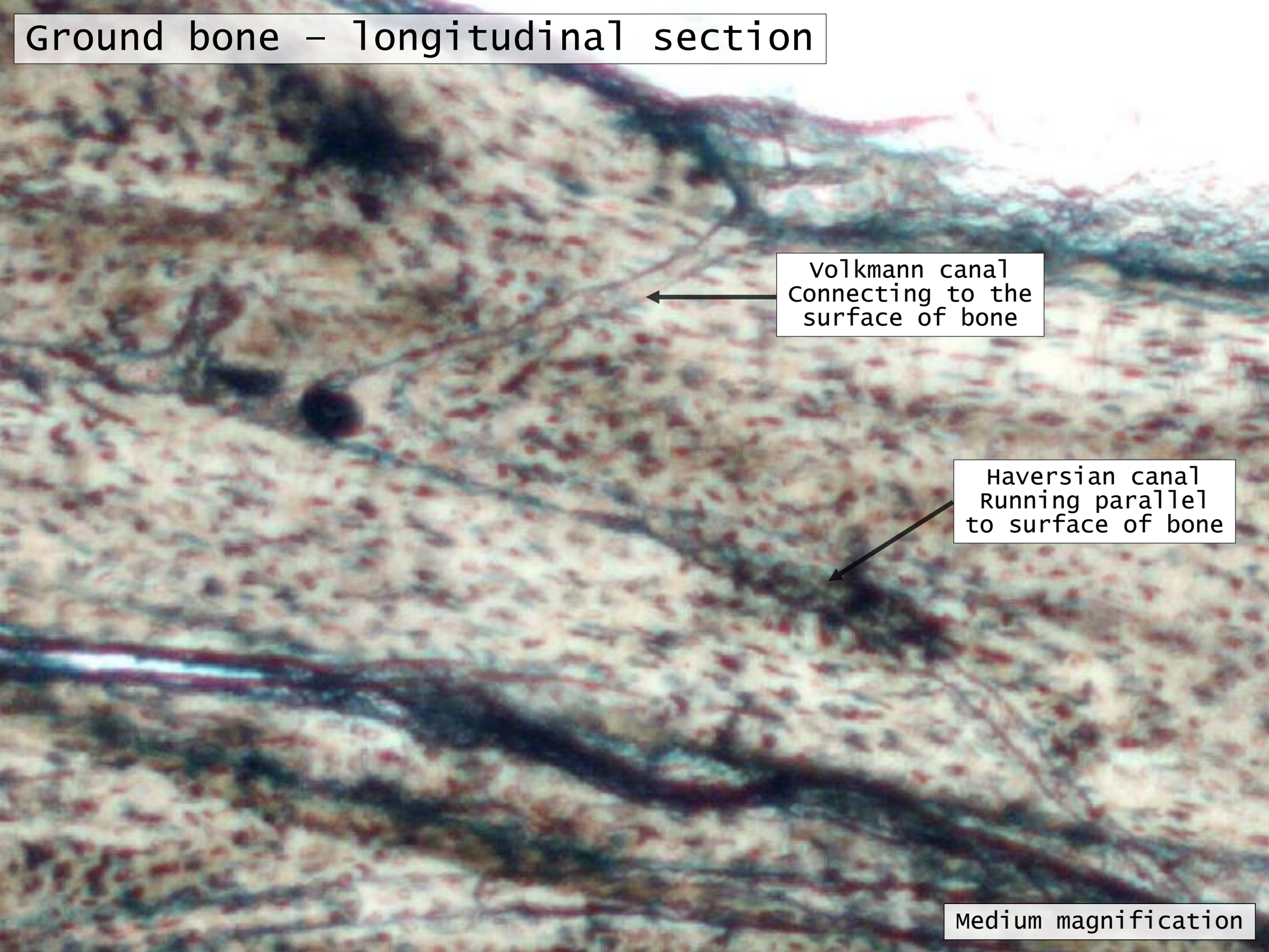

Bone marrow
Developing red and white blood cells
Fat cells
Very high magnification

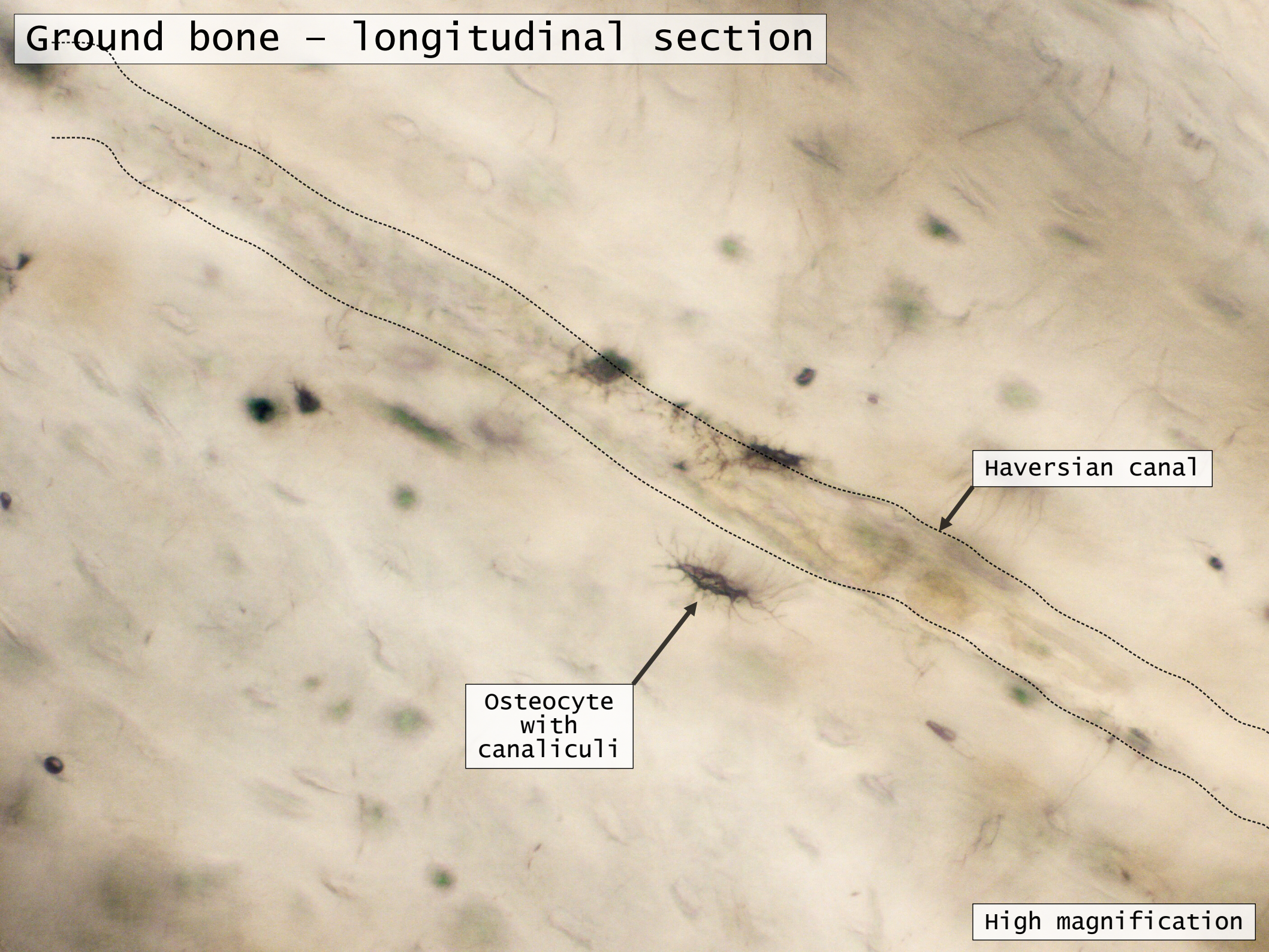
Ground bone – longitudinal section

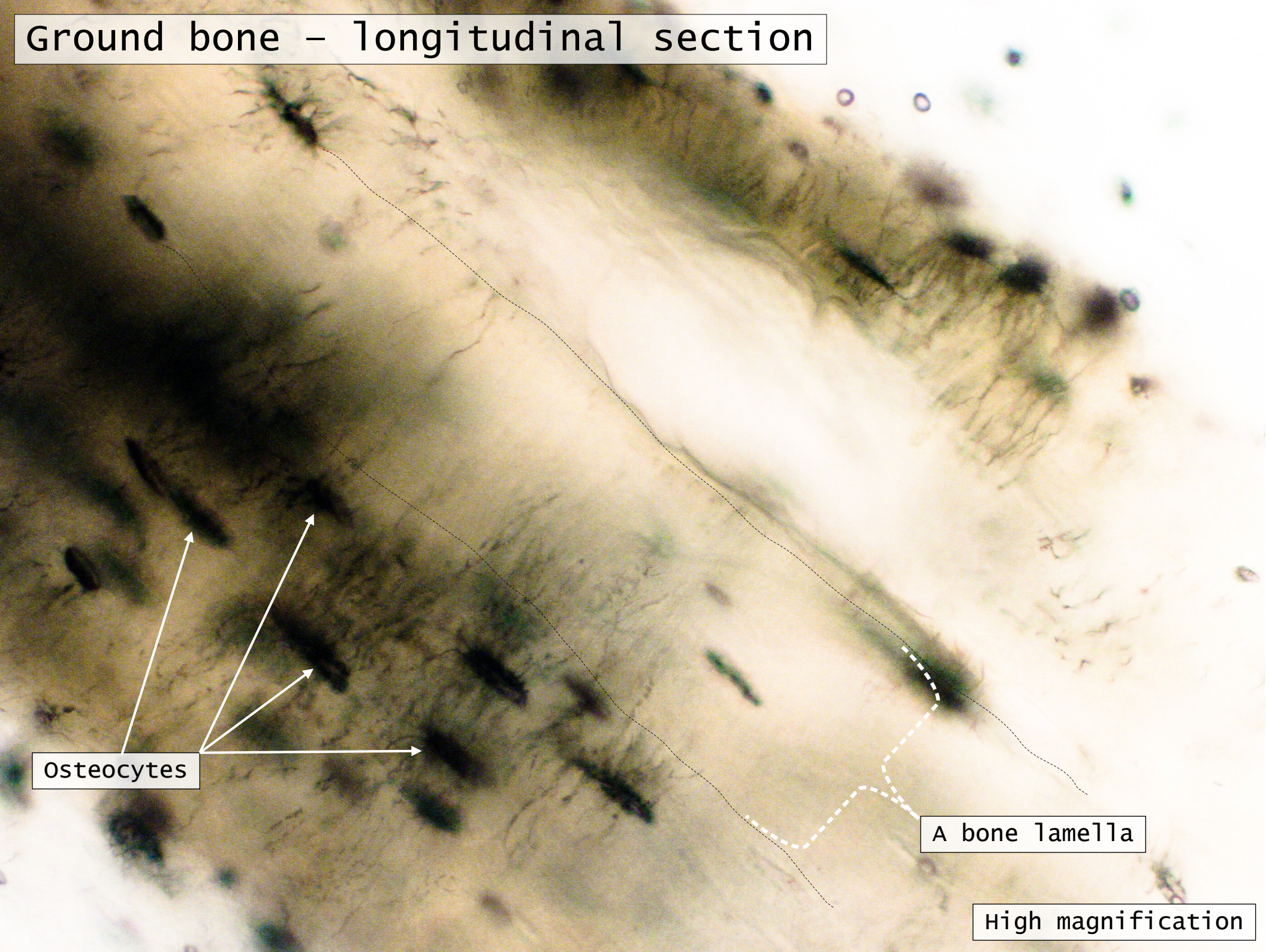


Very low magnification

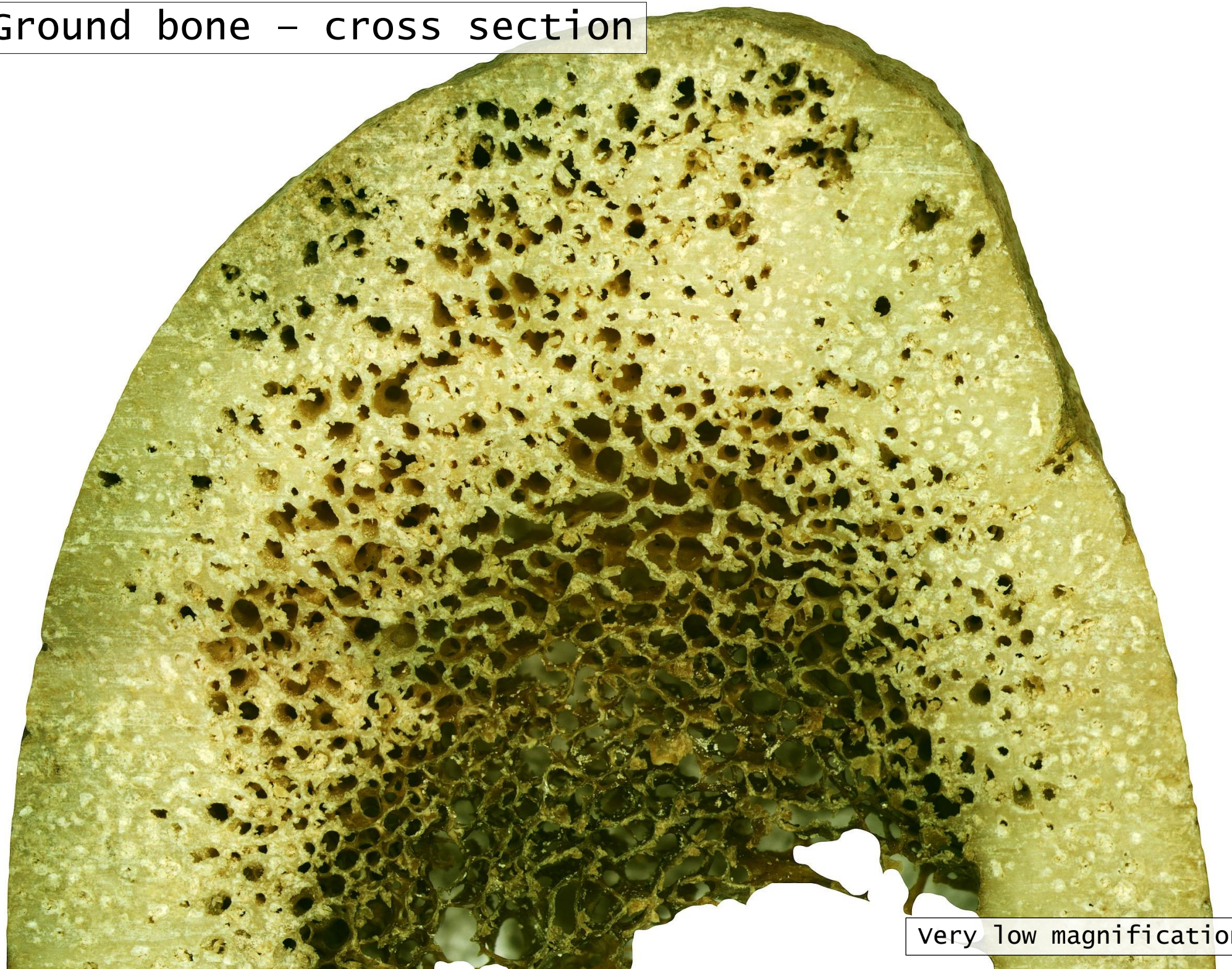
Ground bone – longitudinal section



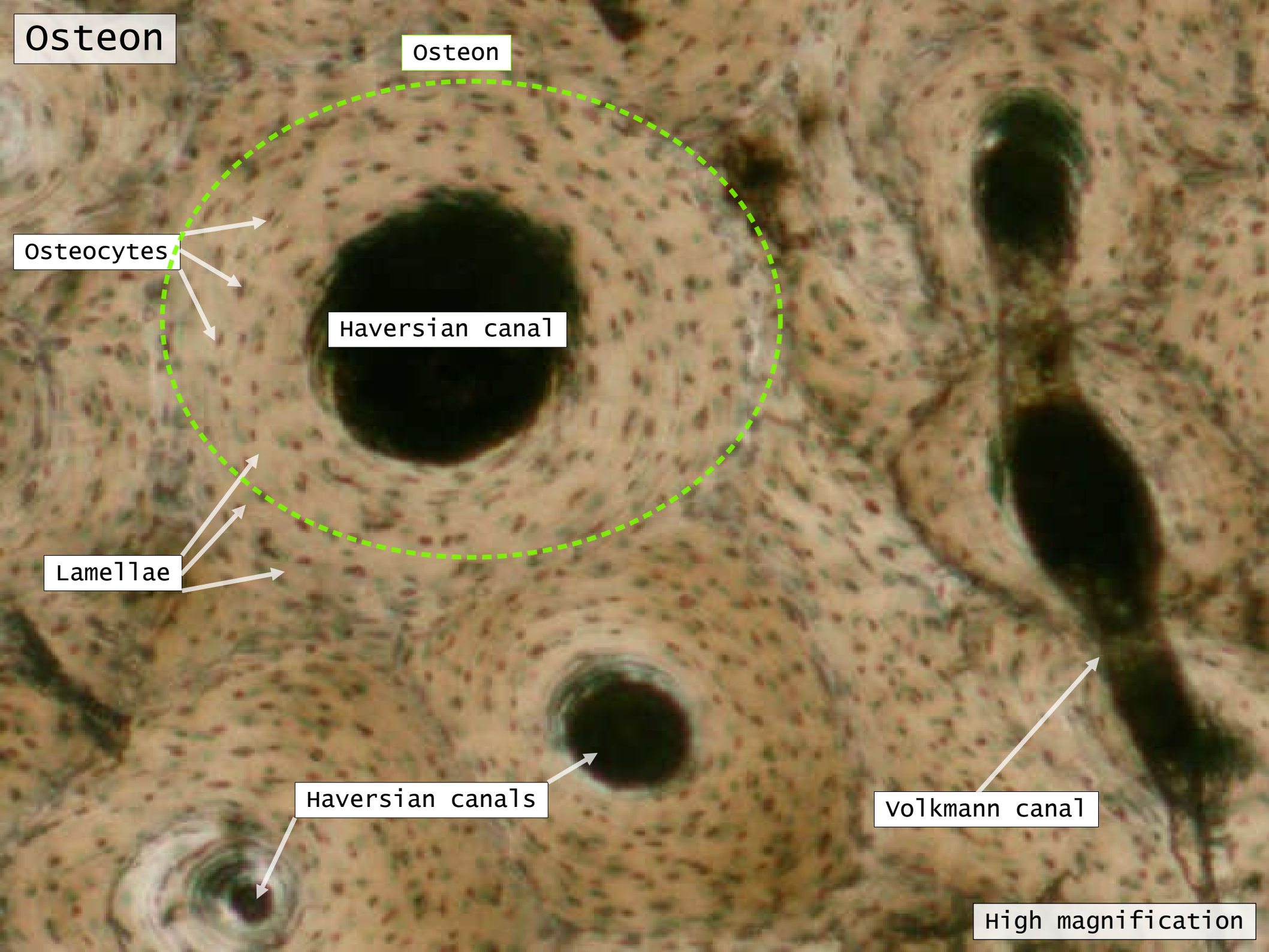

Ground bone – longitudinal section
Haversian canal
Osteocyte with canaliculi
High magnification


Ground bone – longitudinal section
Osteocytes
A bone lamella
High magnification

Ground bone – cross section



Very low magnification


Osteon
Osteon
Osteocytes
Haversian canal
Lamellae
Haversian canals
Volkmann canal
High magnification

Bone development

- Osteogenesis
  - Cell migration
  - Differentiation
  - Extracellular deposition
  - Mineralization

Two processes

- Intramembranous ossification
  - Direct formation of bone
- Endochondral ossification
  - Cartilage as precursor

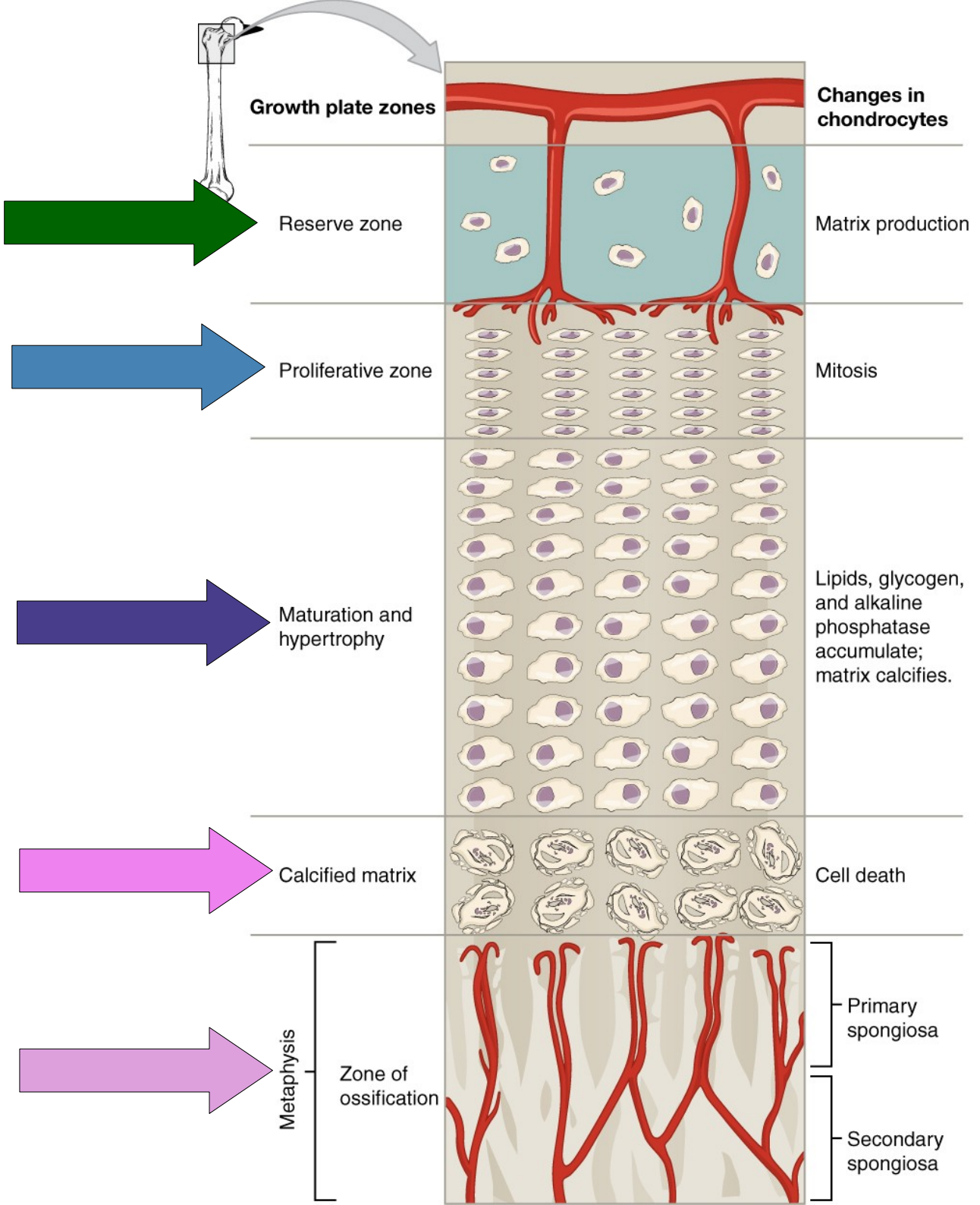
Intramembranous ossification

- During fetal development
- Differentiation mesenchymal cells into osteoblasts
- Secretion of ostoid
- Ostoid undergoes calcification
- Flat bones of skull, mandible, clavicles

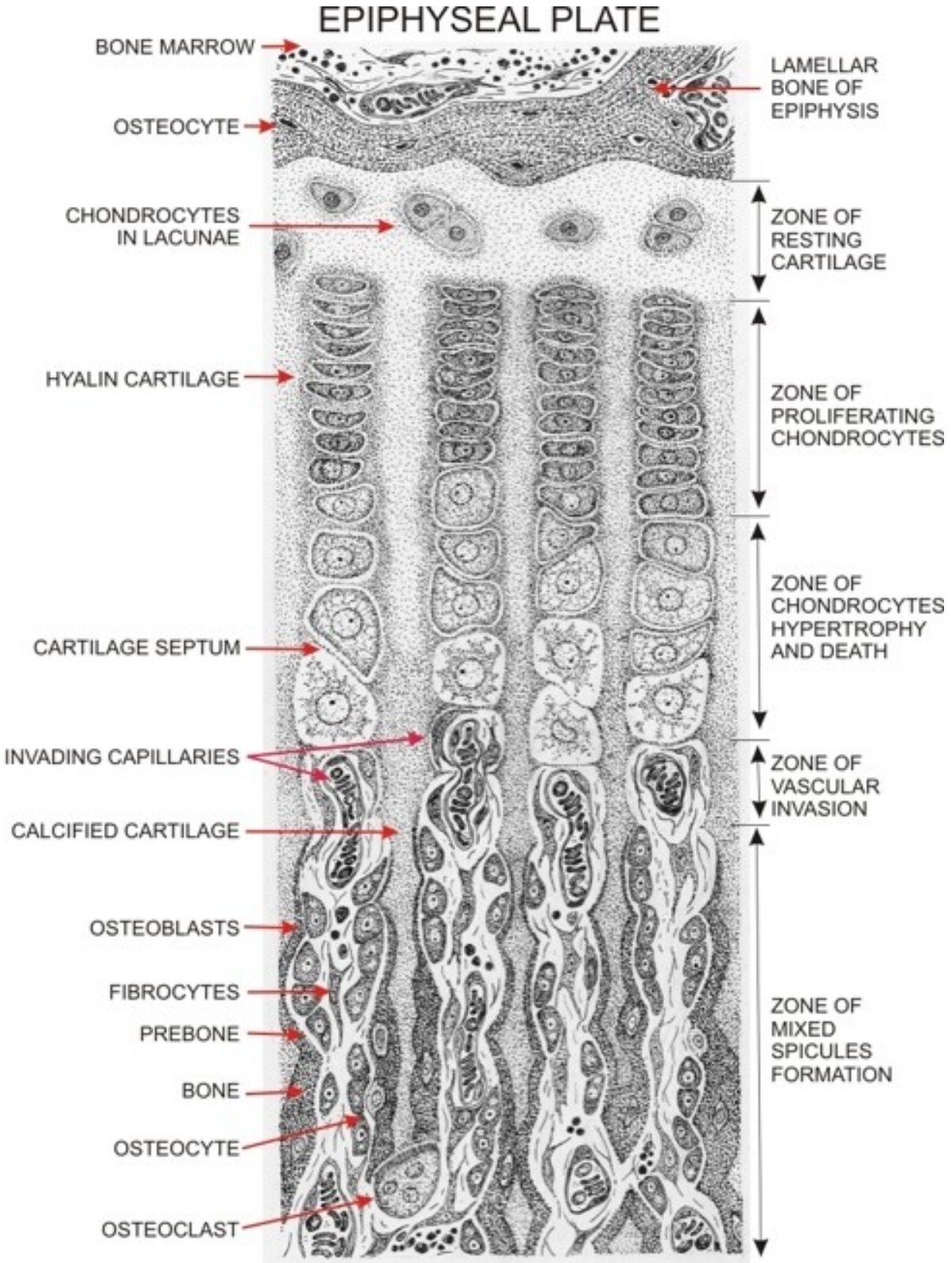
Endochondral ossification

- Formation of hyaline cartilage model
- Replaced by bone
- Most bones
- Epiphyseal plate to enable growth in length

Longitudinal bone growth

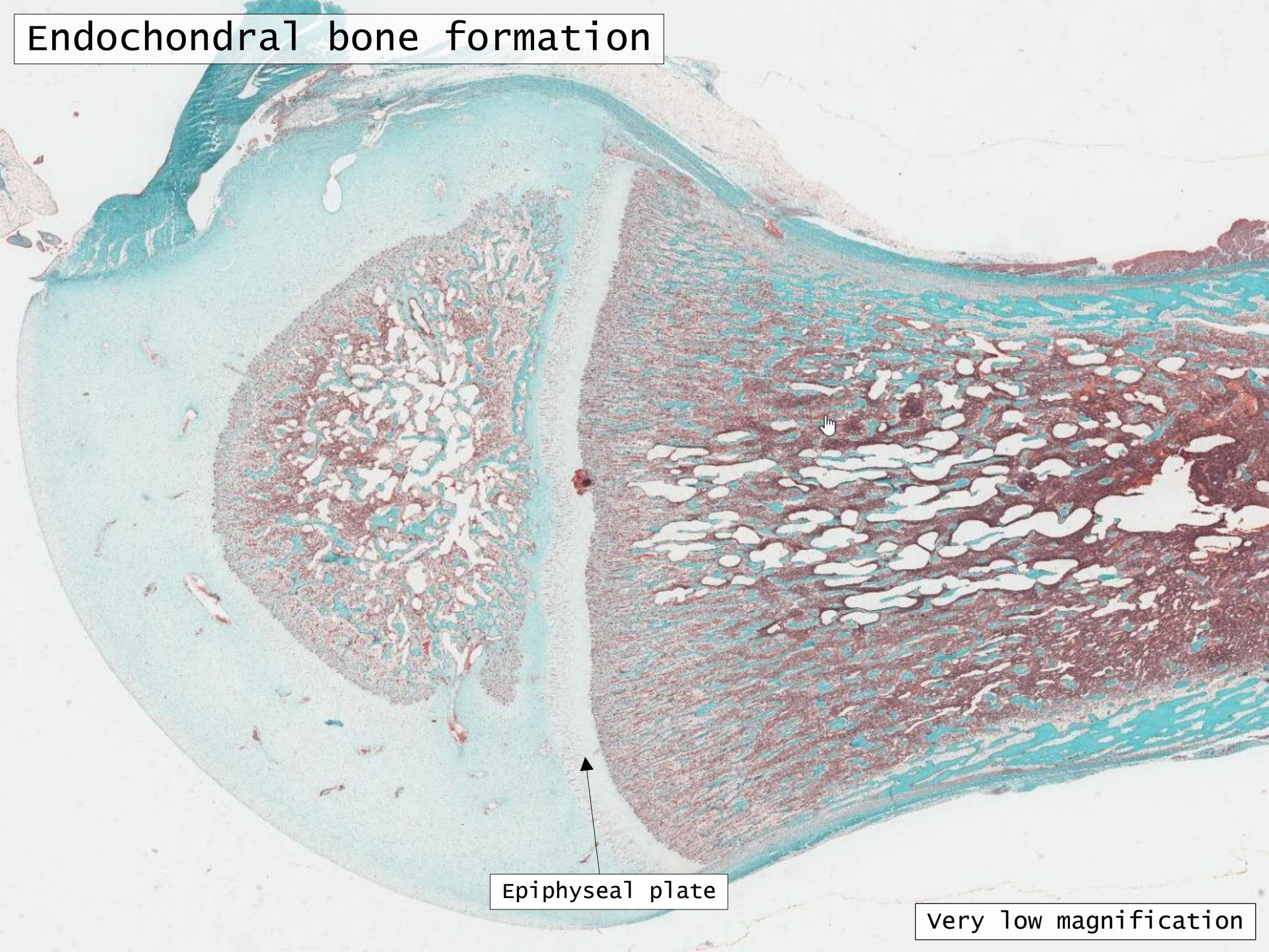


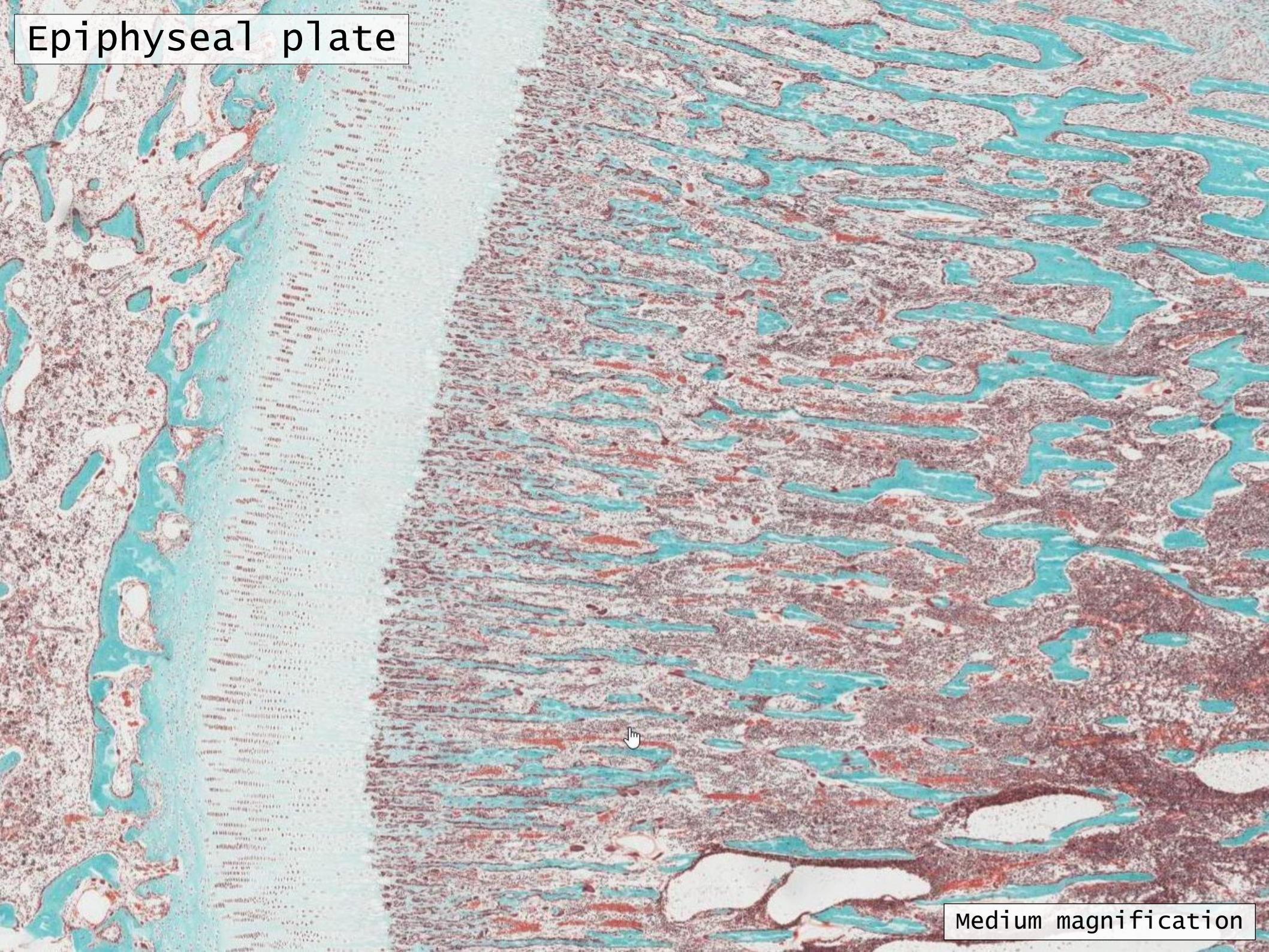
Longitudinal bone growth

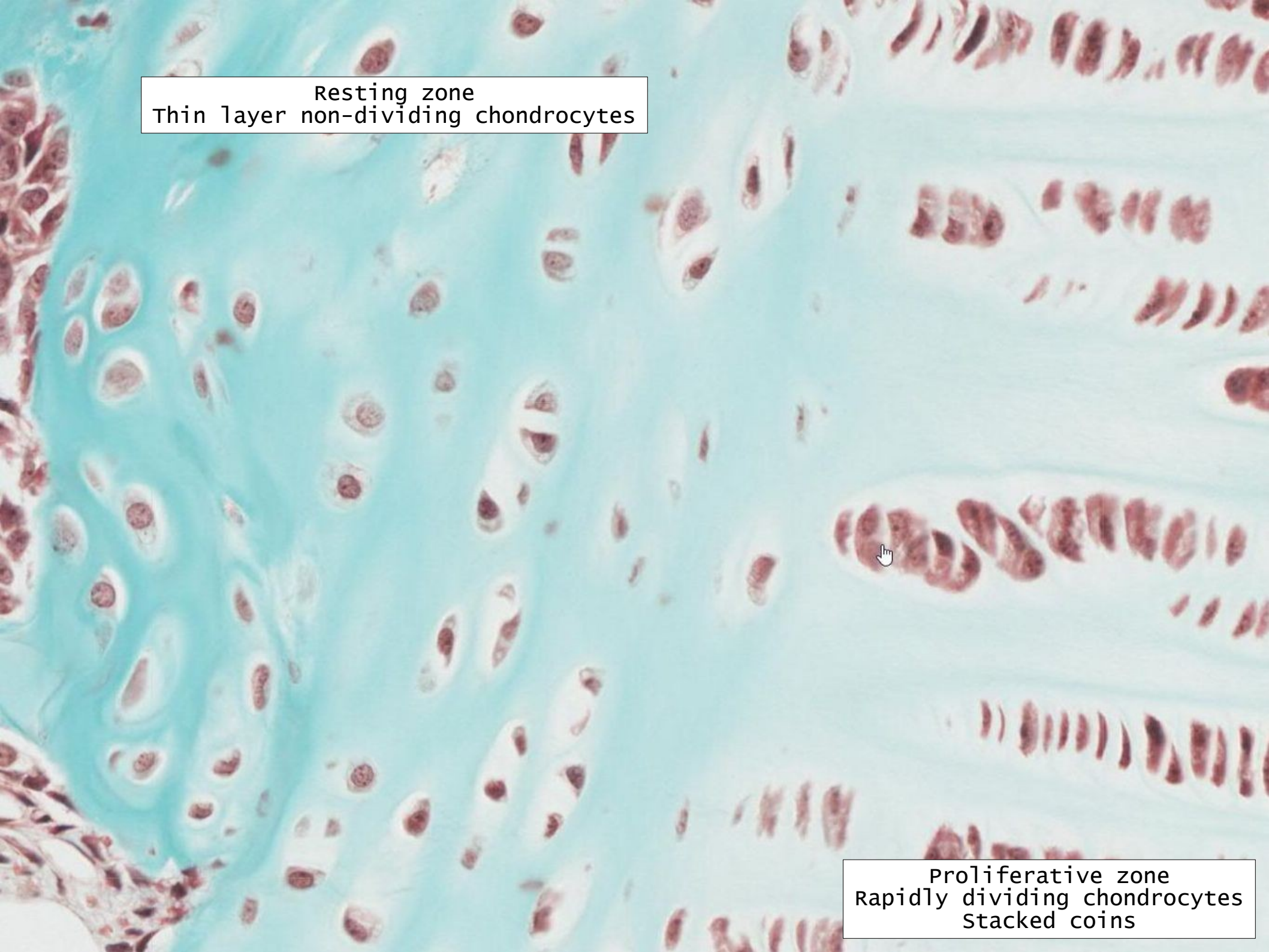


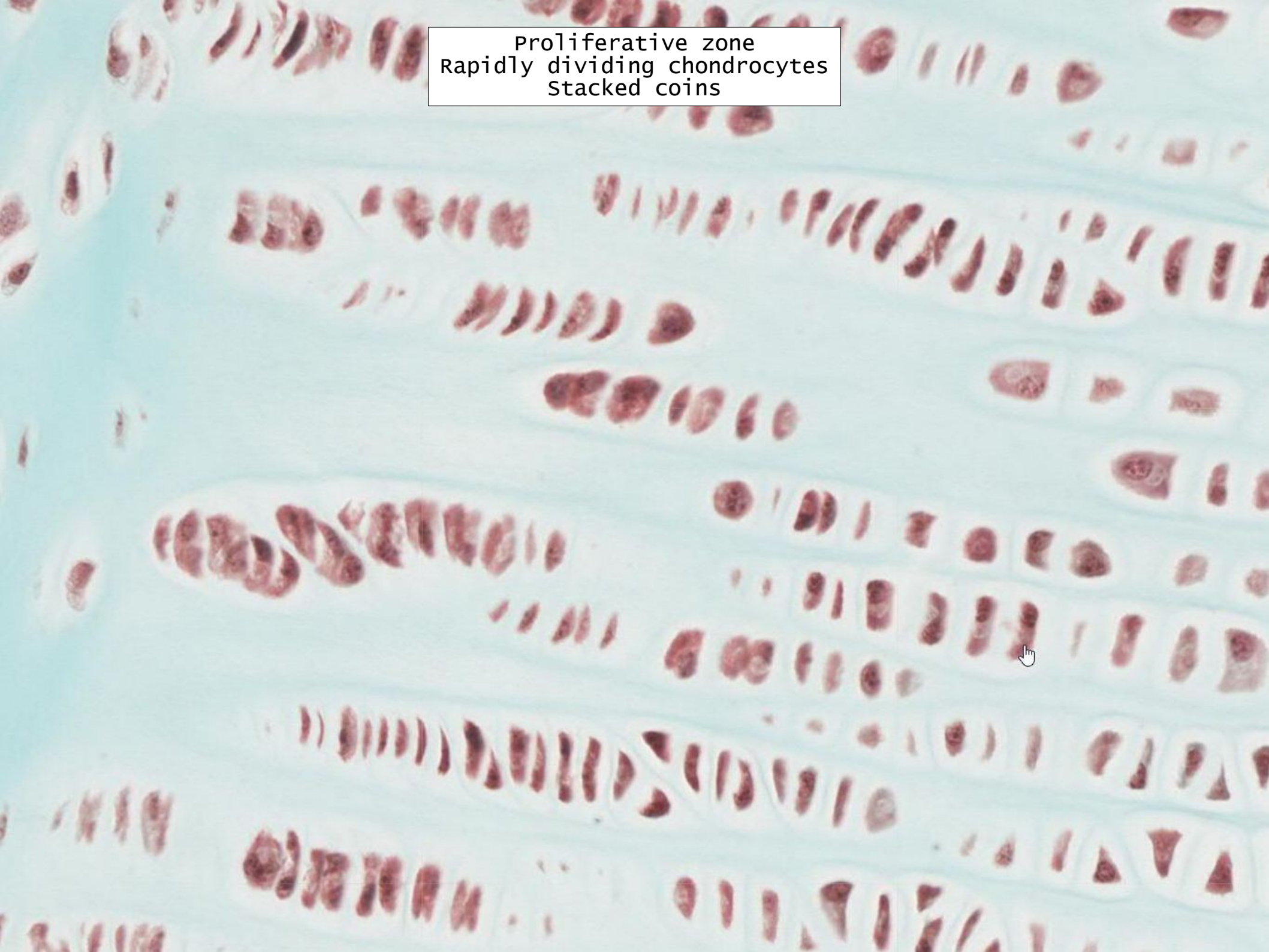
Slide 11

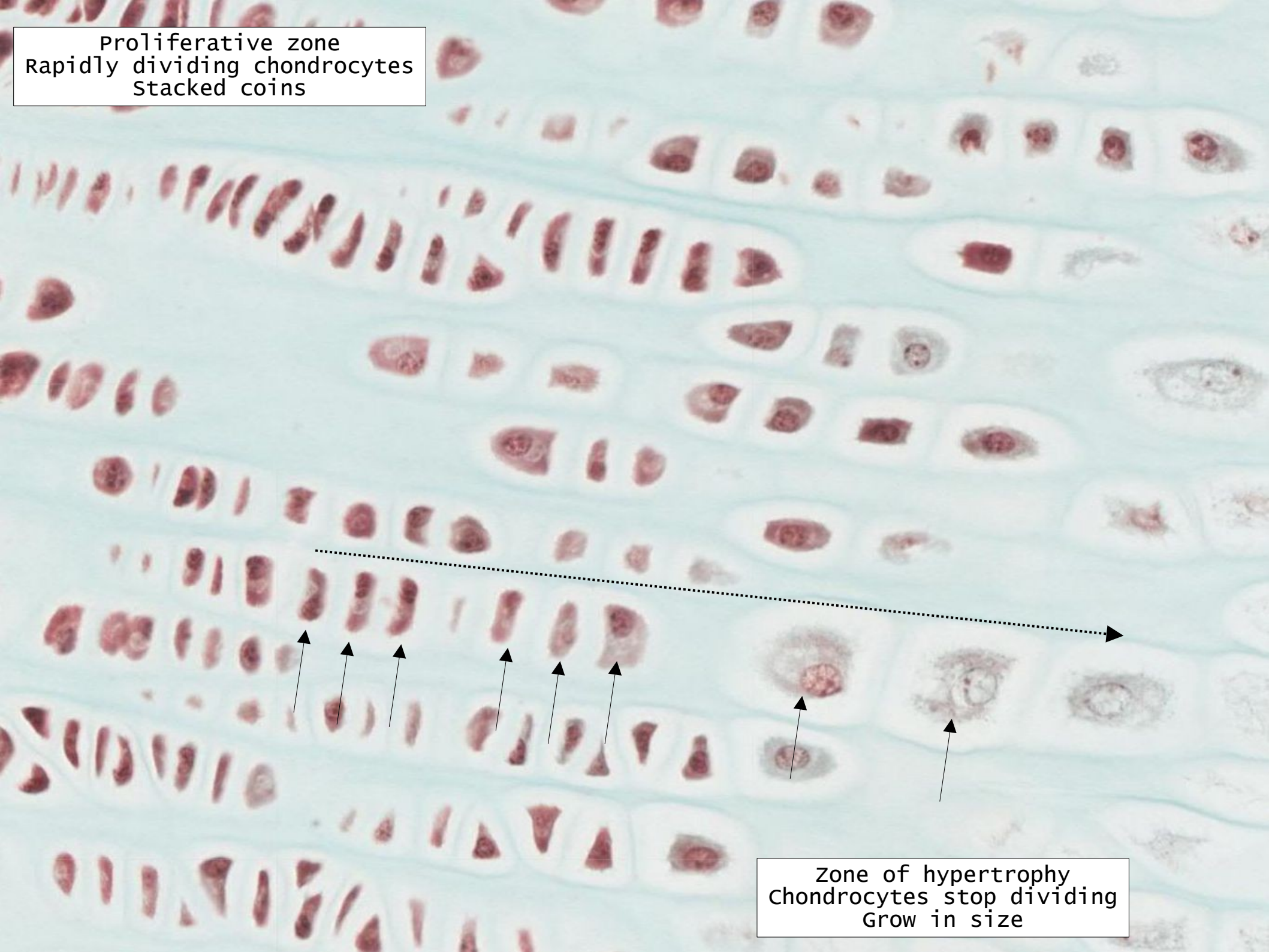
Endochondral bone formation

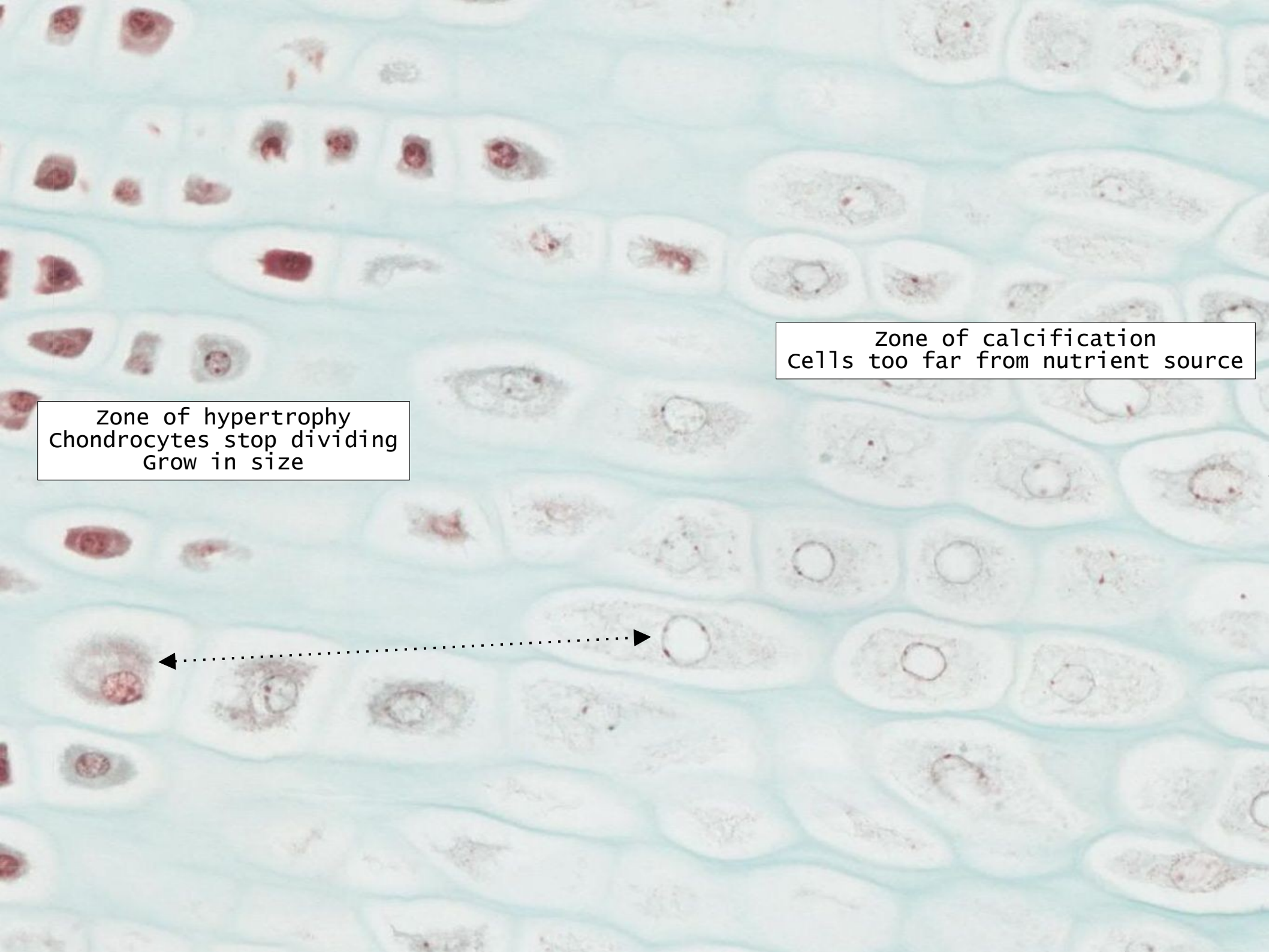


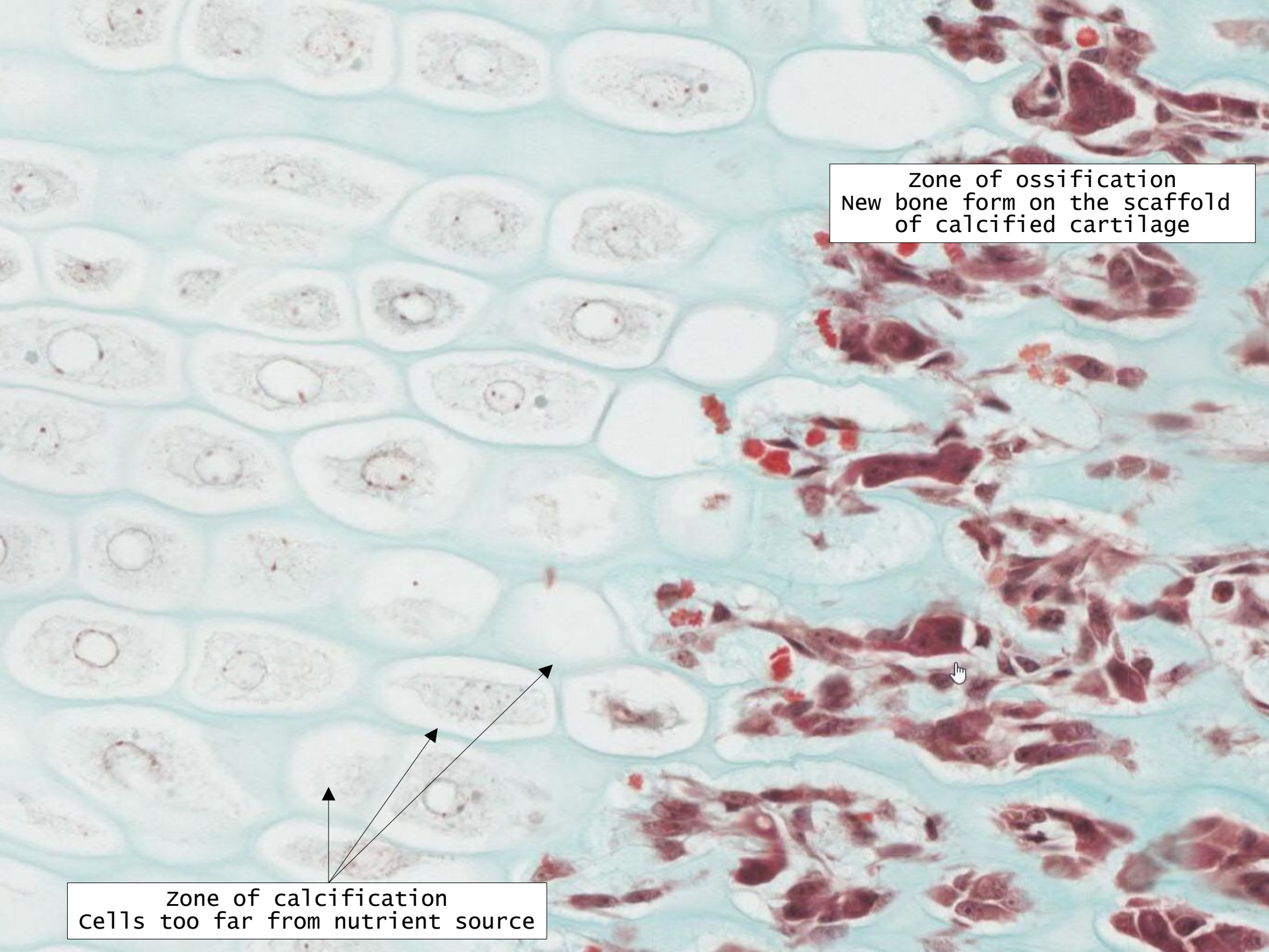

Epiphyseal plate
Medium magnification

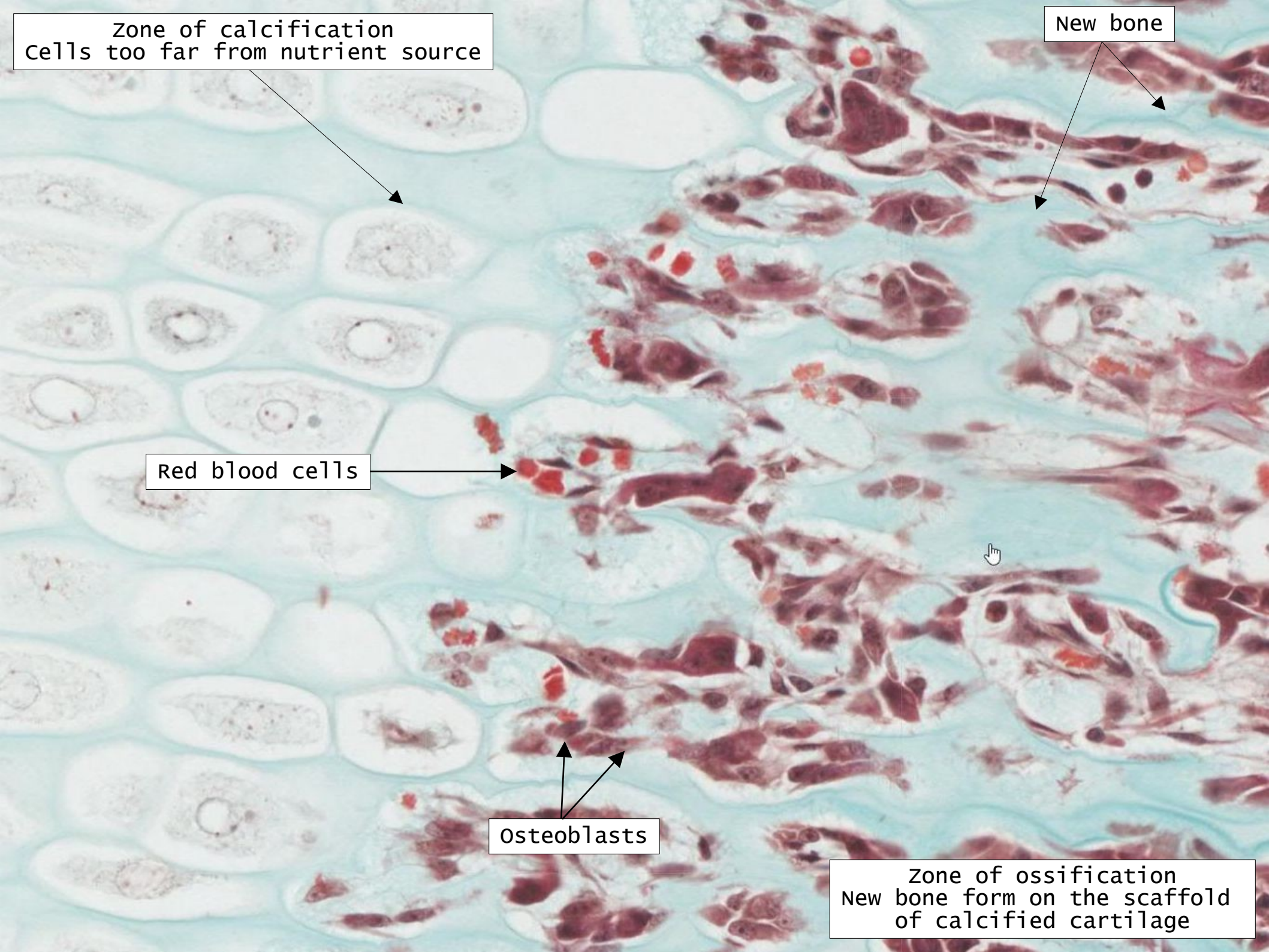

Resting zone
Thin layer non-dividing chondrocytes
Proliferative zone
Rapidly dividing chondrocytes
Stacked coins

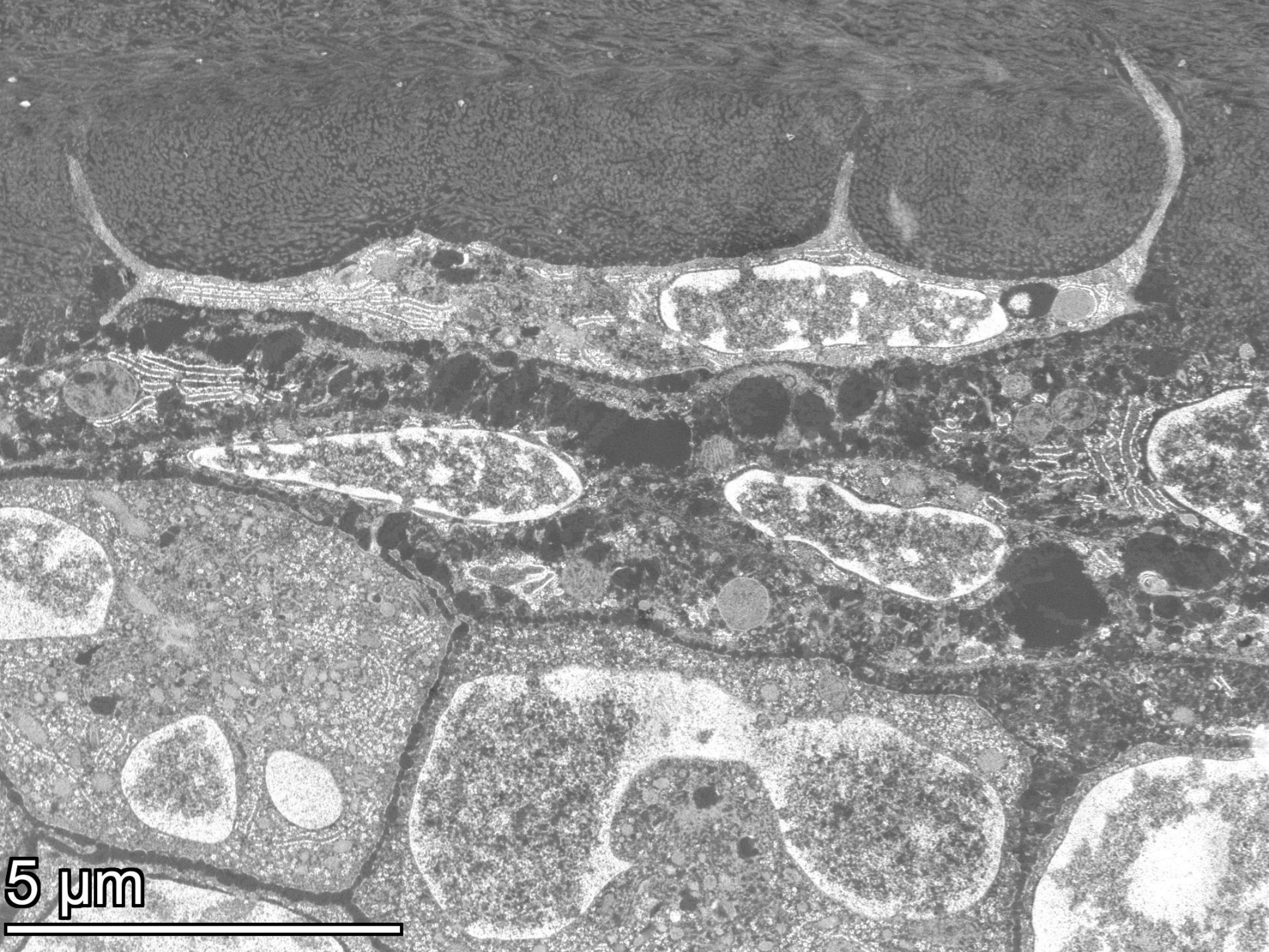

Proliferative zone
Rapidly dividing chondrocytes
Stacked coins

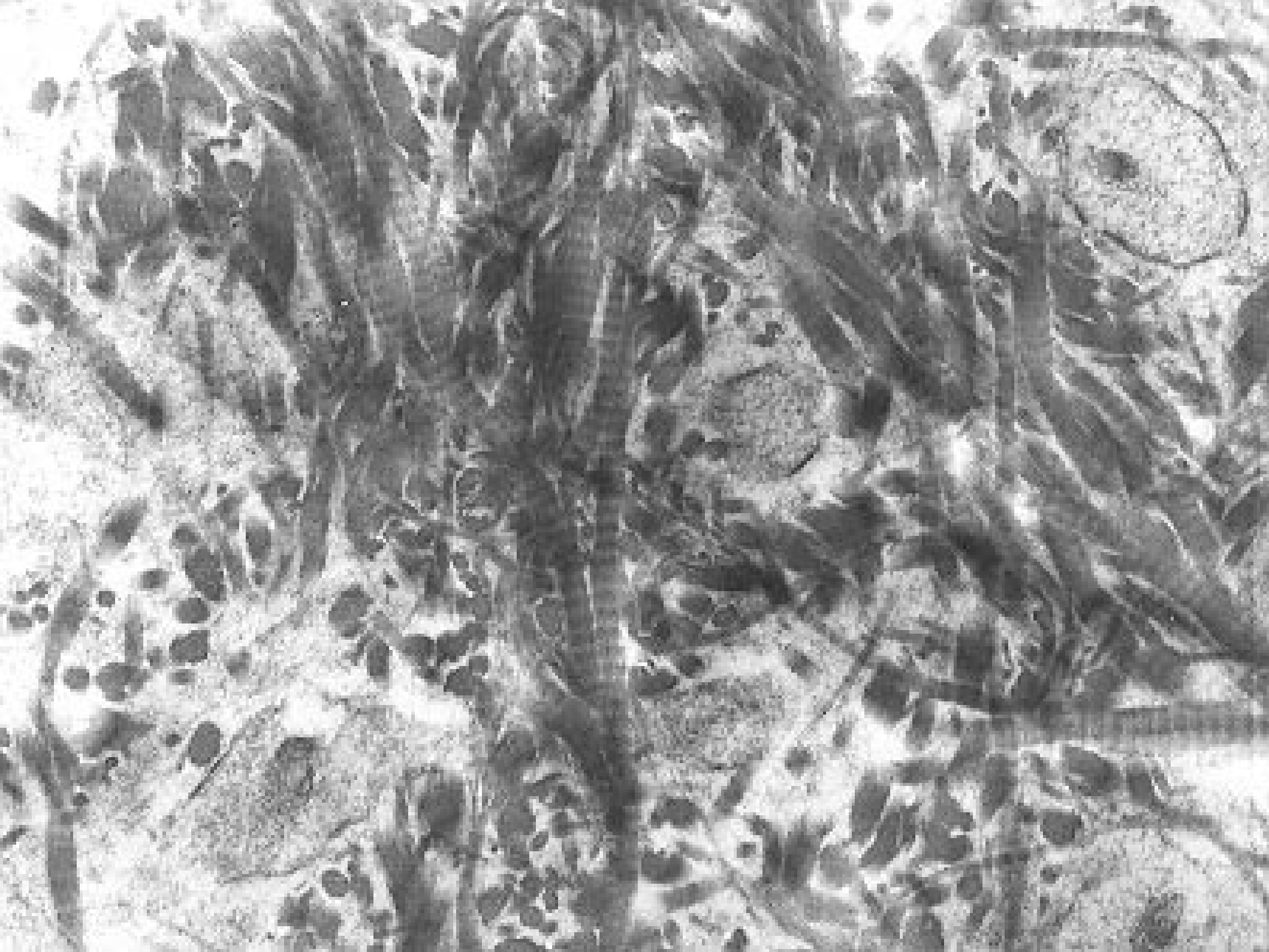

Proliferative zone
Rapidly dividing chondrocytes
Stacked coins
Zone of hypertrophy
Chondrocytes stop dividing
Grow in size

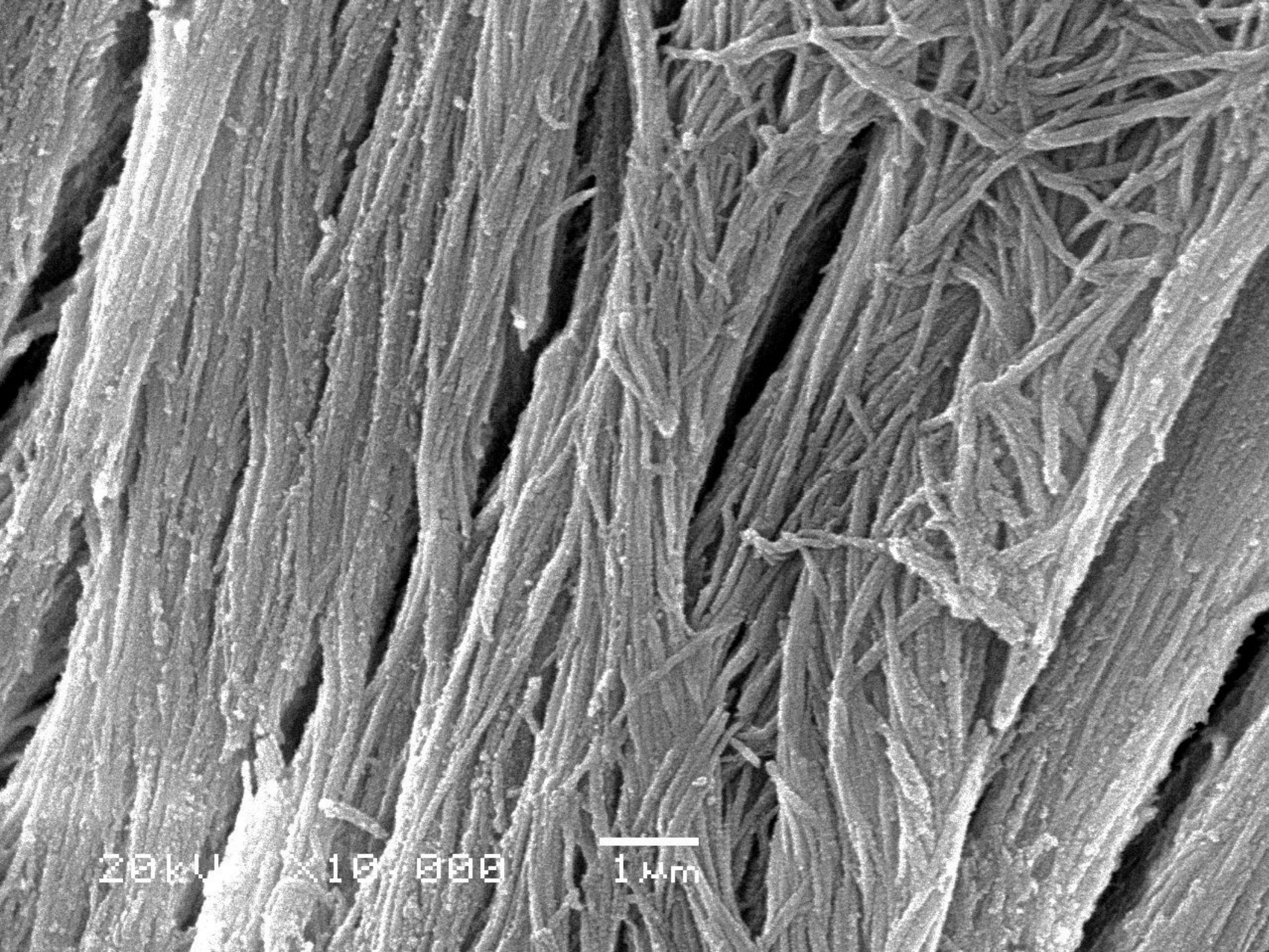

Zone of calcification
Cells too far from nutrient source
Zone of hypertrophy
Chondrocytes stop dividing
Grow in size

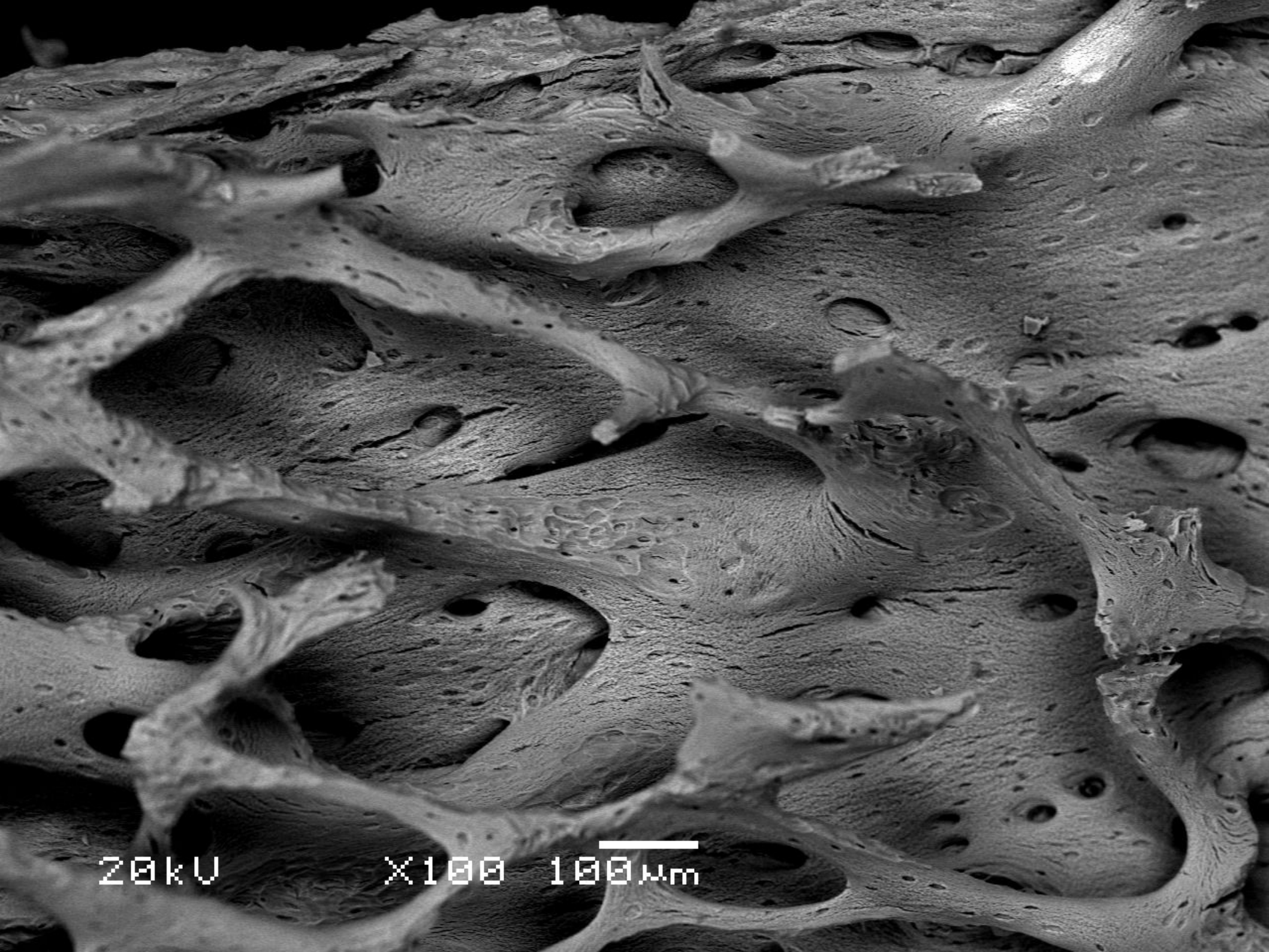

Zone of ossification
New bone form on the scaffold
of calcified cartilage
Zone of calcification
Cells too far from nutrient source


Zone of calcification
Cells too far from nutrient source
New bone
Red blood cells
Osteoblasts
Zone of ossification
New bone form on the scaffold
of calcified cartilage


5 µm




20kV
×10,000
1μm


20kV X100 100µm

Slides: Cartilage

- Hyaline cartilage: Slide 73
- Elastic cartilage: Slide 9
- Fibrous cartilage: Slide 10

Slides: Bone

- Compact bone (cross section): Slide 12
- Compact bone (ground cross section): Slide 13
- Compact bone (ground longitudinal section): Slide 14
- Bone development: Slide 11

Annotated Drawing

Osteon

Drawing of an osteon

- Name and student number
- Drawing
- With annotations
- As best you can!