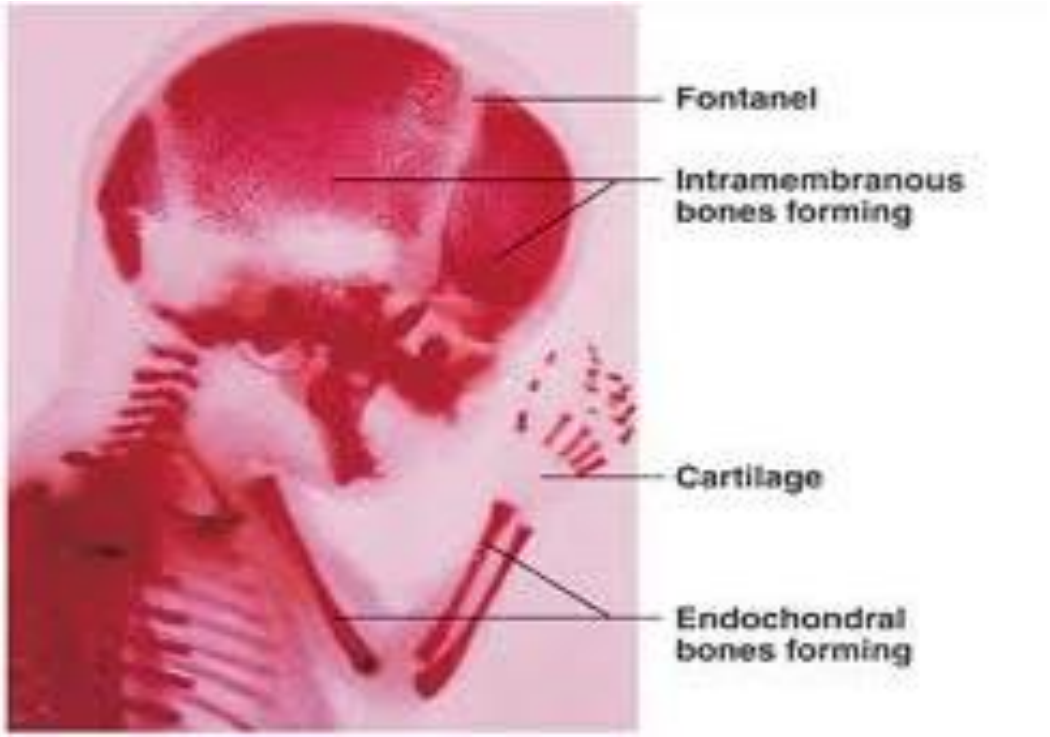
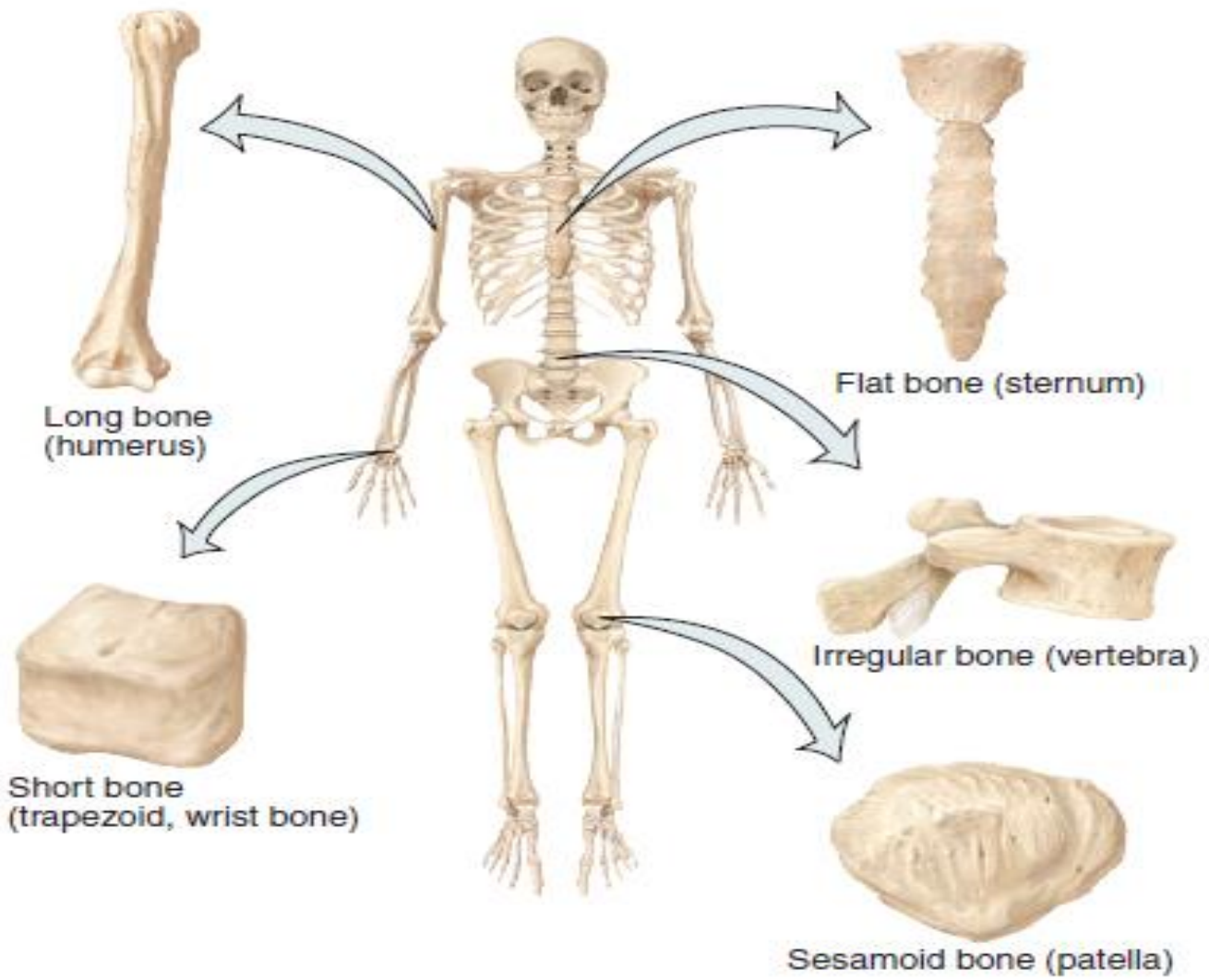
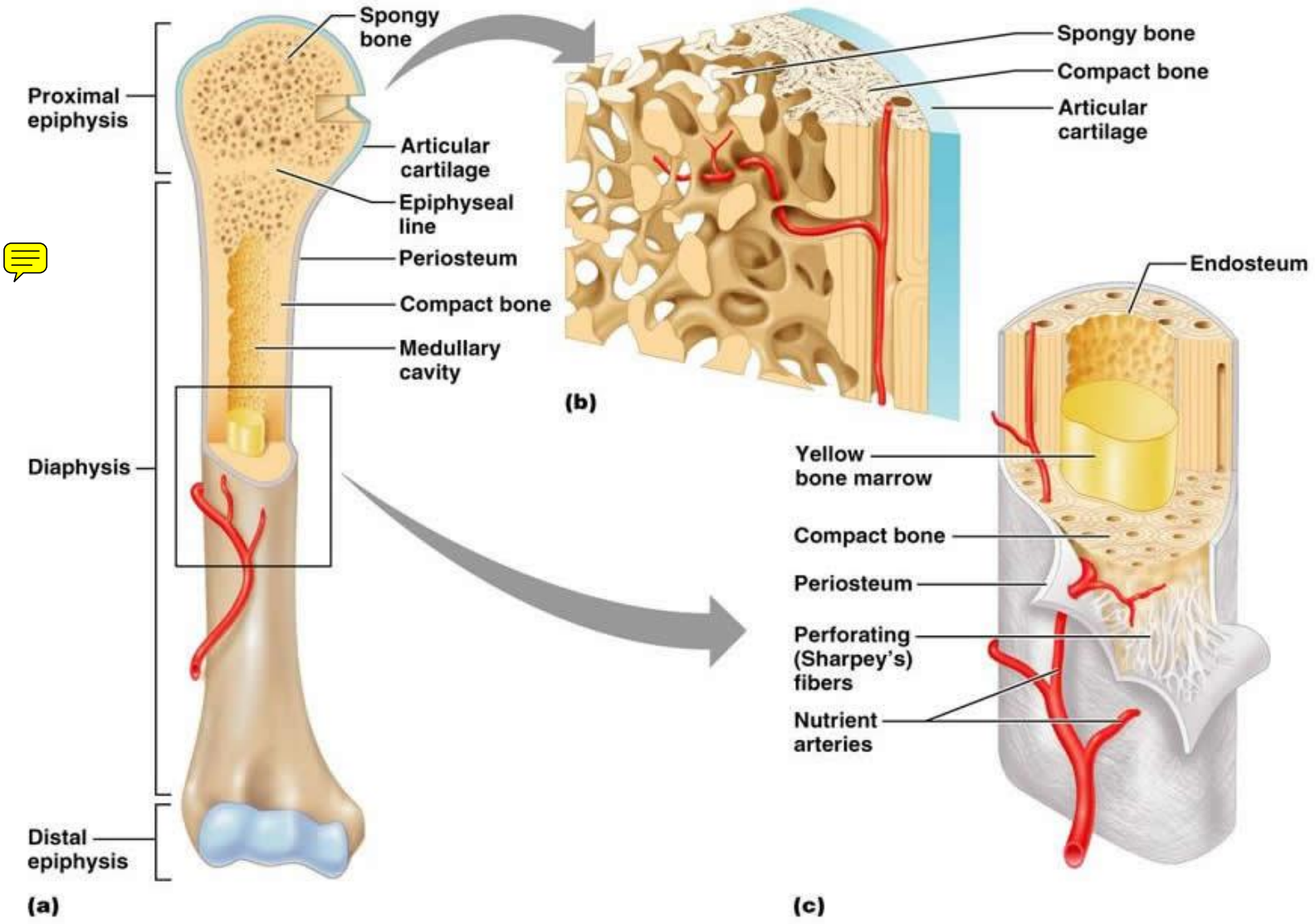
Bone Ossification

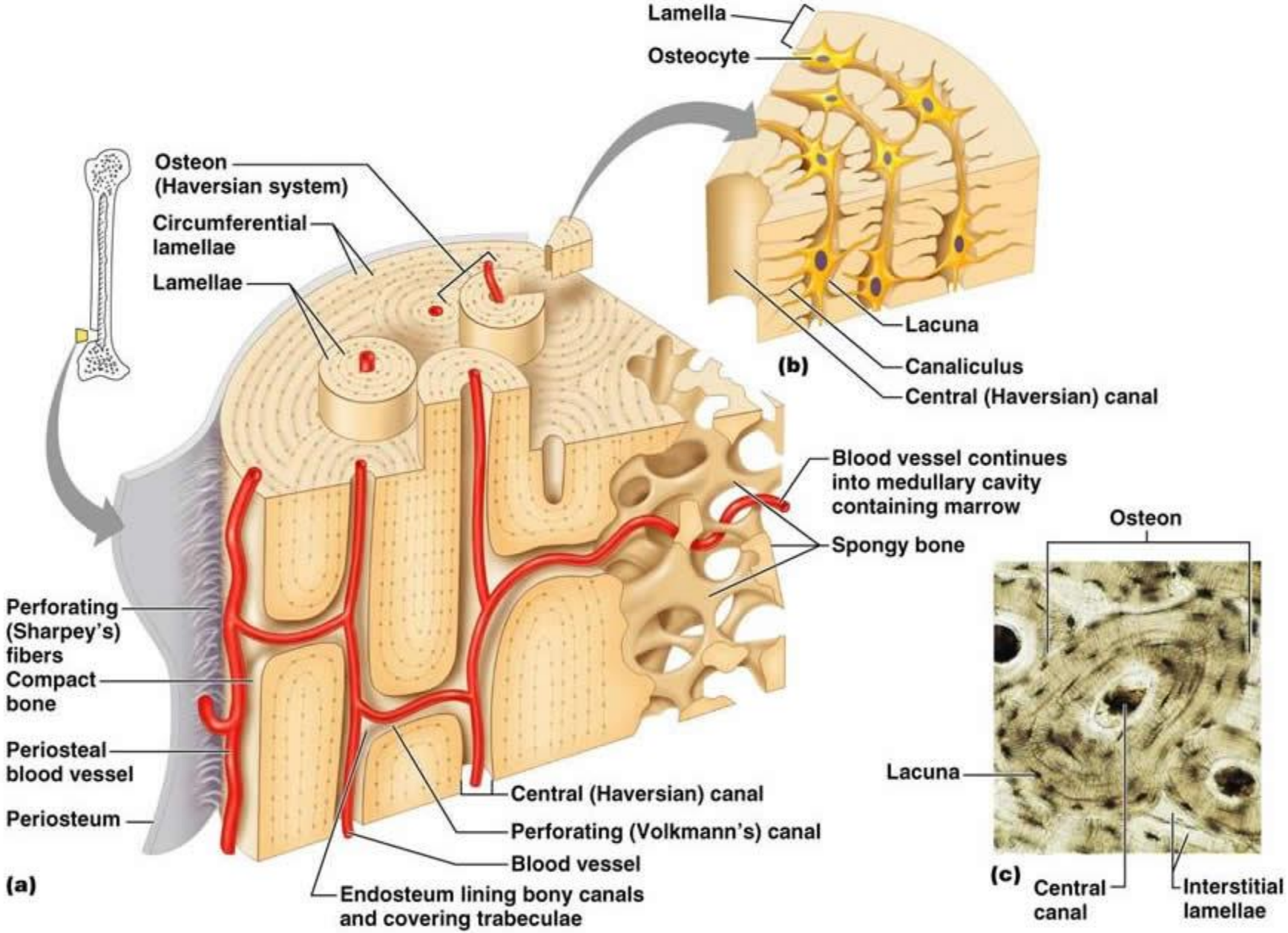


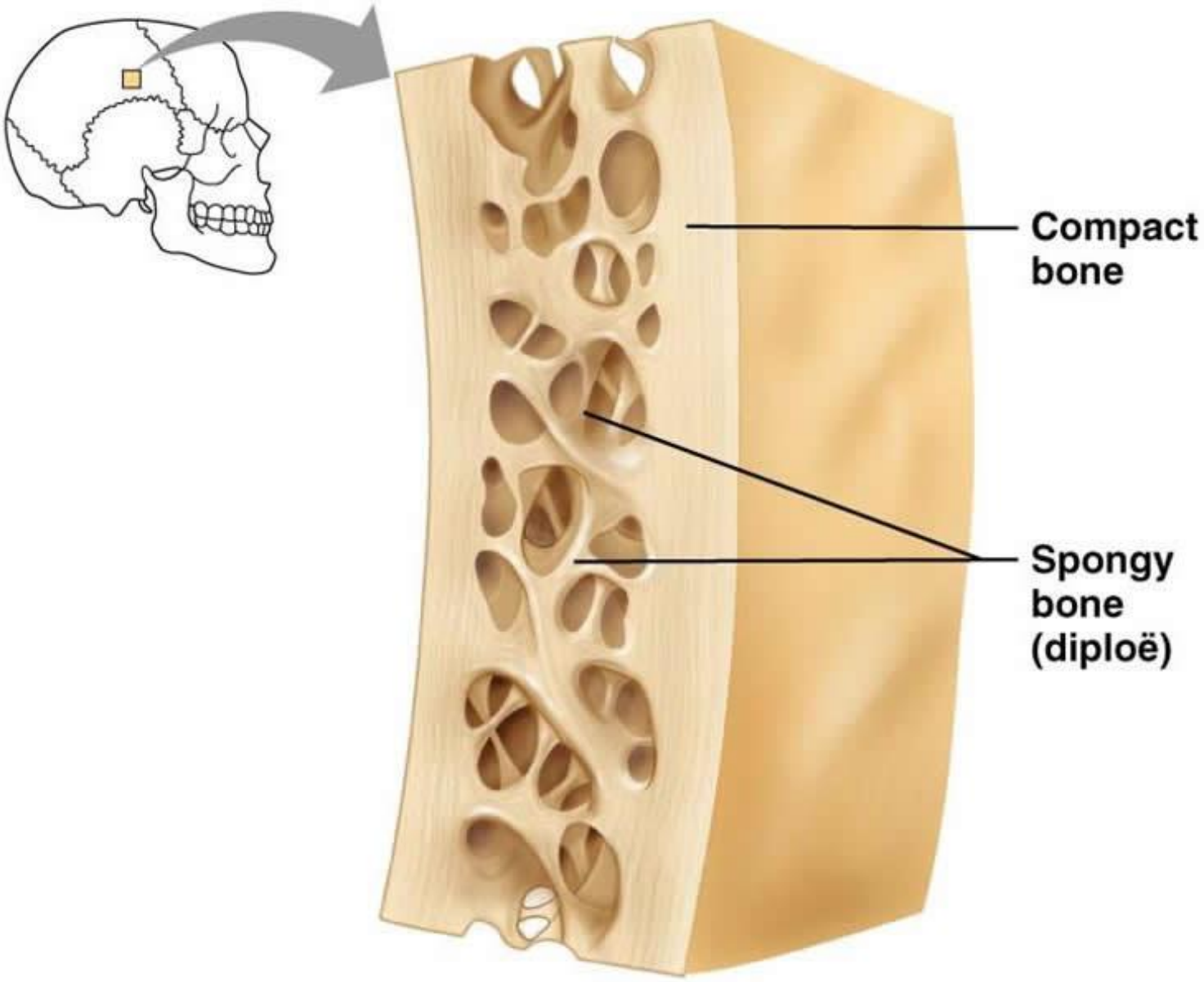
Shape of bones



Types of bone tissue




Lamella
Osteocyte
Osteon
(Haversian system)
Circumferential
lamellae
Lamellae
Lacuna
Canaliculus
Central (Haversian) canal
(b)
Blood vessel continues
into medullary cavity
containing marrow
Spongy bone
Perforating
(Sharpey's)
fibers
Compact
bone
Periosteal
blood vessel
Periosteum
Central (Haversian) canal
Perforating (Volkmann's) canal
Blood vessel
Endosteum lining bony canals
and covering trabeculae
(a)
Osteon
Lacuna
Central
canal
Interstitial
lamellae
(c)


Compact bone
Spongy bone (diploë)

Bone Development

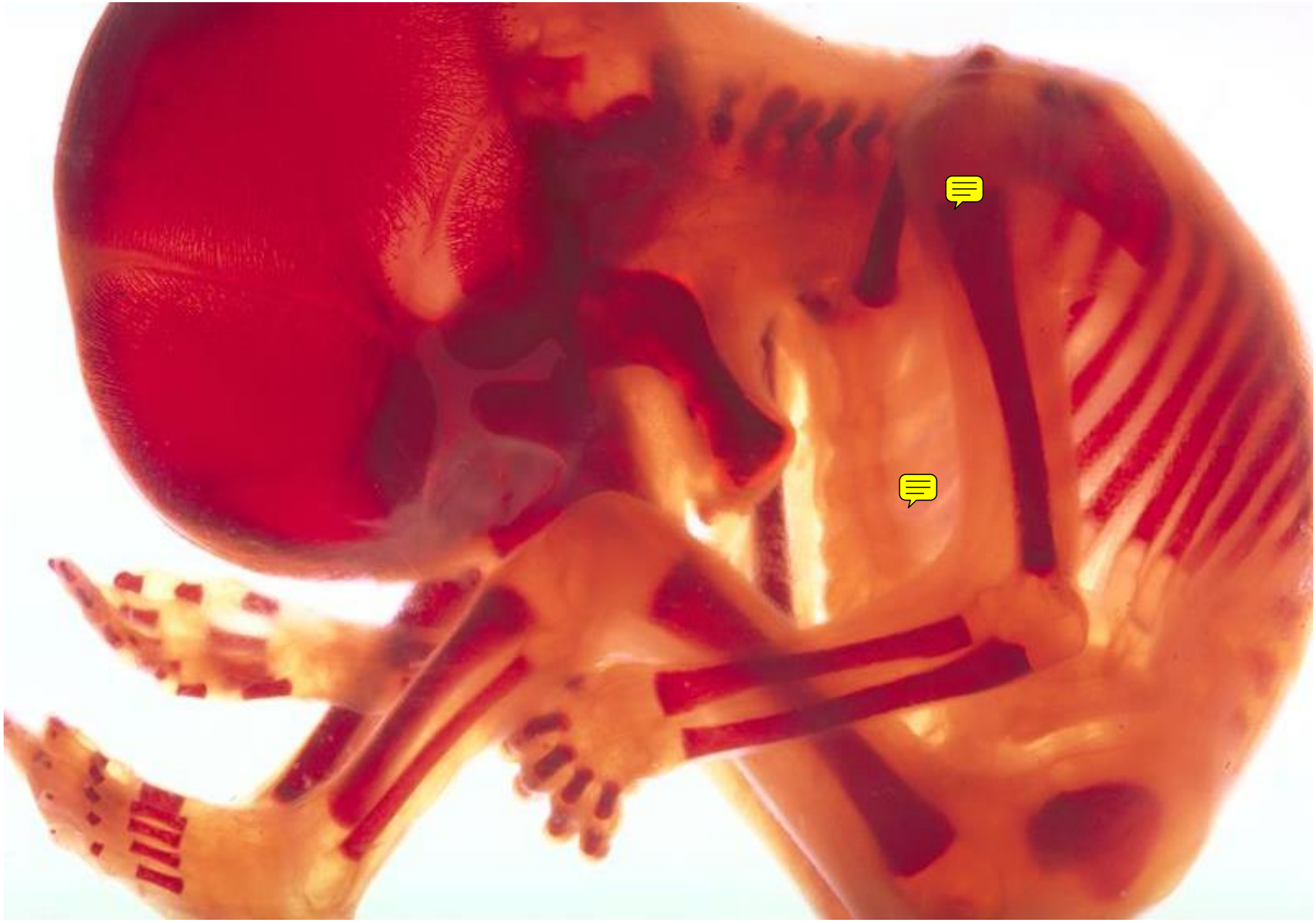
- Osteogenesis (ossification)—bone tissue formation

- Stages:
  - Bone formation—begins around 8th week of development
  - Postnatal bone growth—until early adulthood
  - Bone remodeling and repair—lifelong

Postnatal Bone Growth

- Interstitial growth:
  - ↑ length of long bones

- Appositional growth:
  - ↑ thickness and remodeling of all bones by osteoblasts and osteoclasts on bone surfaces



Ossification

The process by which bone forms.

Different methods of development in which both replace preexisting connective tissue with bone, both methods lead to the same structure in mature bone

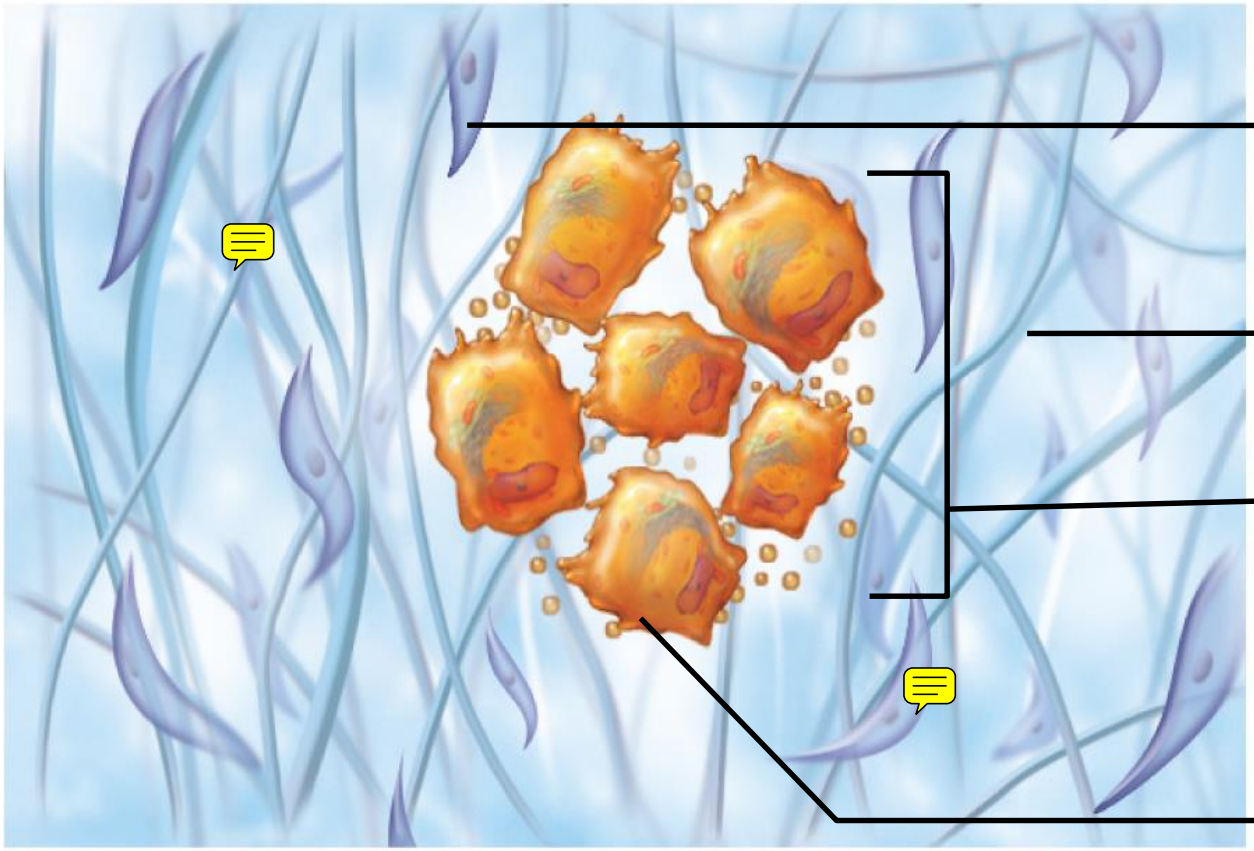
Two Types of Ossification

1. Intramembranous ossification
   - Formation directly on or within fibrous connective tissue.
   - Forms flat bones, e.g. clavicles and cranial bones of the skull

2. Endochondral ossification
   - Formation of bone within cartilage.
   - Forms most of the rest of the skeleton

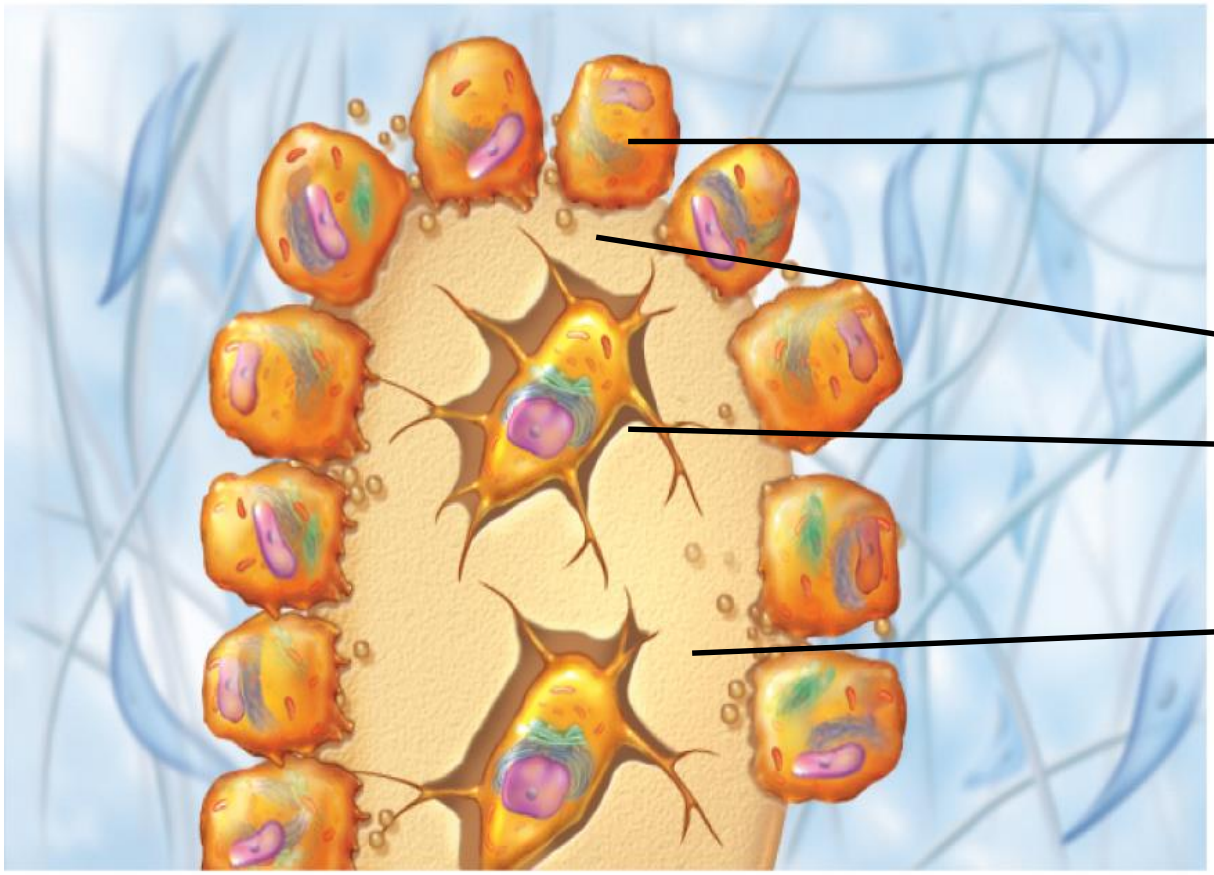
Intramembranous Ossification

- Direct formation of bone (membrane bone) within highly vascular sheets or ‘membranes’ of condensed mesenchyme.



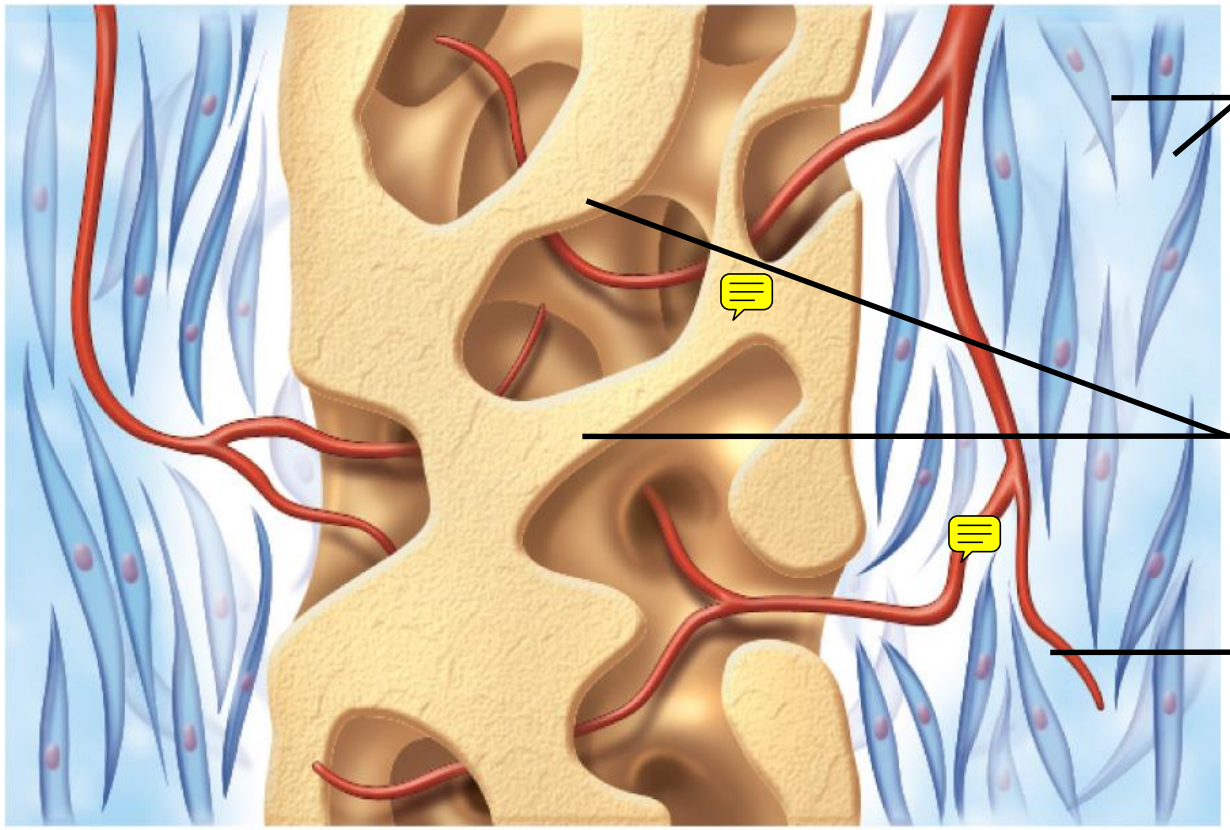
1 Ossification centers appear in the fibrous connective tissue membrane.

- Selected centrally located mesenchymal cells cluster and differentiate into osteoblasts, forming an ossification center.



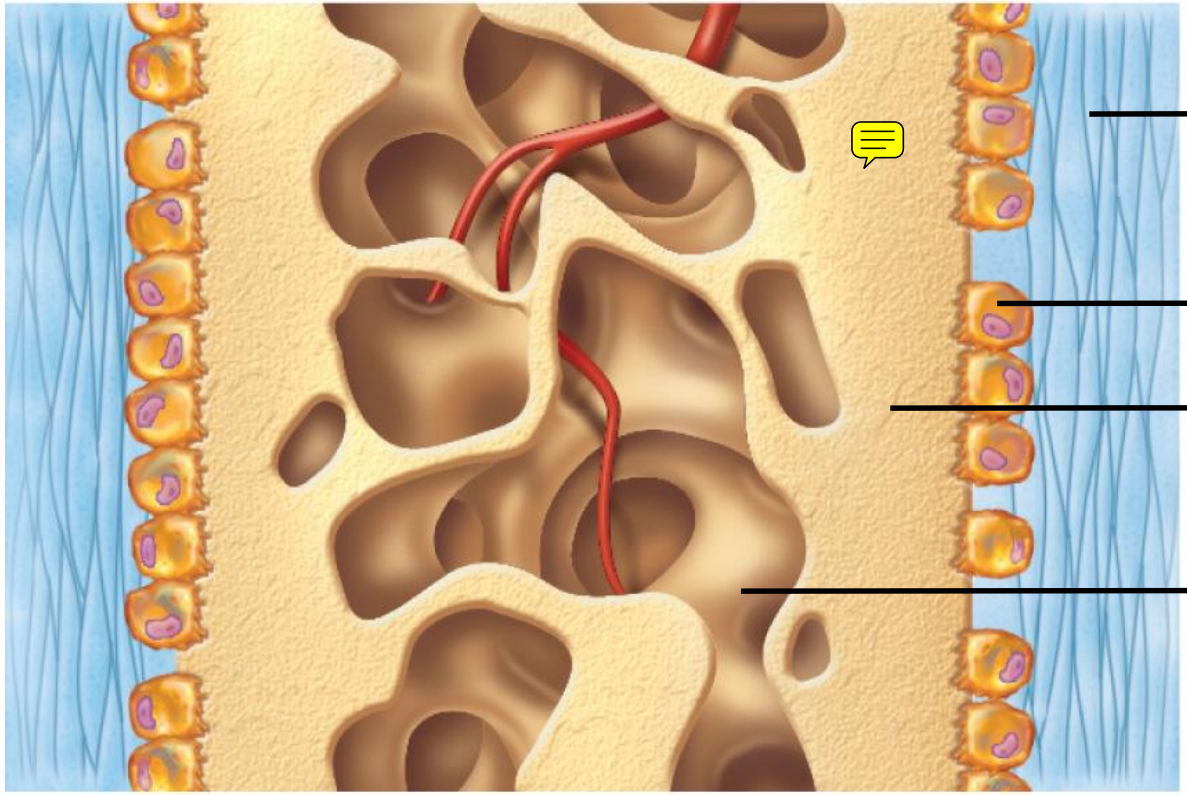
2 Bone matrix (osteoid) is secreted within the fibrous membrane and calcifies.

- Osteoblasts begin to secrete osteoid, which is calcified within a few days.
- Trapped osteoblasts become osteocytes.



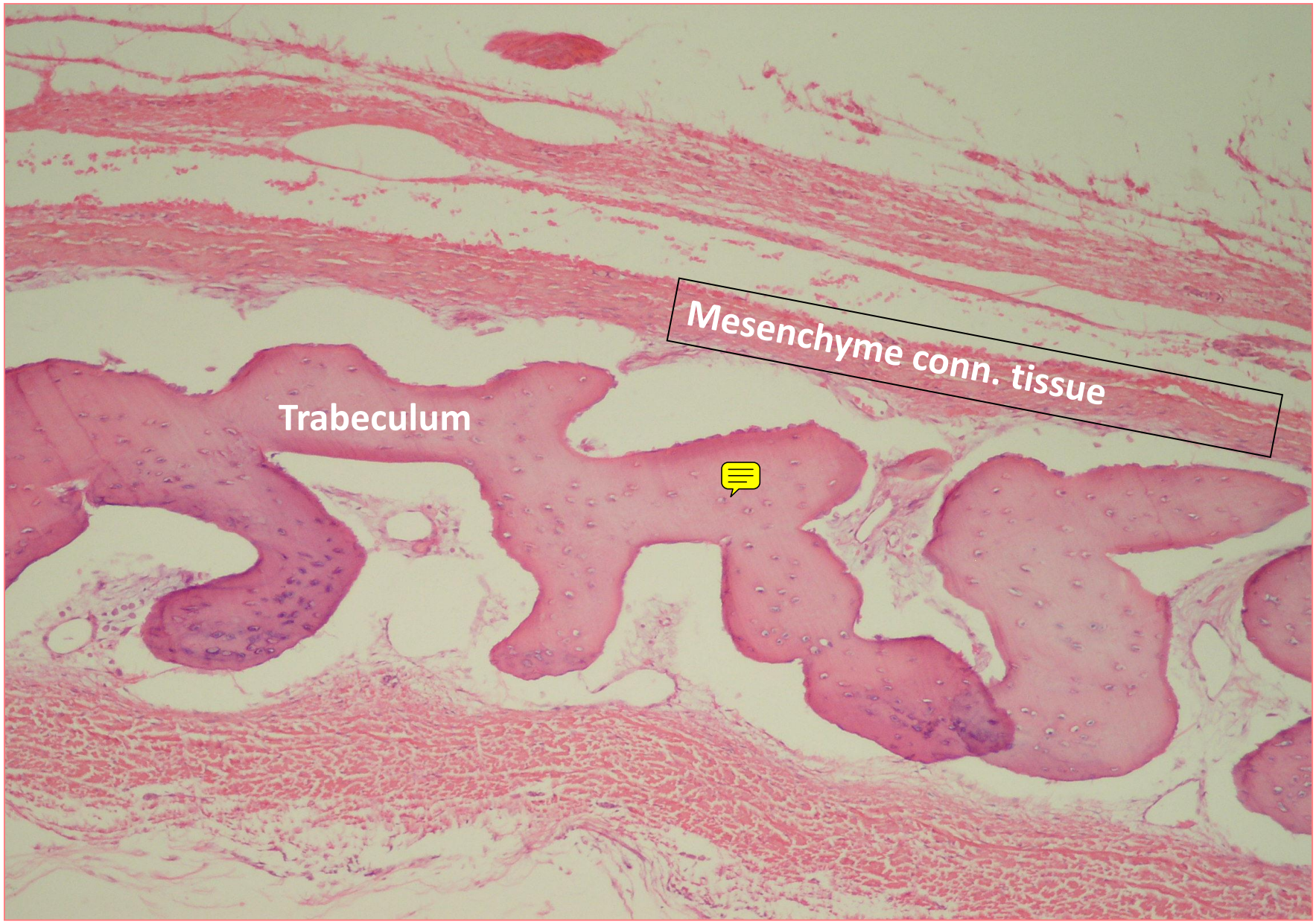
3 **Woven bone and periosteum form.**

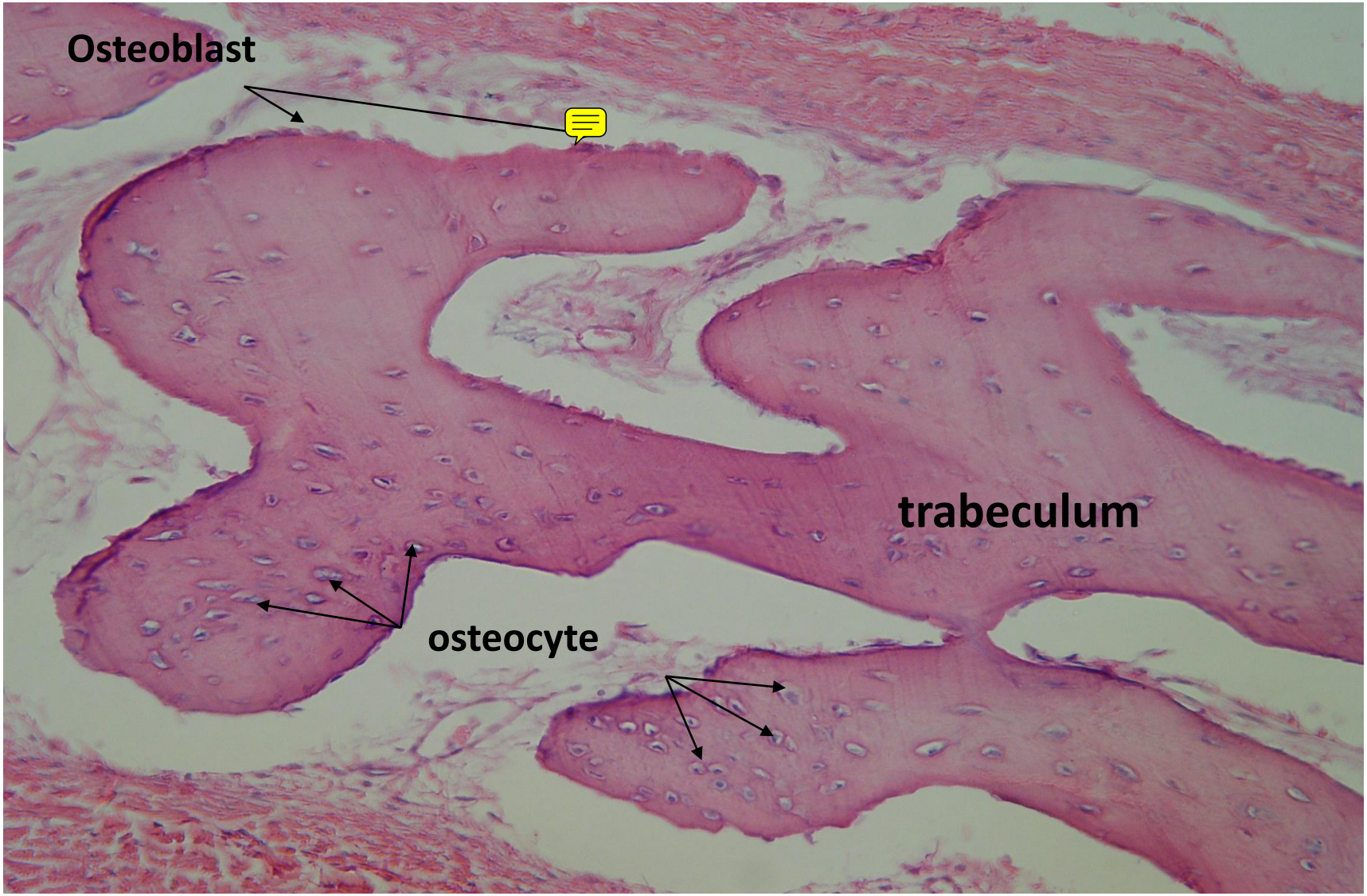
- Accumulating osteoid is laid down between embryonic blood vessels in a random manner. The result is a network (instead of lamellae) of trabeculae called woven bone.
- Vascularized mesenchyme condenses on the external face of the woven bone and becomes the periosteum.

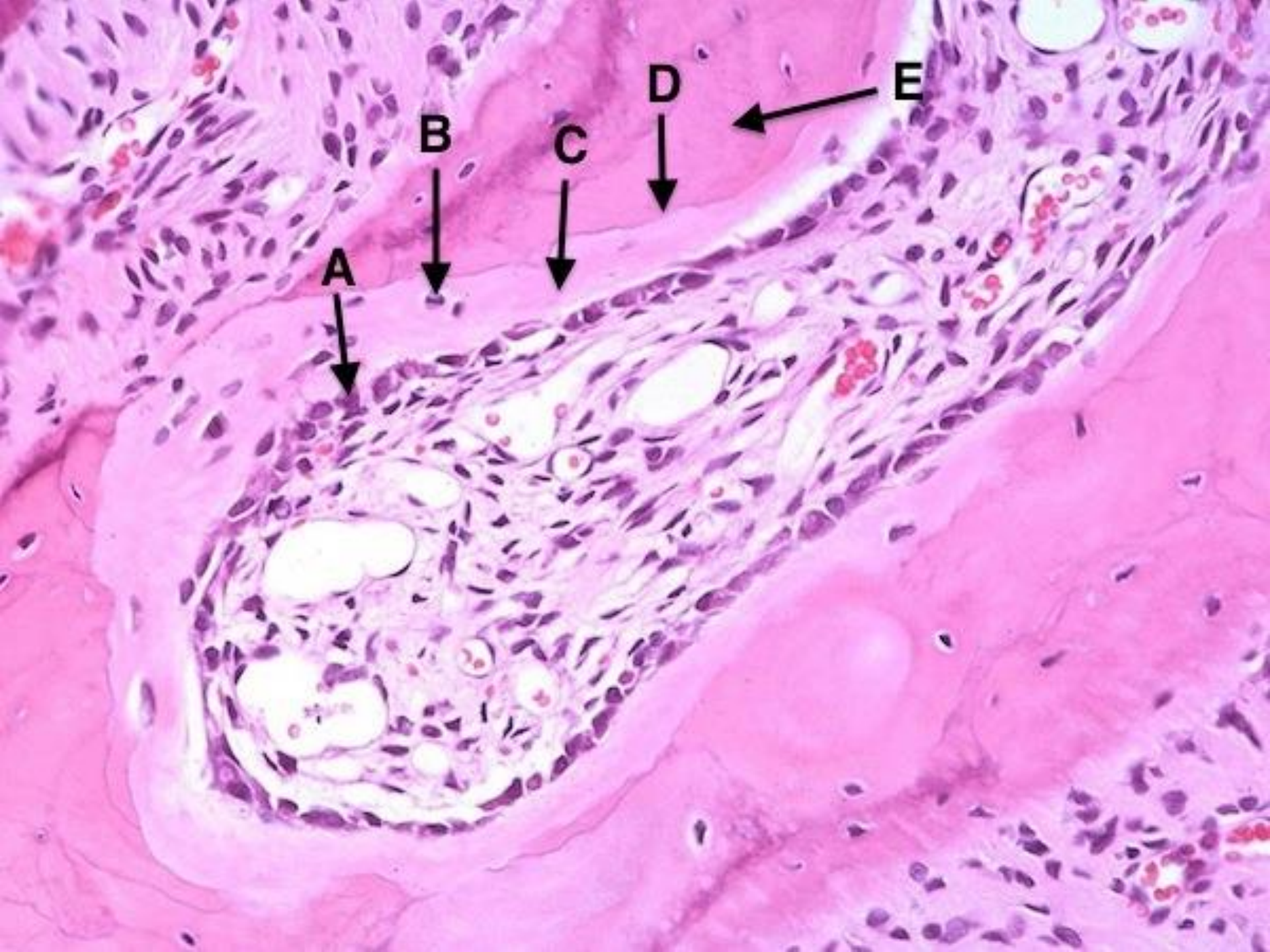


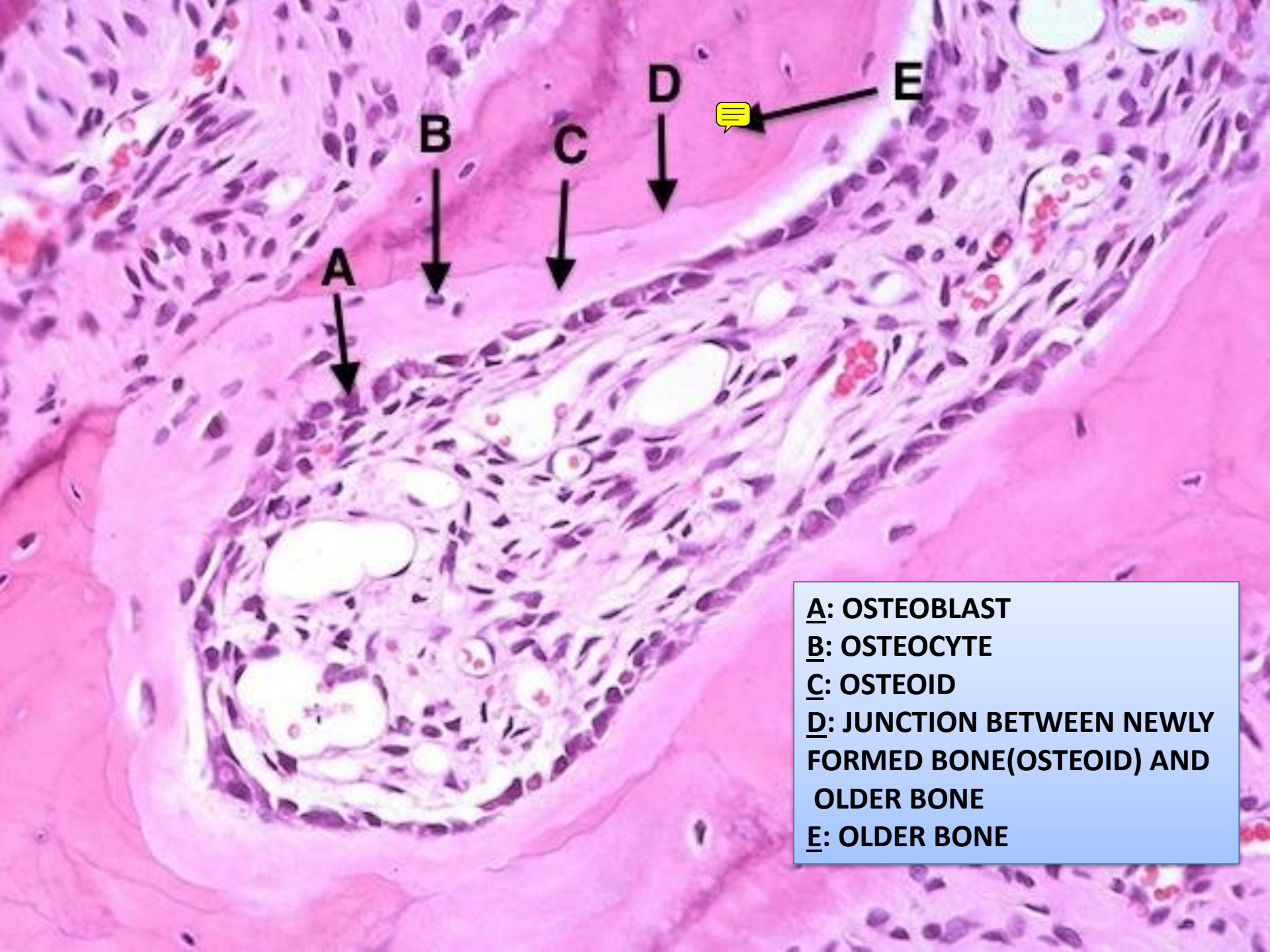
4 Lamellar bone replaces woven bone, just deep to the periosteum. Red marrow appears.

- Trabeculae just deep to the periosteum thicken, and are later replaced with mature lamellar bone, forming compact bone plates.
- Spongy bone (diploë), consisting of distinct trabeculae, persists internally and its vascular tissue becomes red marrow.

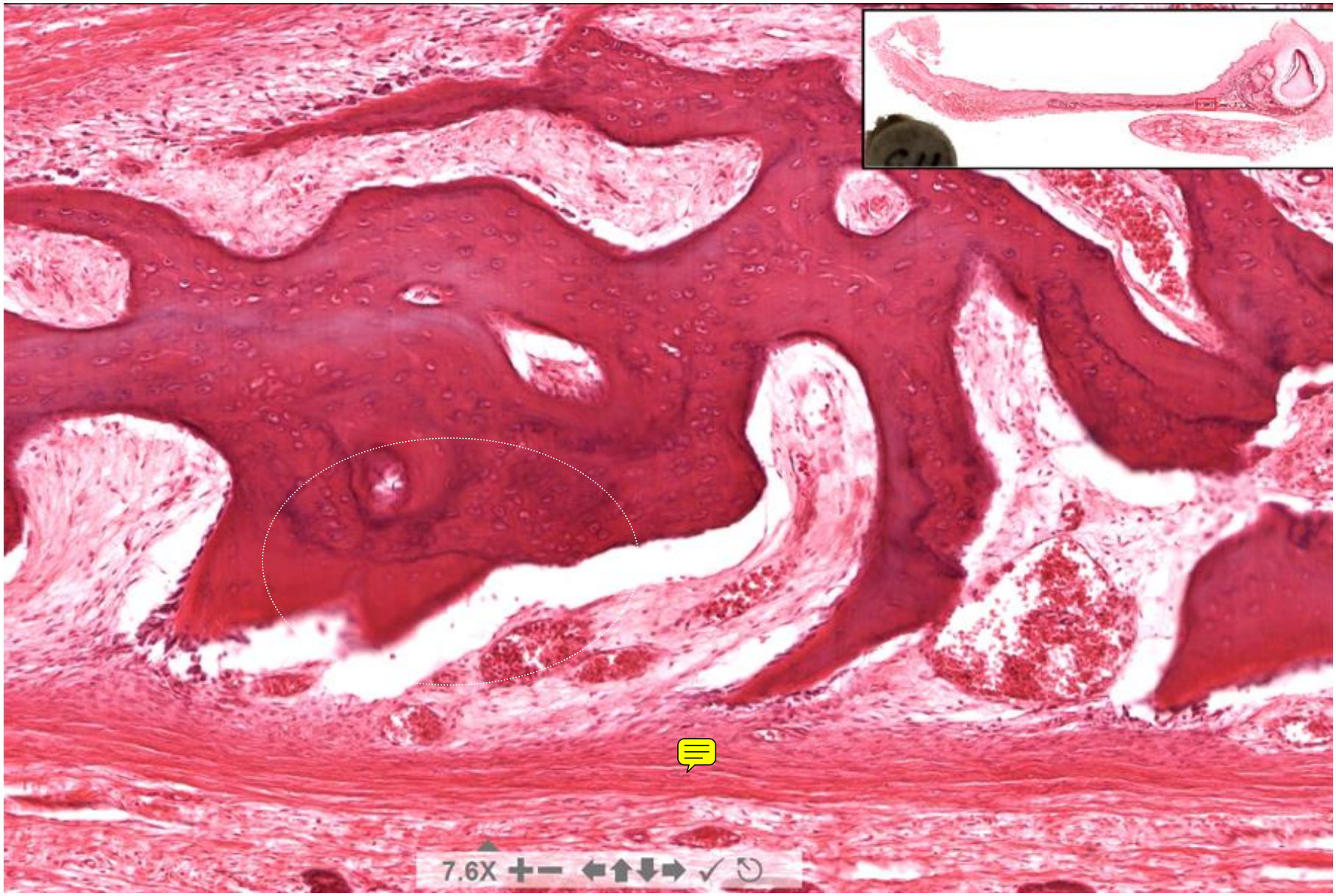

Mesenchyme conn. tissue
Trabeculum


Osteoblast
trabeculum
osteocyte


A
B
C
D
E



A: OSTEOBLAST
B: OSTEOCYTE
C: OSTEOID
D: JUNCTION BETWEEN NEWLY FORMED BONE(OSTEOID) AND OLDER BONE
E: OLDER BONE

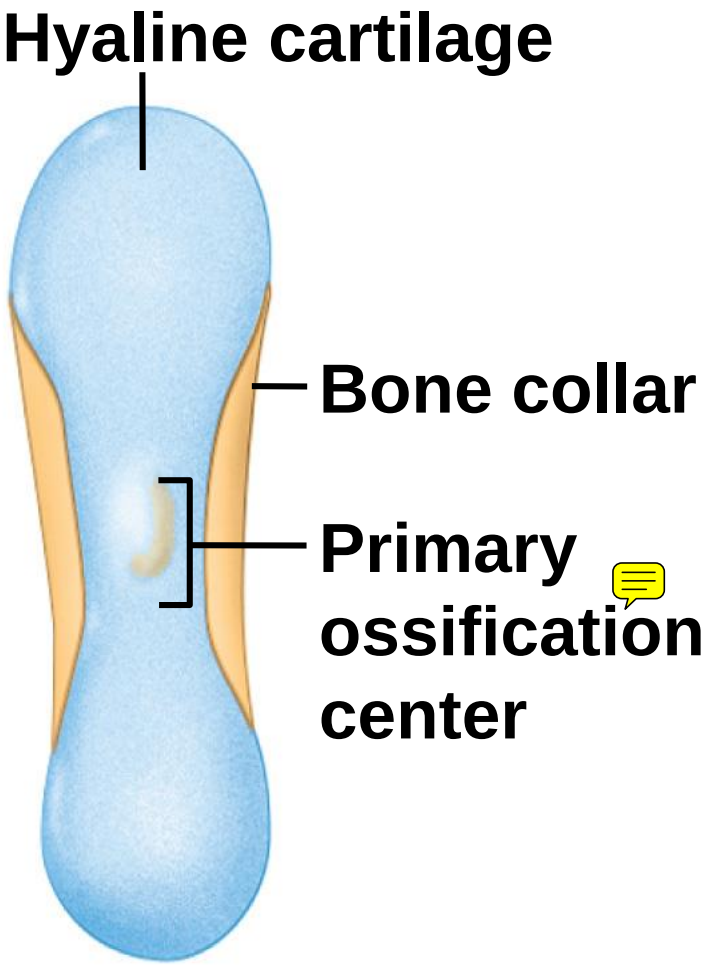


Immature (woven) bone

Beginning of osteon formation

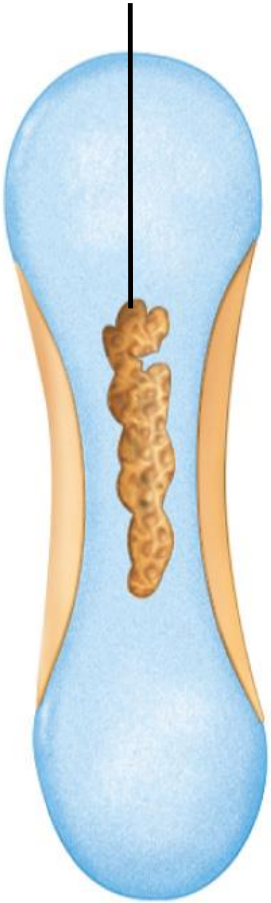
Endochondral Ossification

- Uses hyaline cartilage models
- Most of the long and short bones of the body develop by endochondral ossification
- Requires breakdown of hyaline cartilage prior to ossification

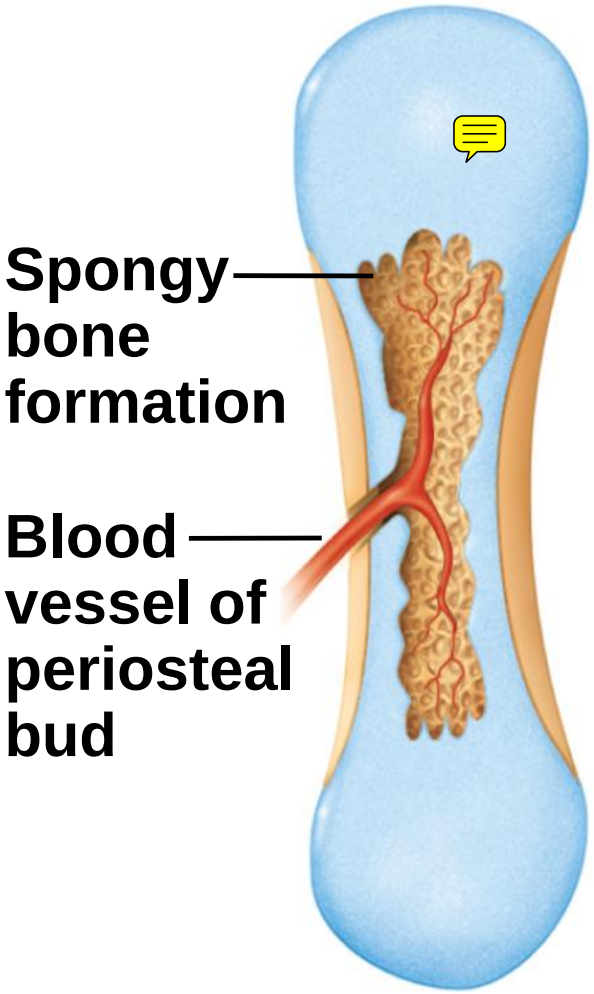


1 Bone collar forms around hyaline cartilage model.

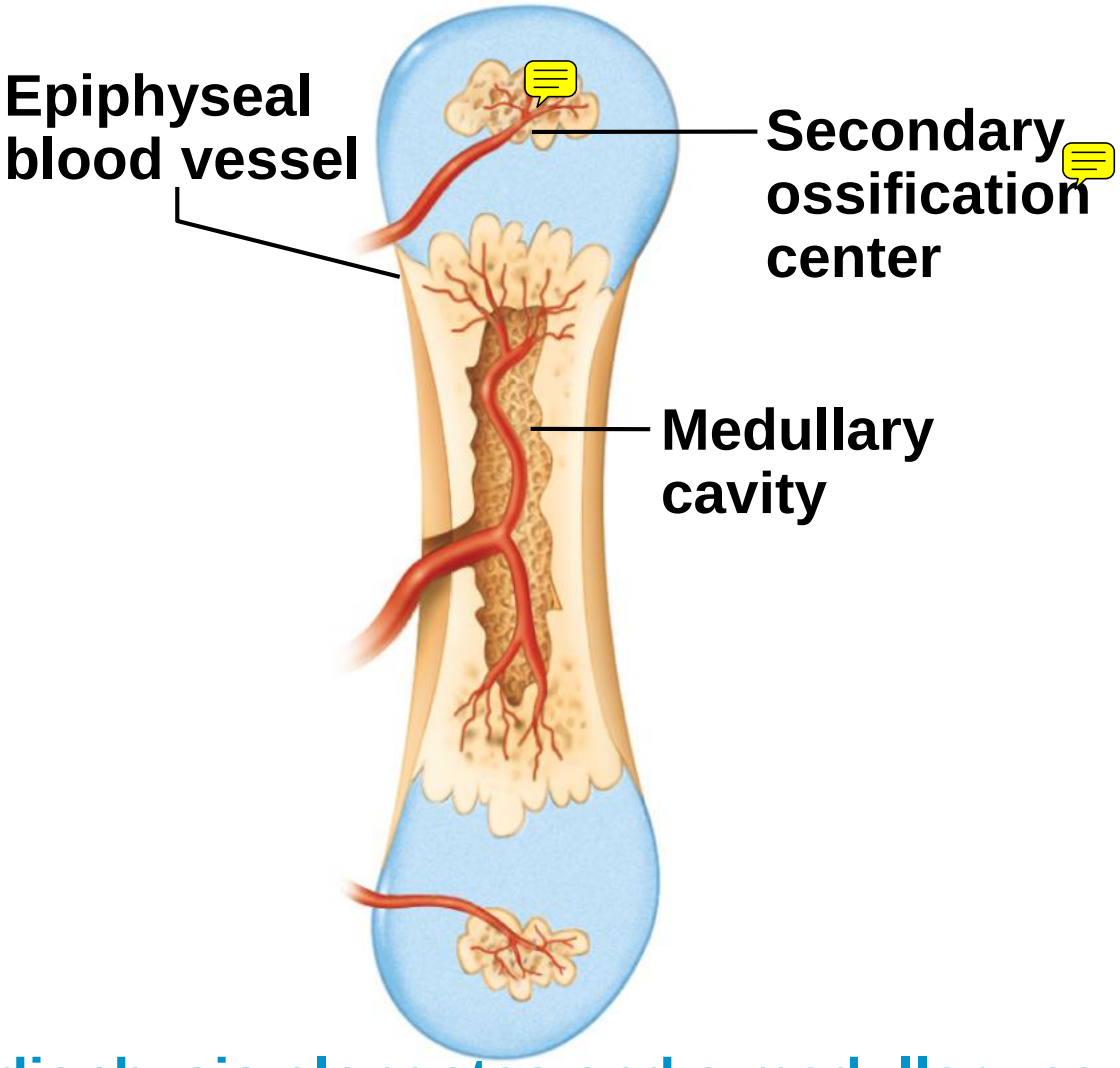
Area of deteriorating cartilage matrix



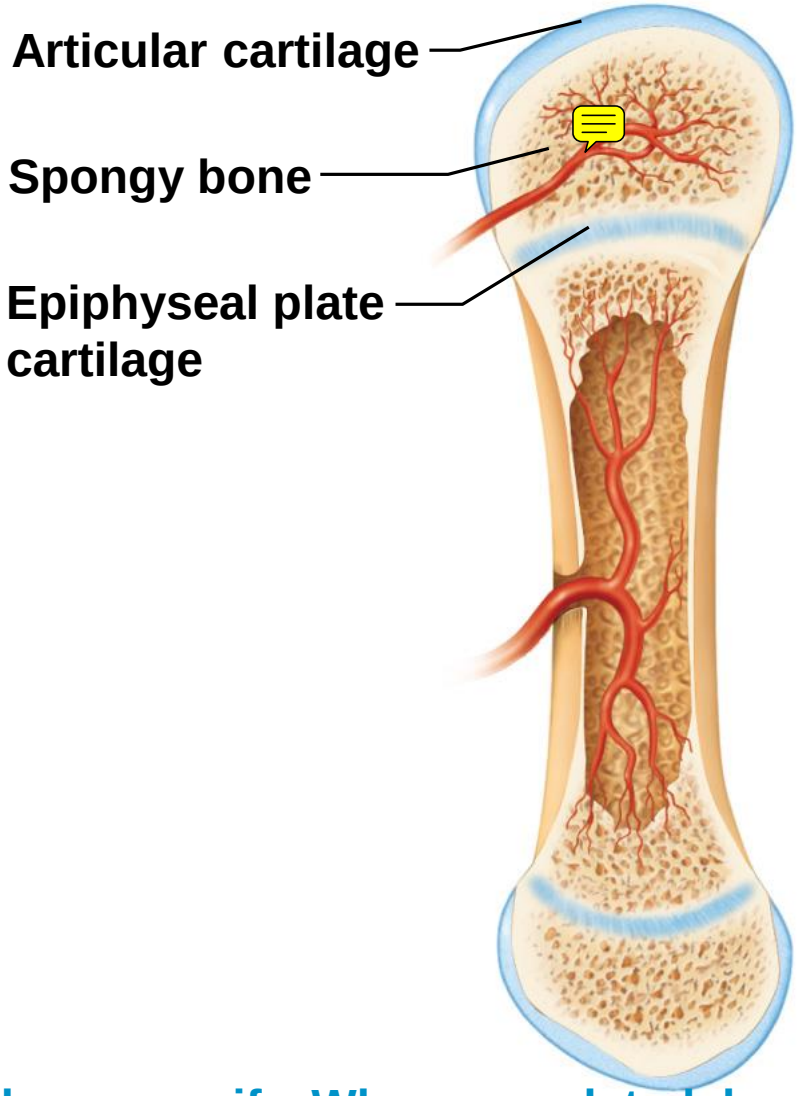
② Cartilage in the center of the diaphysis calcifies and then develops cavities.



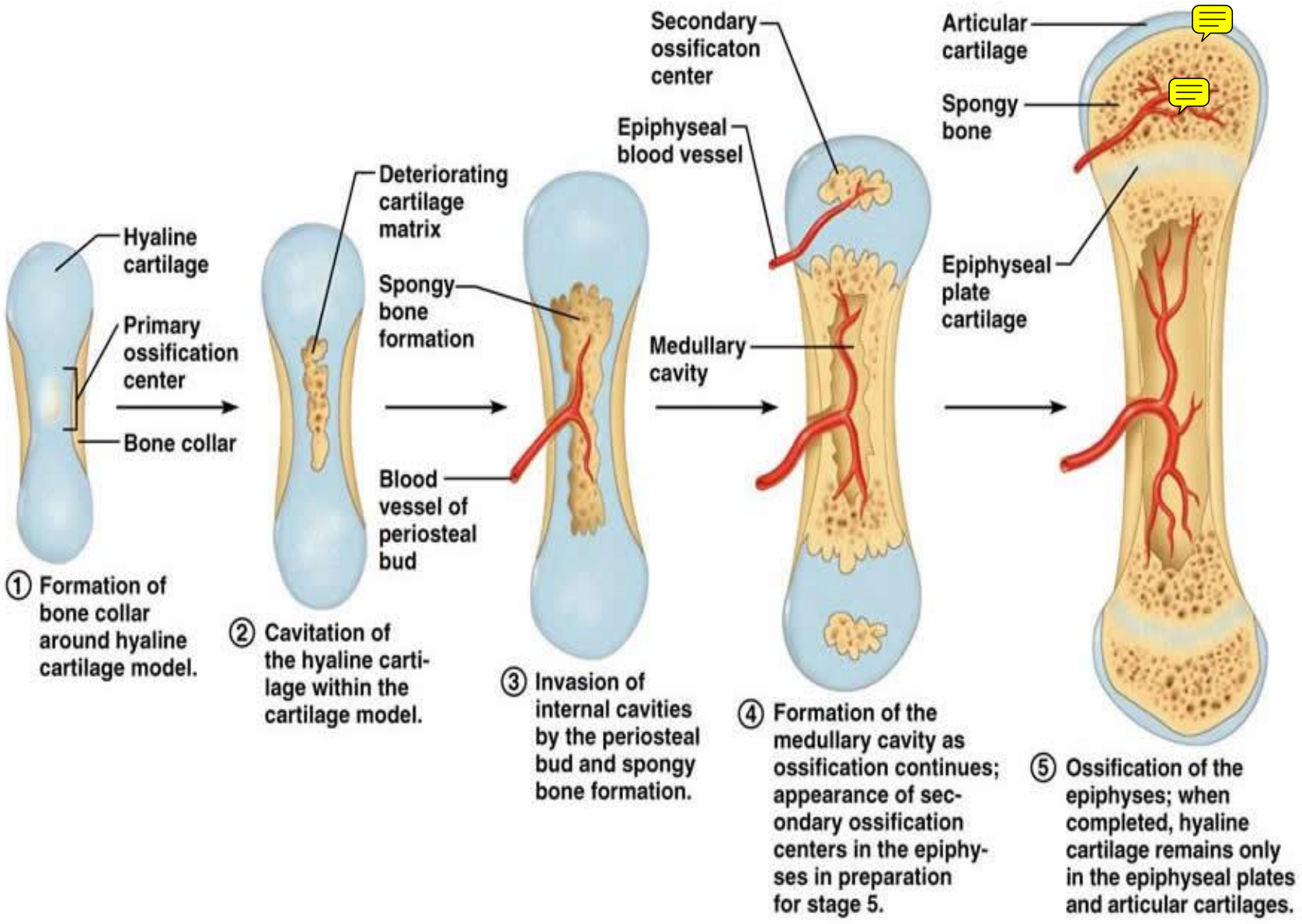
③ The periosteal bud invades the internal cavities and spongy bone begins to form.

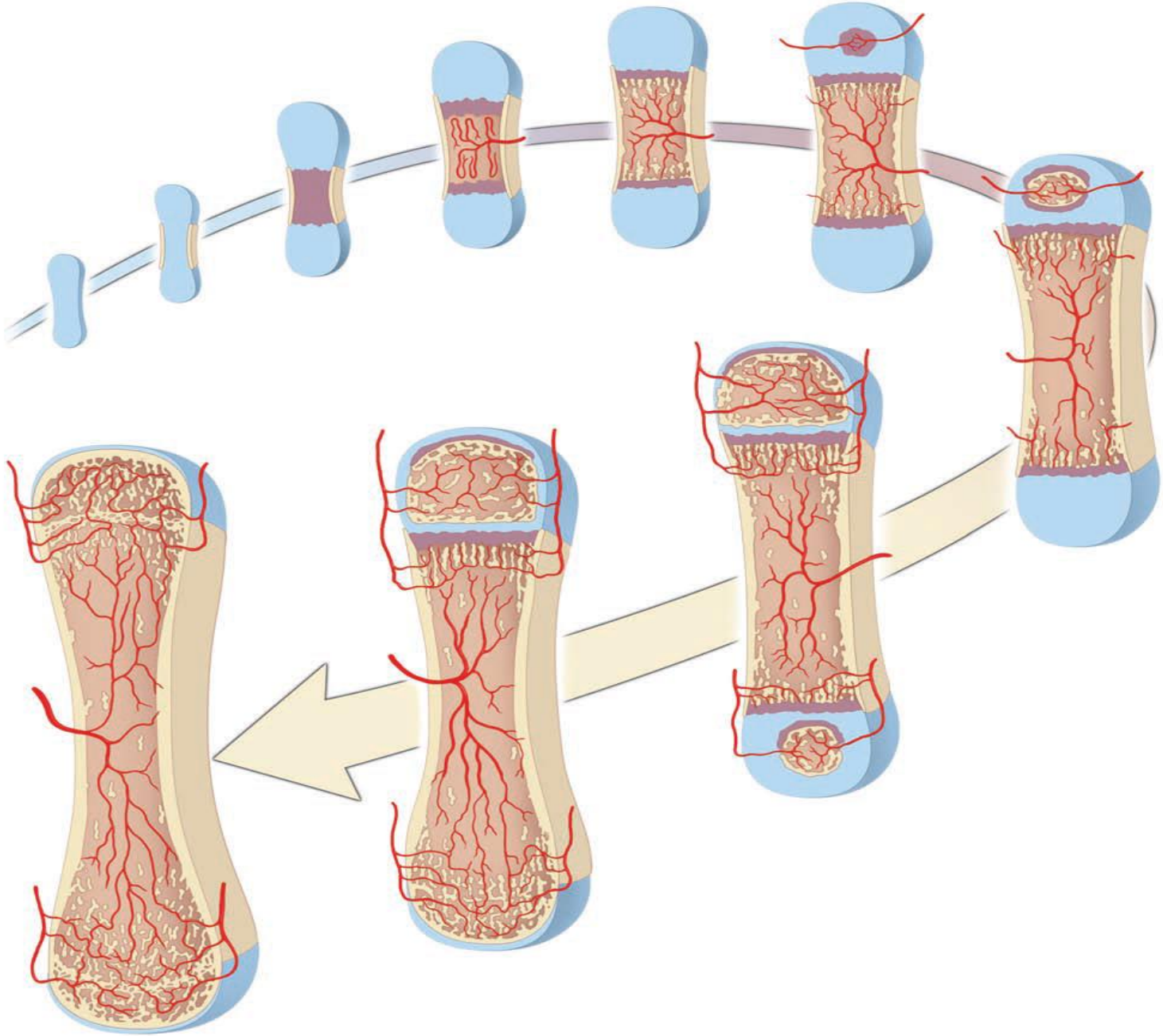


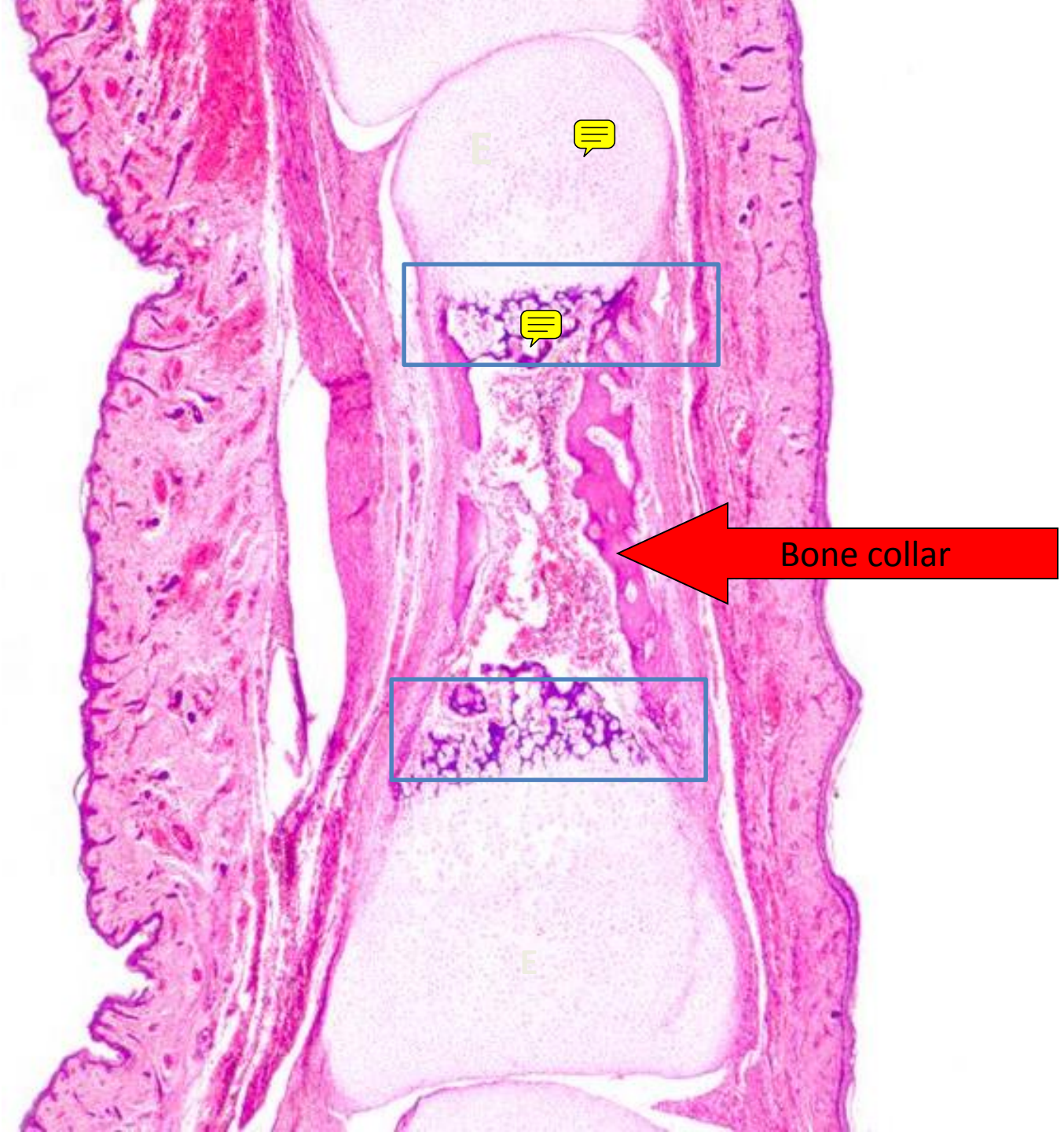
④ The diaphysis elongates and a medullary cavity forms as ossification continues. Secondary ossification centers appear in the epiphyses.

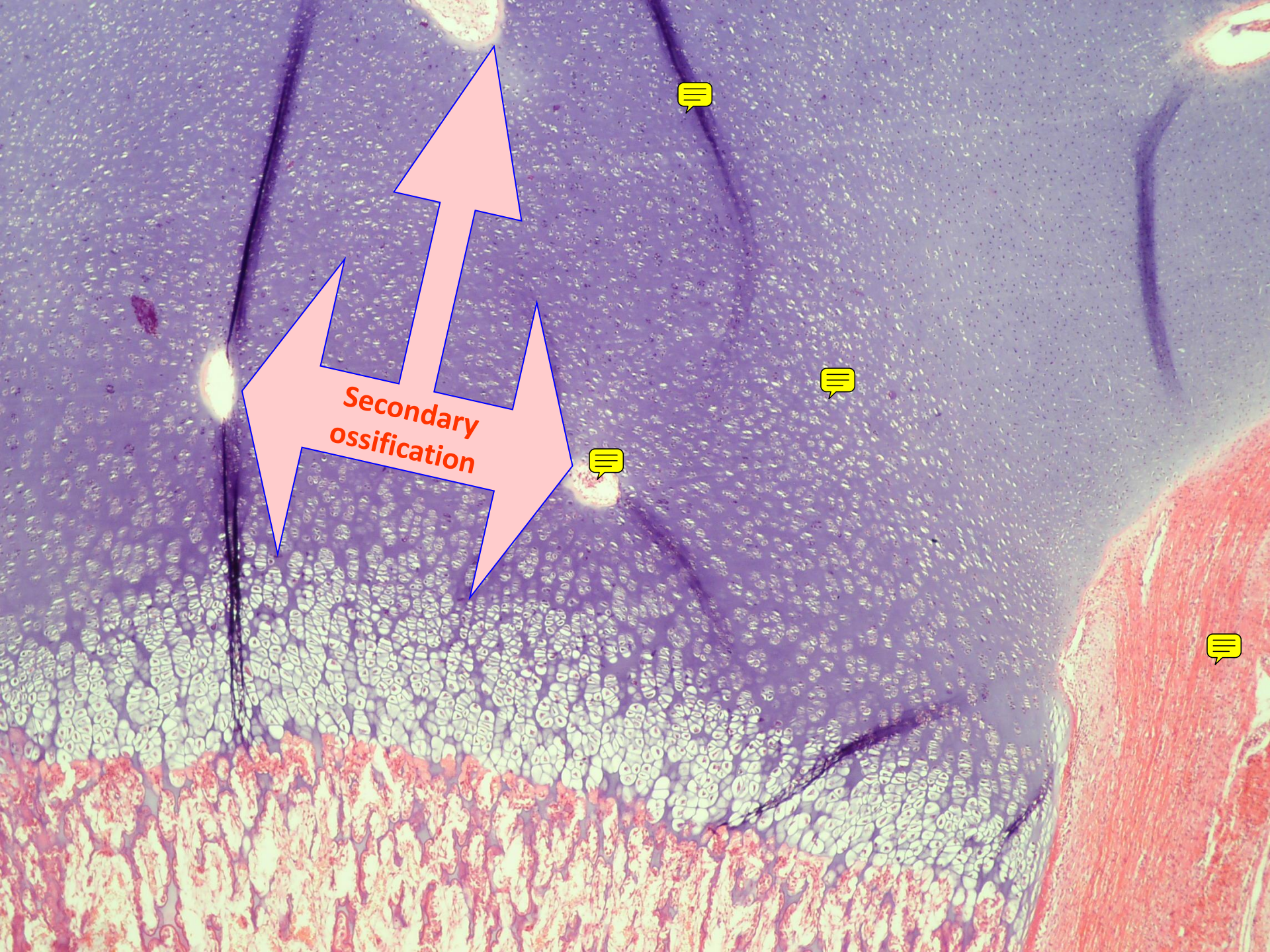


⑤ The epiphyses ossify. When completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.

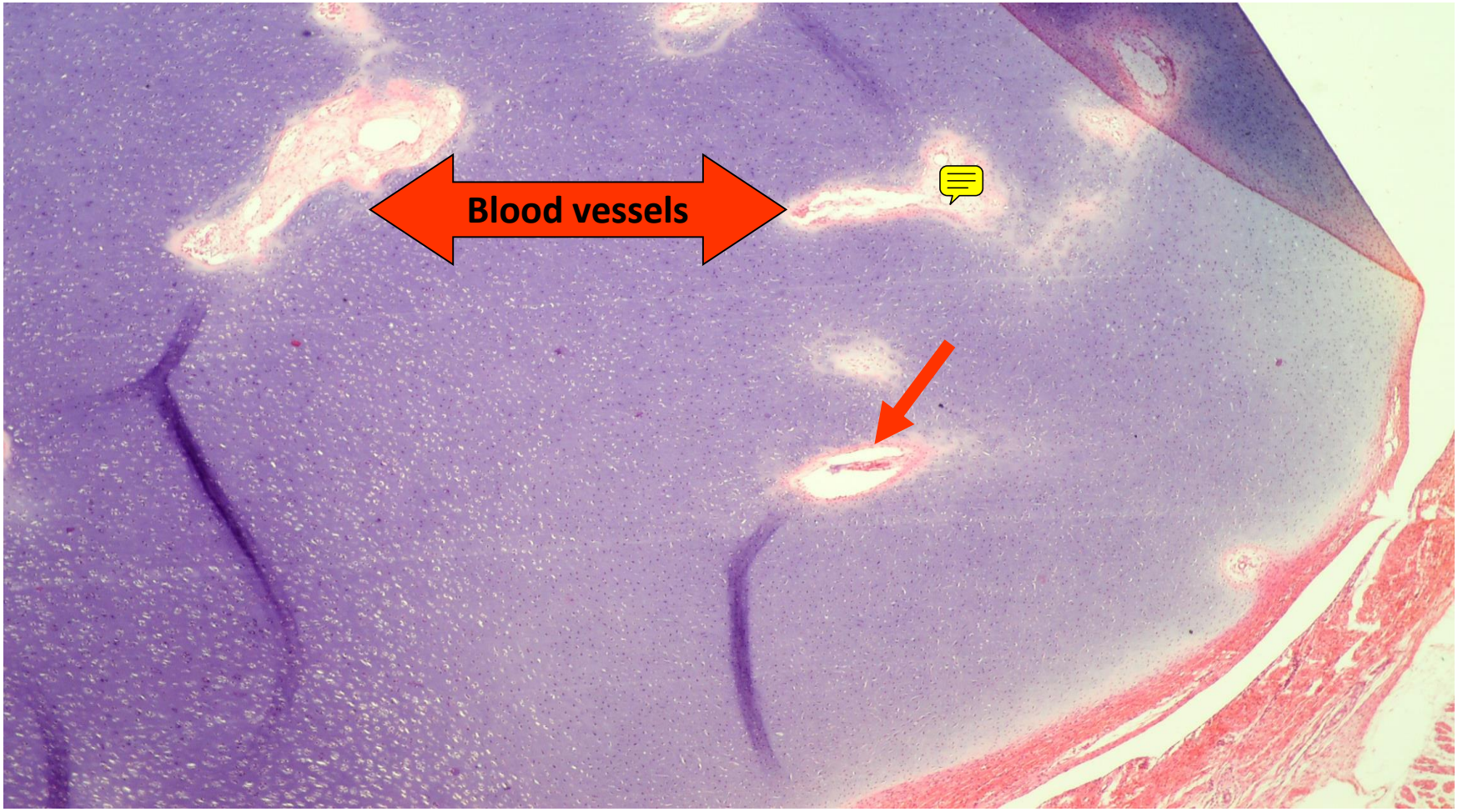

Hyaline cartilage
Primary ossification center
Bone collar
① Formation of bone collar around hyaline cartilage model.
Deteriorating cartilage matrix
② Cavitation of the hyaline cartilage within the cartilage model.
Spongy bone formation
Blood vessel of periosteal bud
③ Invasion of internal cavities by the periosteal bud and spongy bone formation.
Secondary ossificaton center
Epiphyseal blood vessel
Medullary cavity
④ Formation of the medullary cavity as ossification continues; appearance of secondary ossification centers in the epiphyses in preparation for stage 5.
Articular cartilage
Spongy bone
Epiphyseal plate cartilage
⑤ Ossification of the epiphyses; when completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.




Bone collar


Secondary ossification

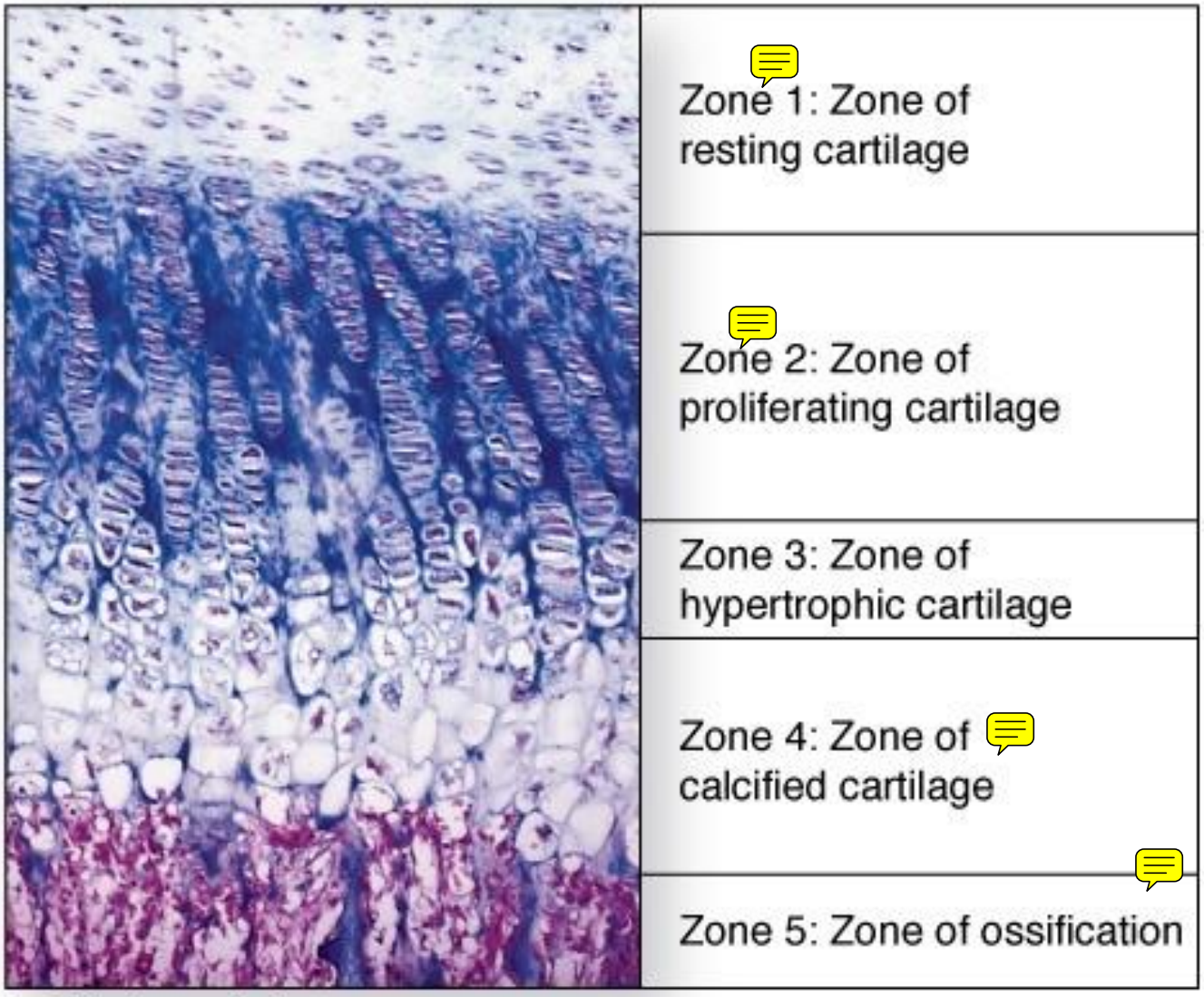
Secondary ossification center



Growth in Length of Long Bones

- Epiphyseal plate cartilage organizes into four important functional zones:

1. Resting (reserve)
2. Proliferation (growth)
3. Hypertrophy and Calcification
4. Ossification



b Epiphyseal plate

Consider these two zones as one zone

Zones of epiphyseal plate

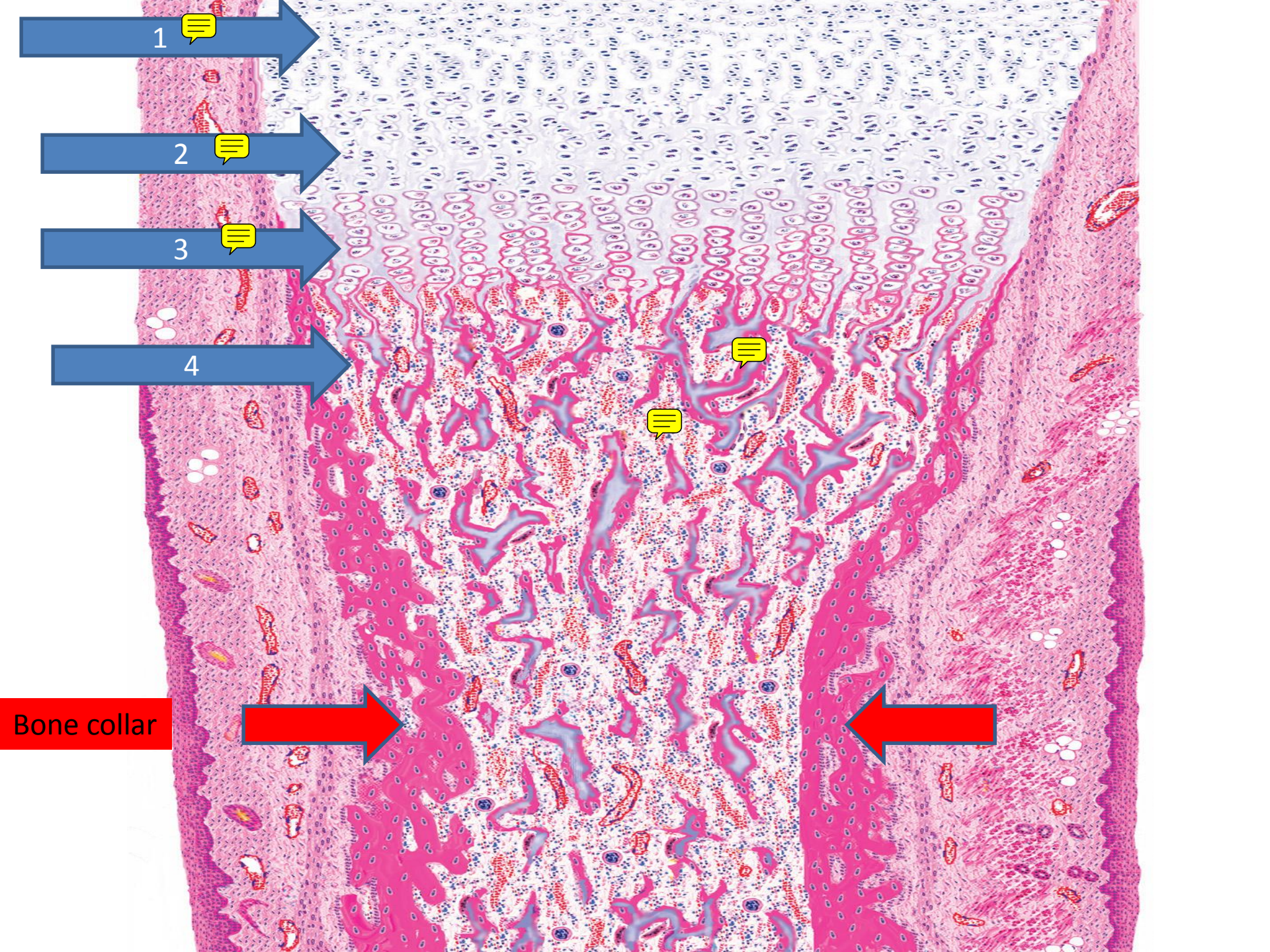
- **Zone of reserve cartilage:** Chondrocytes randomly distributed throughout the matrix

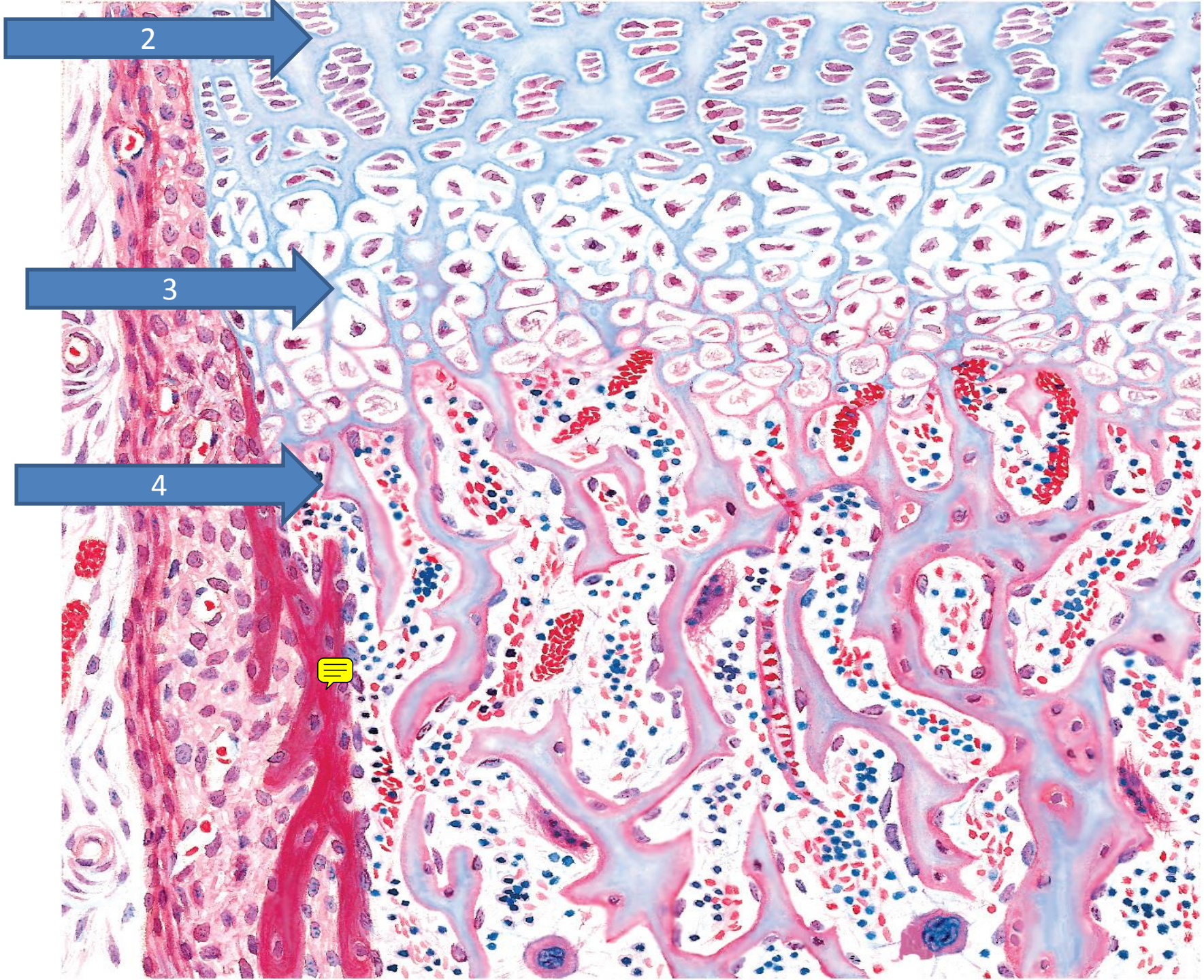
- **Zone of proliferation:** Chondrocytes, rapidly proliferating, form columns of isogenous cells that are parallel to the direction of bone growth.

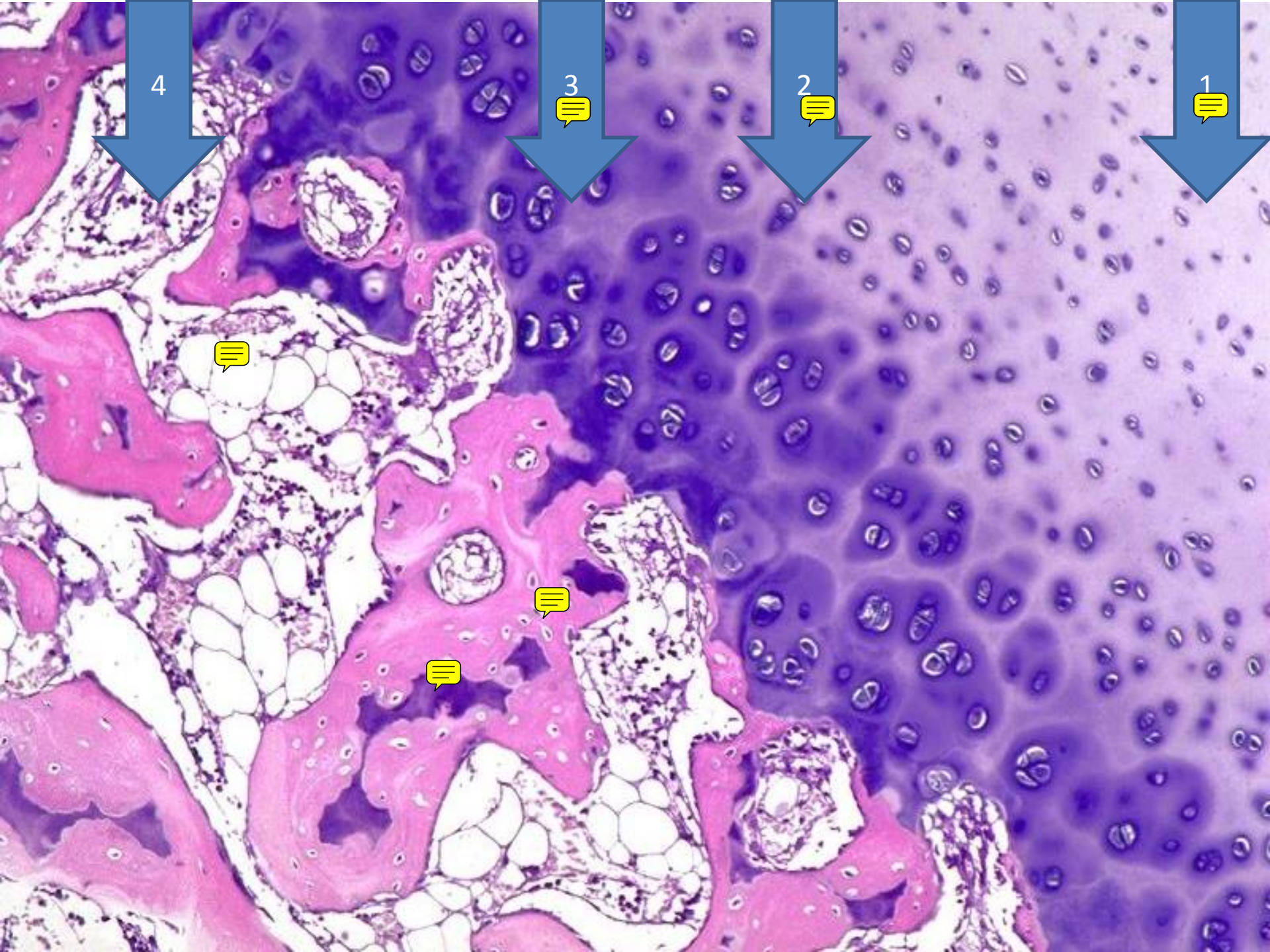
- **Zone of hypertrophy and calcification:**
- Chondrocytes mature, hypertrophy, and accumulate glycogen in their cytoplasm

- The matrix between chondrocytes narrows
- Chondrocytes die, and cartilage matrix becomes calcified

- **Zone of ossification:** Osteoprogenitor cells invade the area and differentiate into osteoblasts, which secrete matrix that on the surface of calcified cartilage

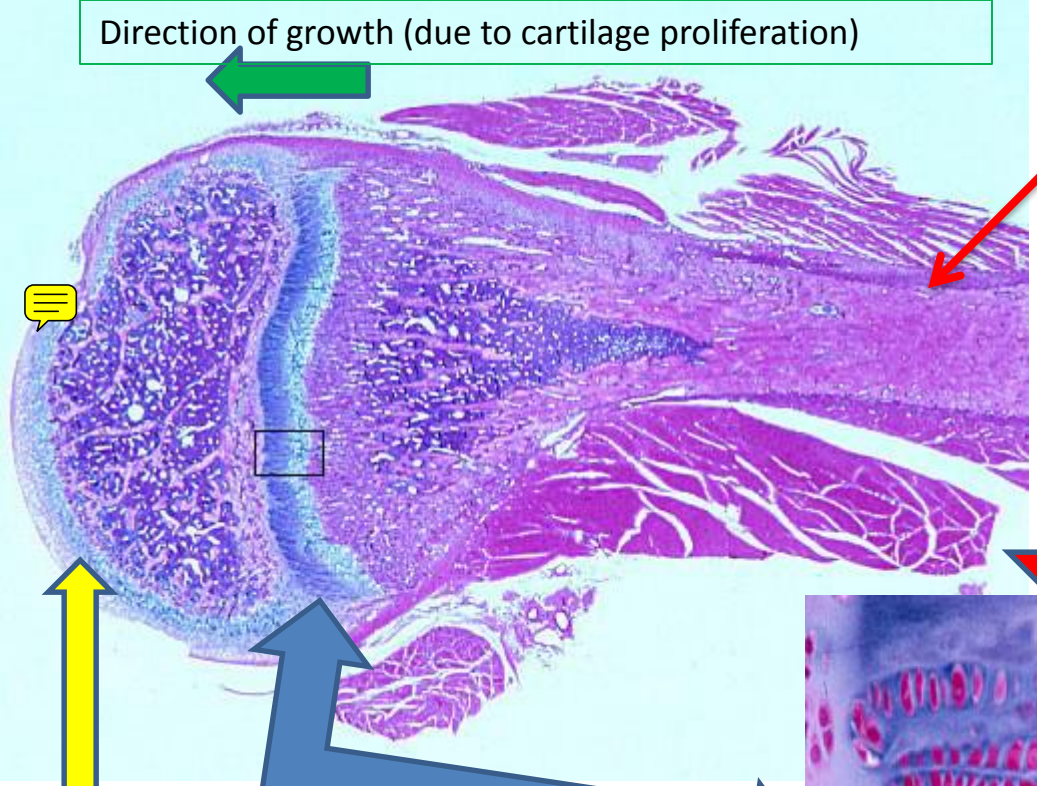

1
2
3
4
Bone collar


2
3
4


4
3
2
1

Direction of growth (due to cartilage proliferation)

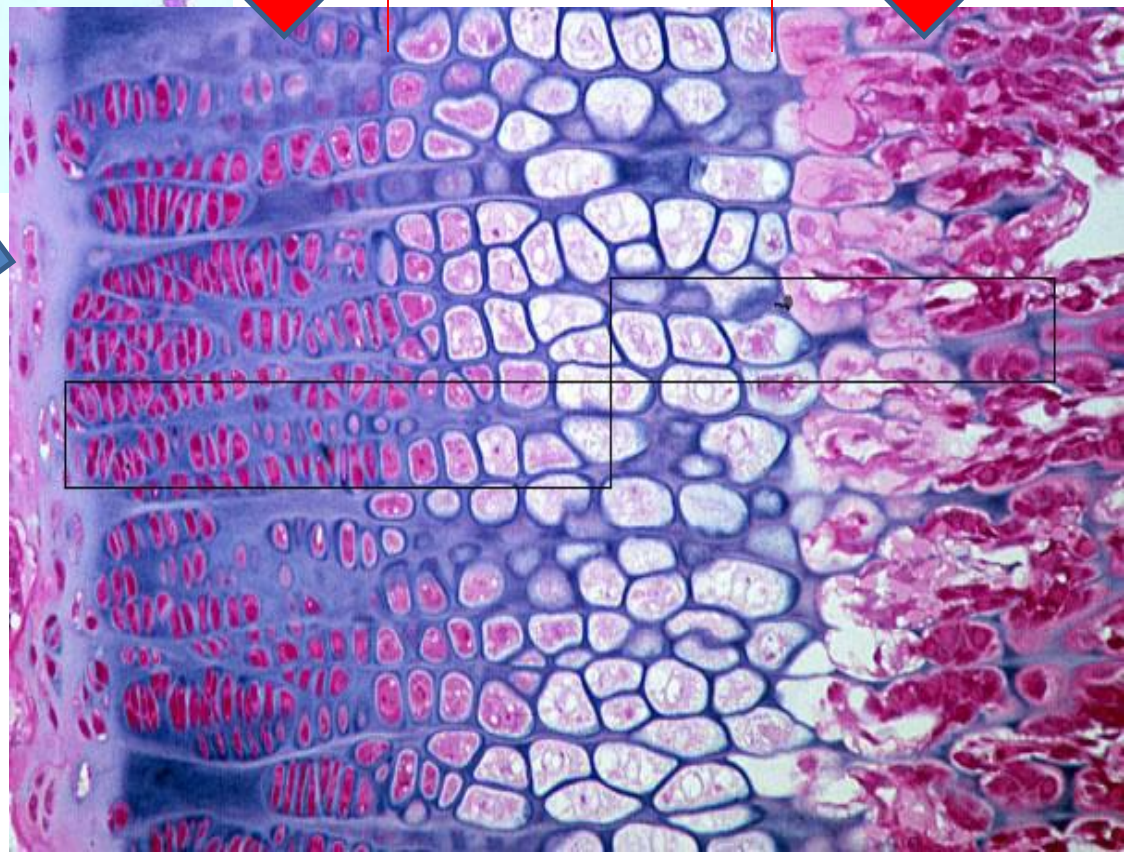
Shaft (diaphysis) becomes **compact bone**



2

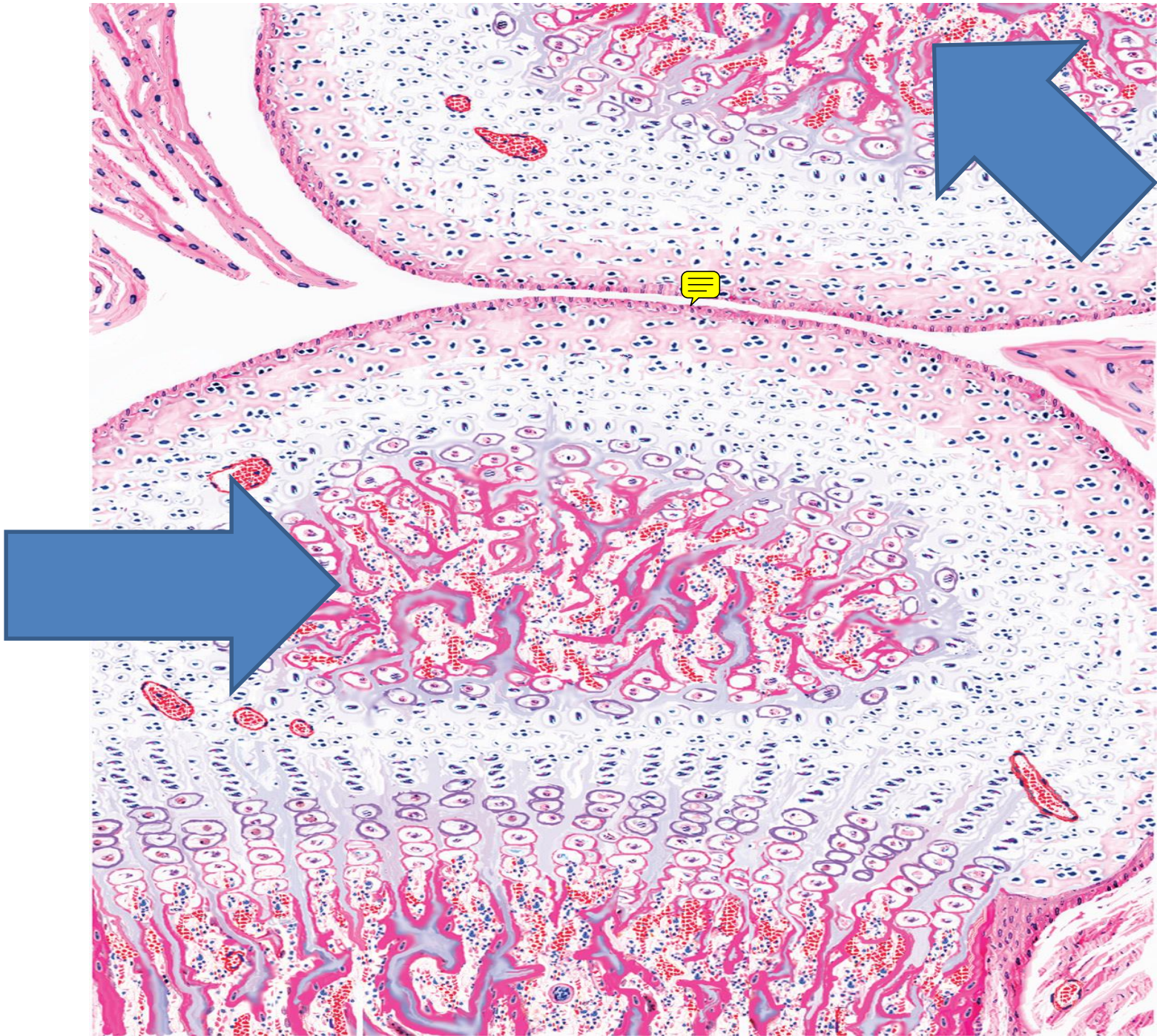
3

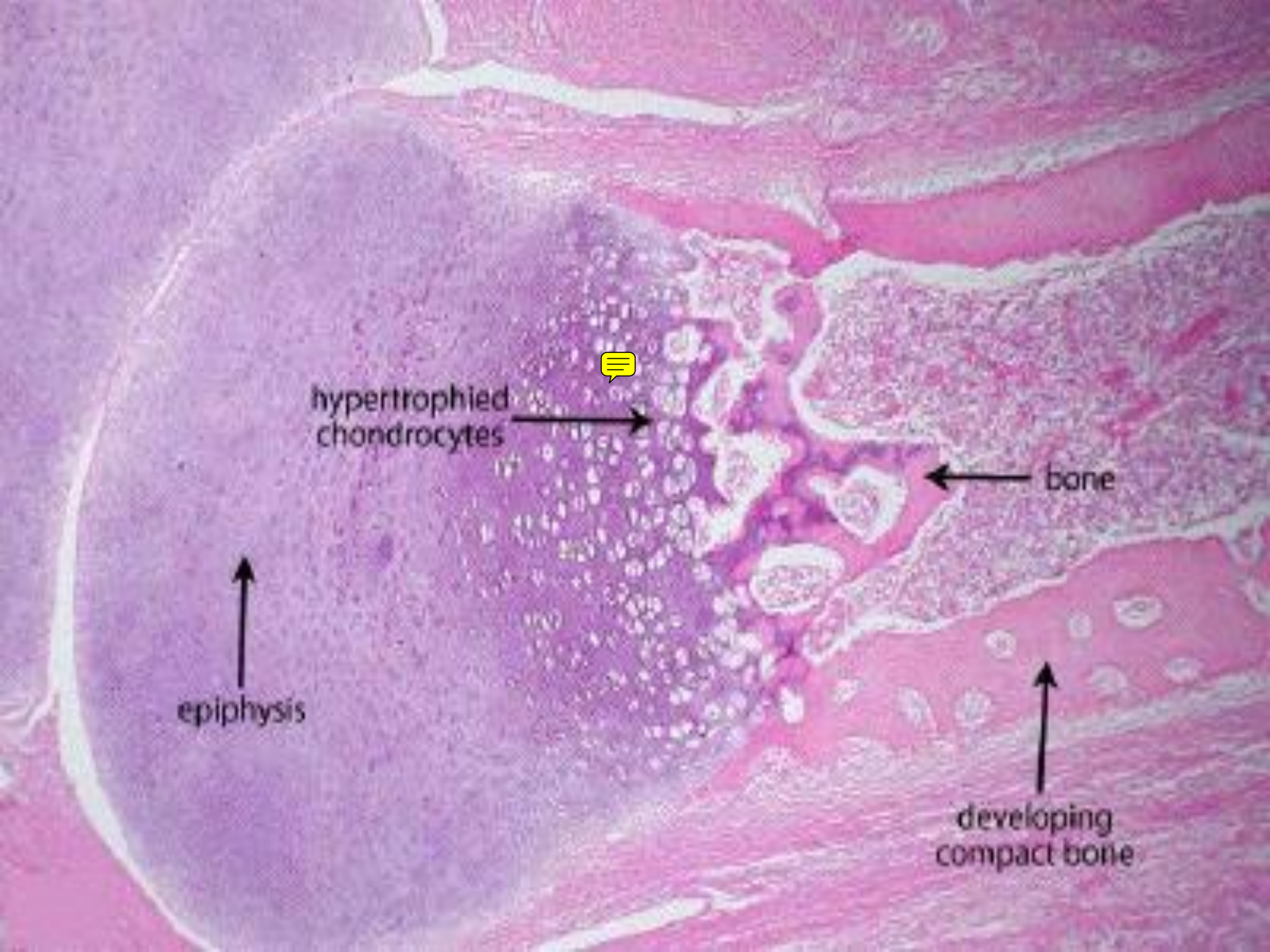
4

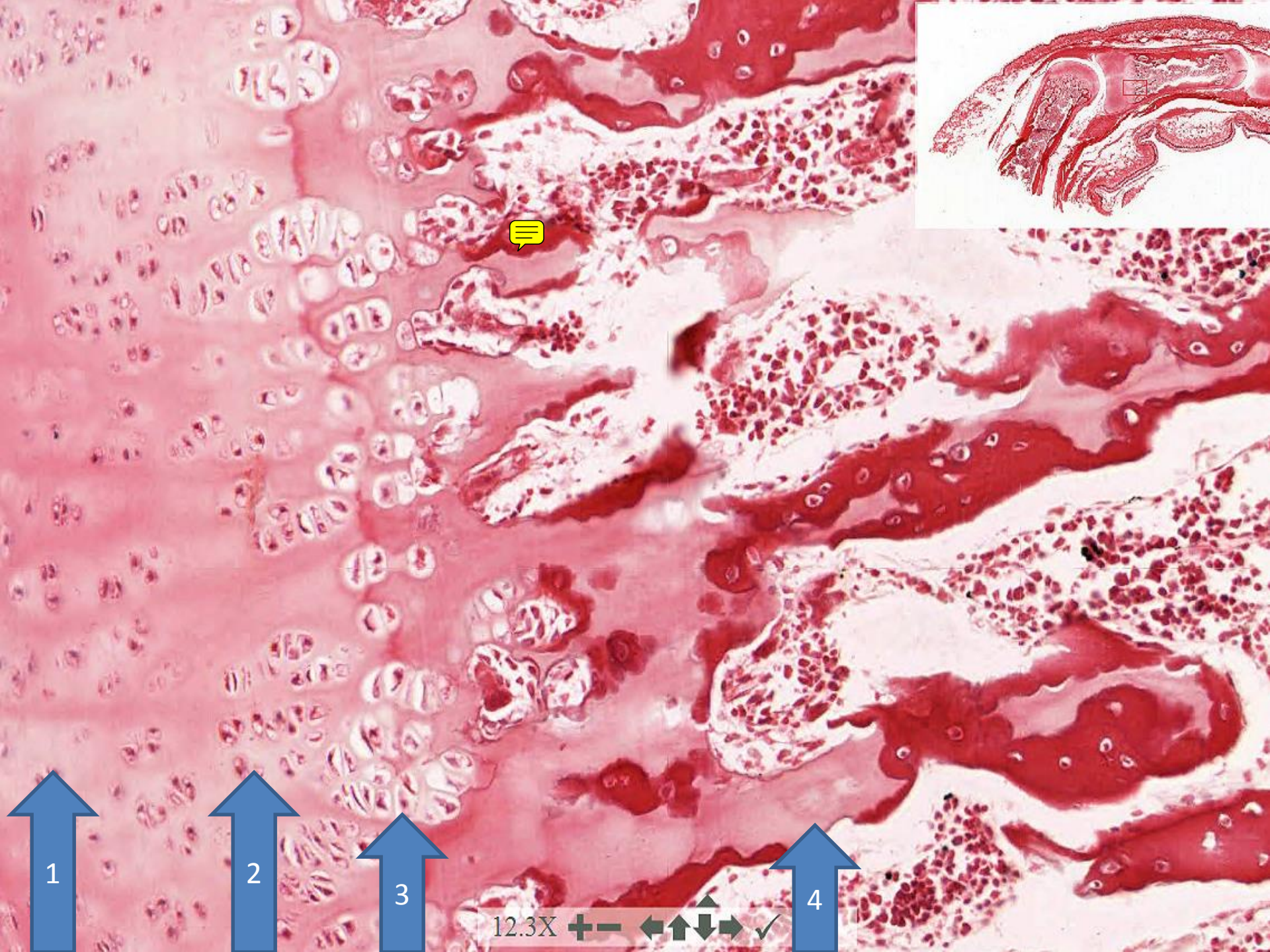


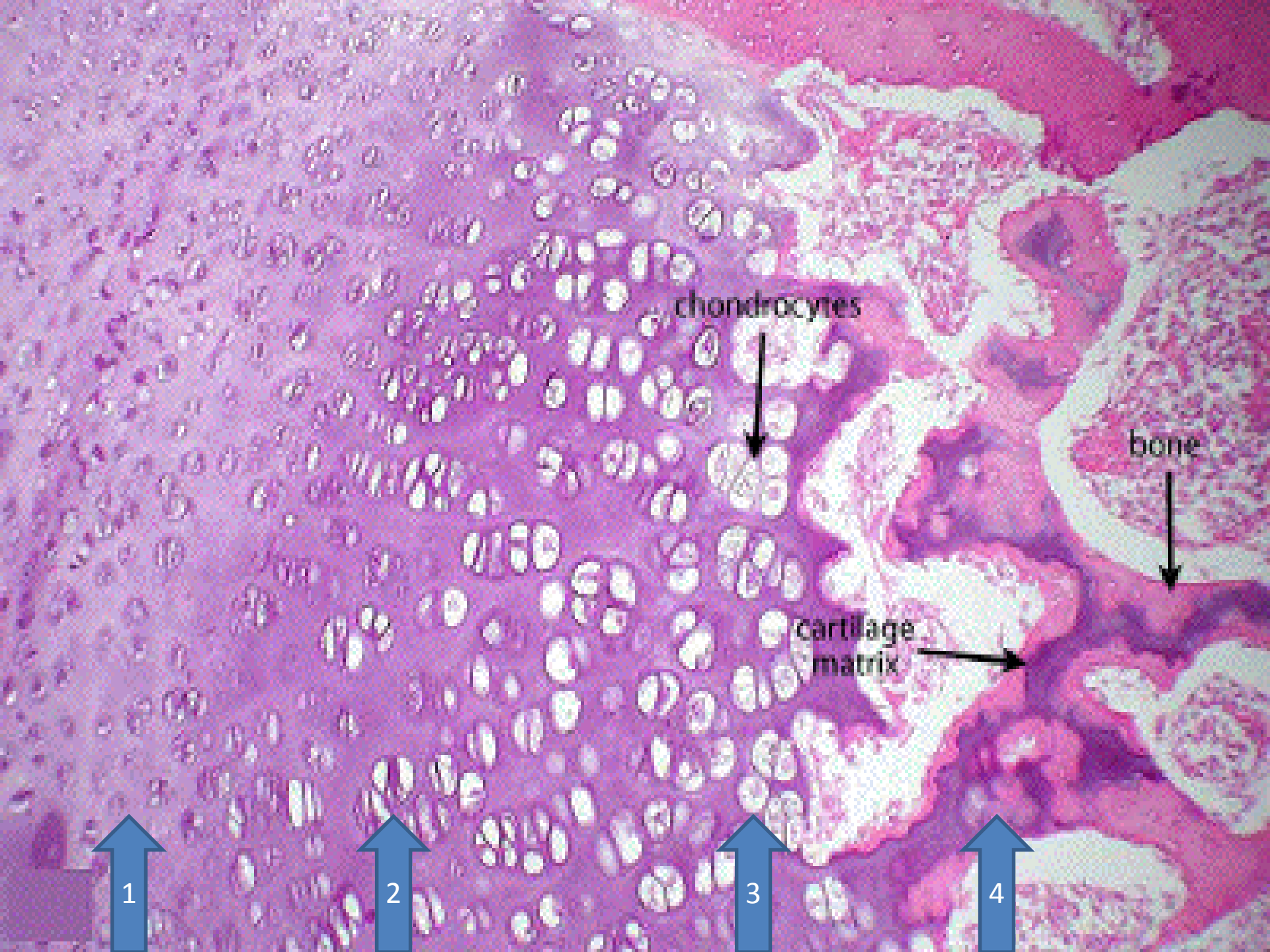
Cartilage at the head of the bone remains – this is the **articular cartilage (no perichondrium!)**

Secondary center of ossification

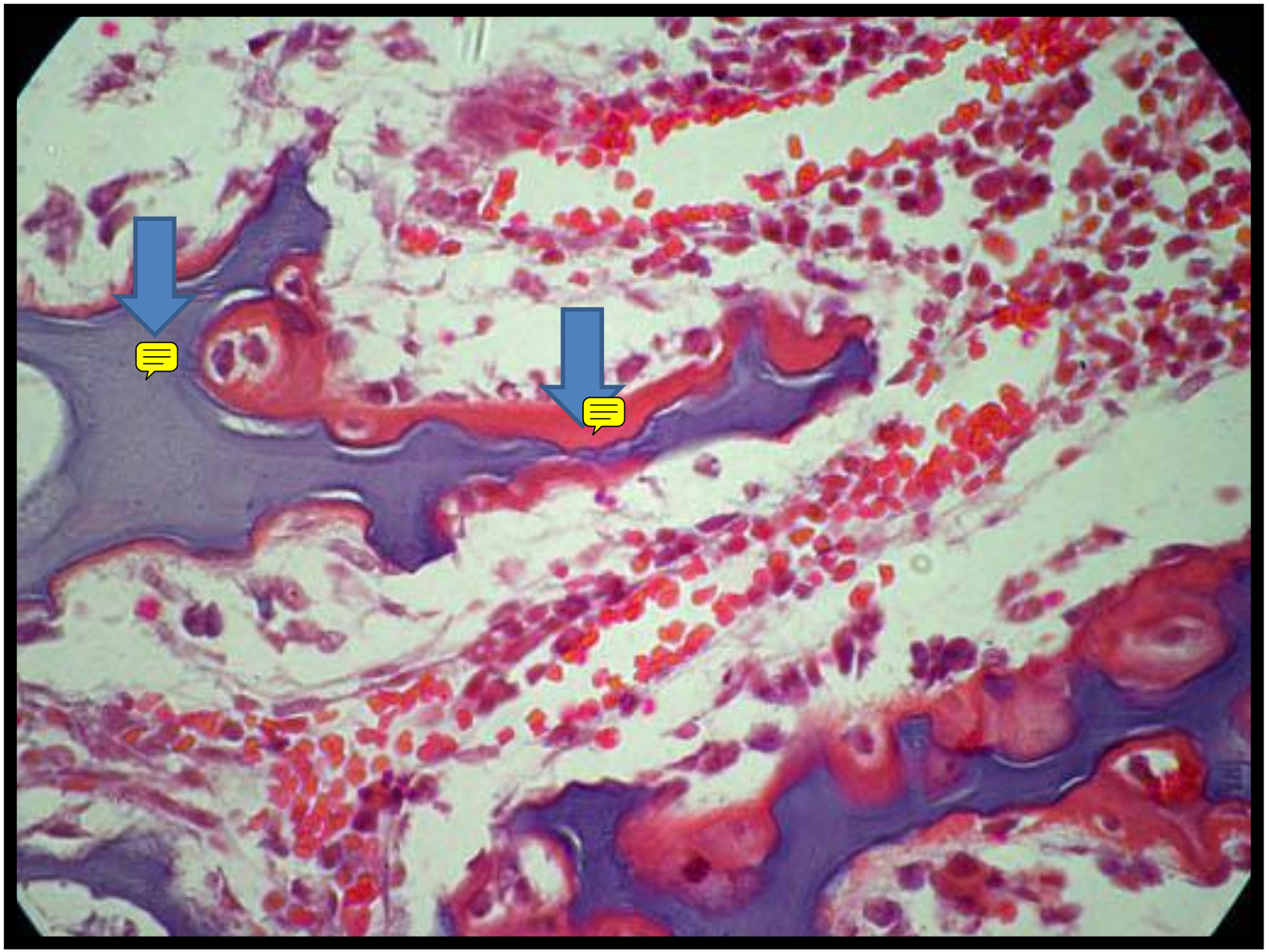



hypertrophied chondrocytes
bone
epiphysis
developing compact bone

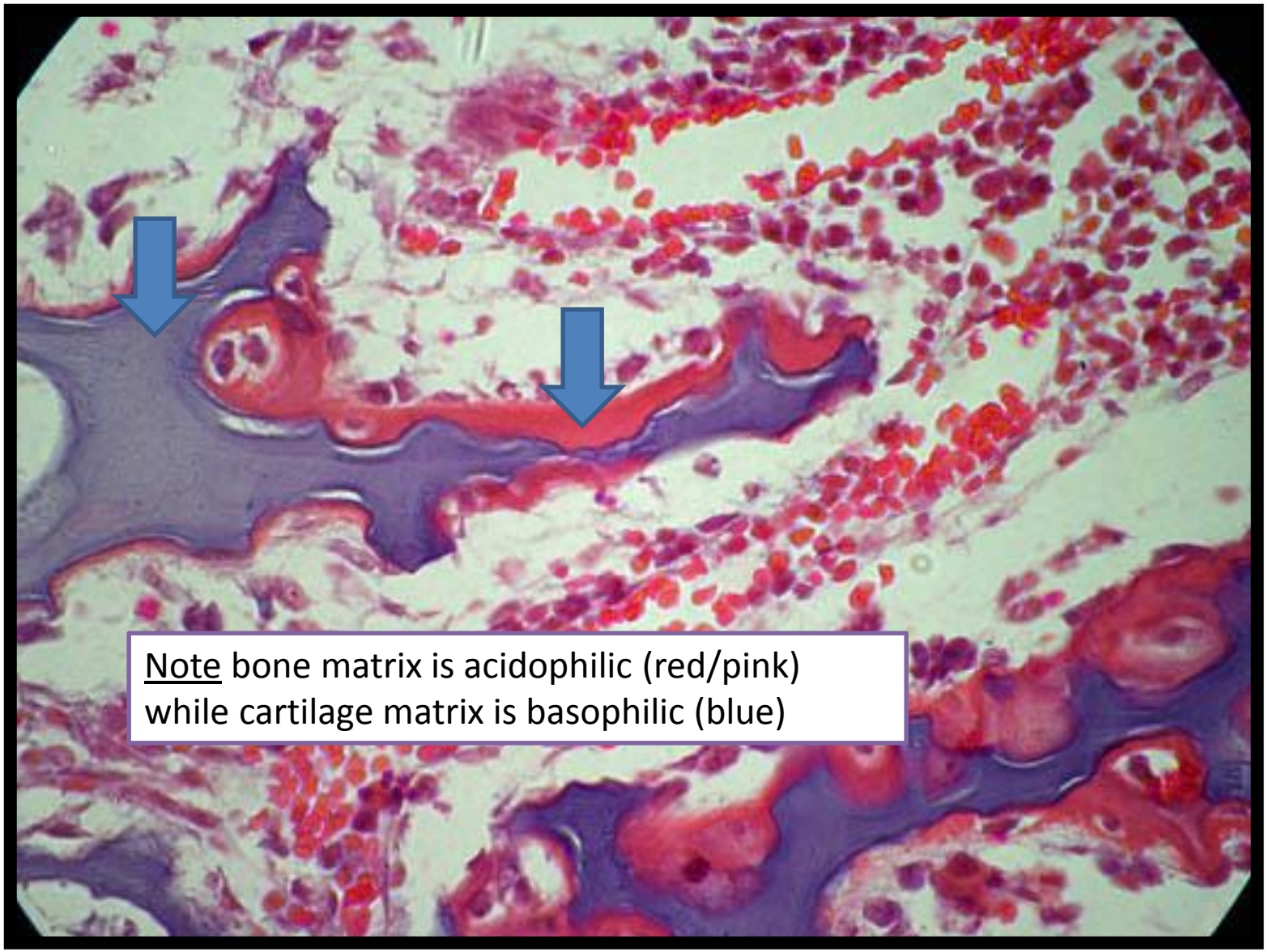

1
2
3
4
12.3X

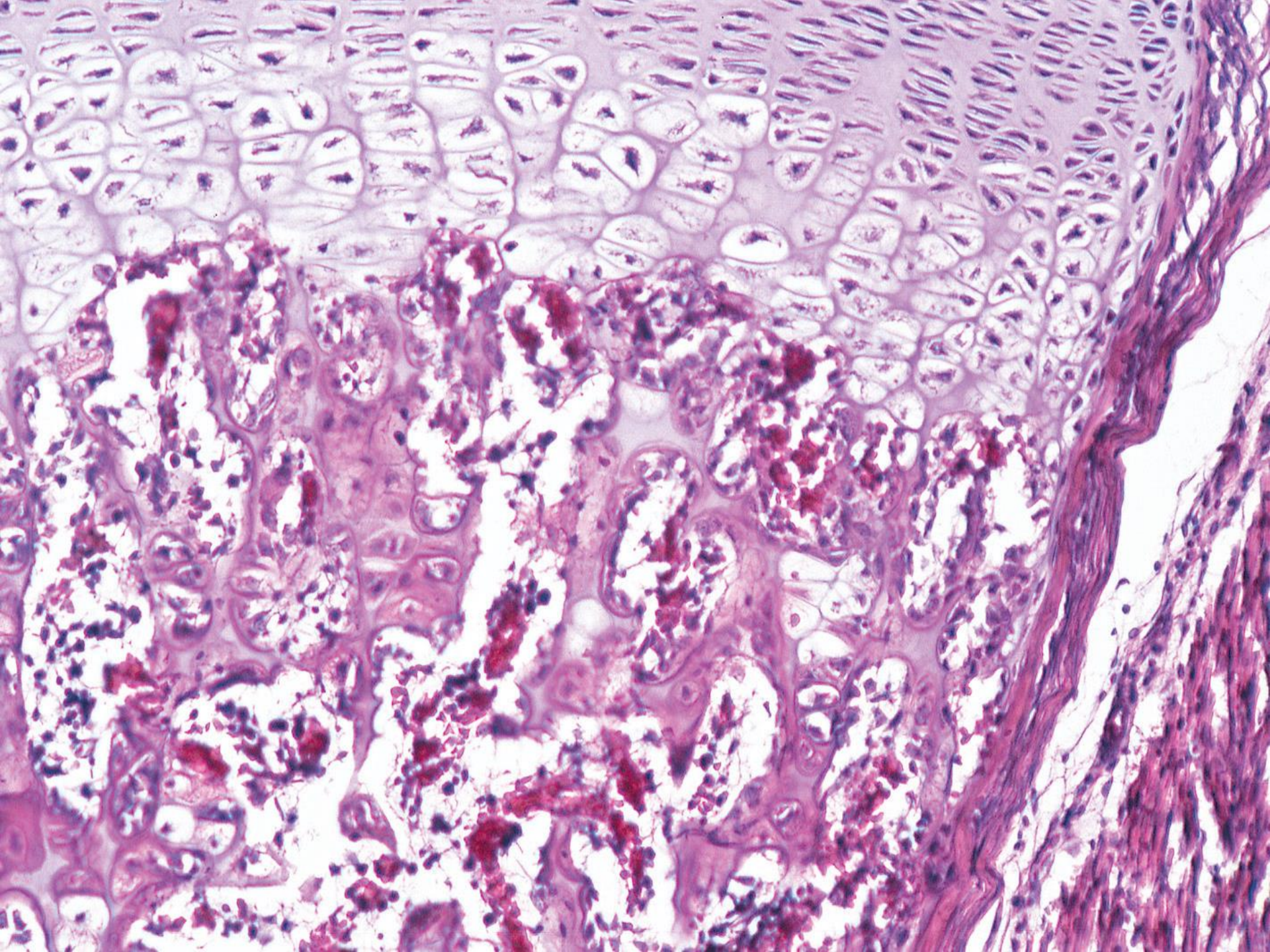

chondrocytes
bone
cartilage matrix
1
2
3
4

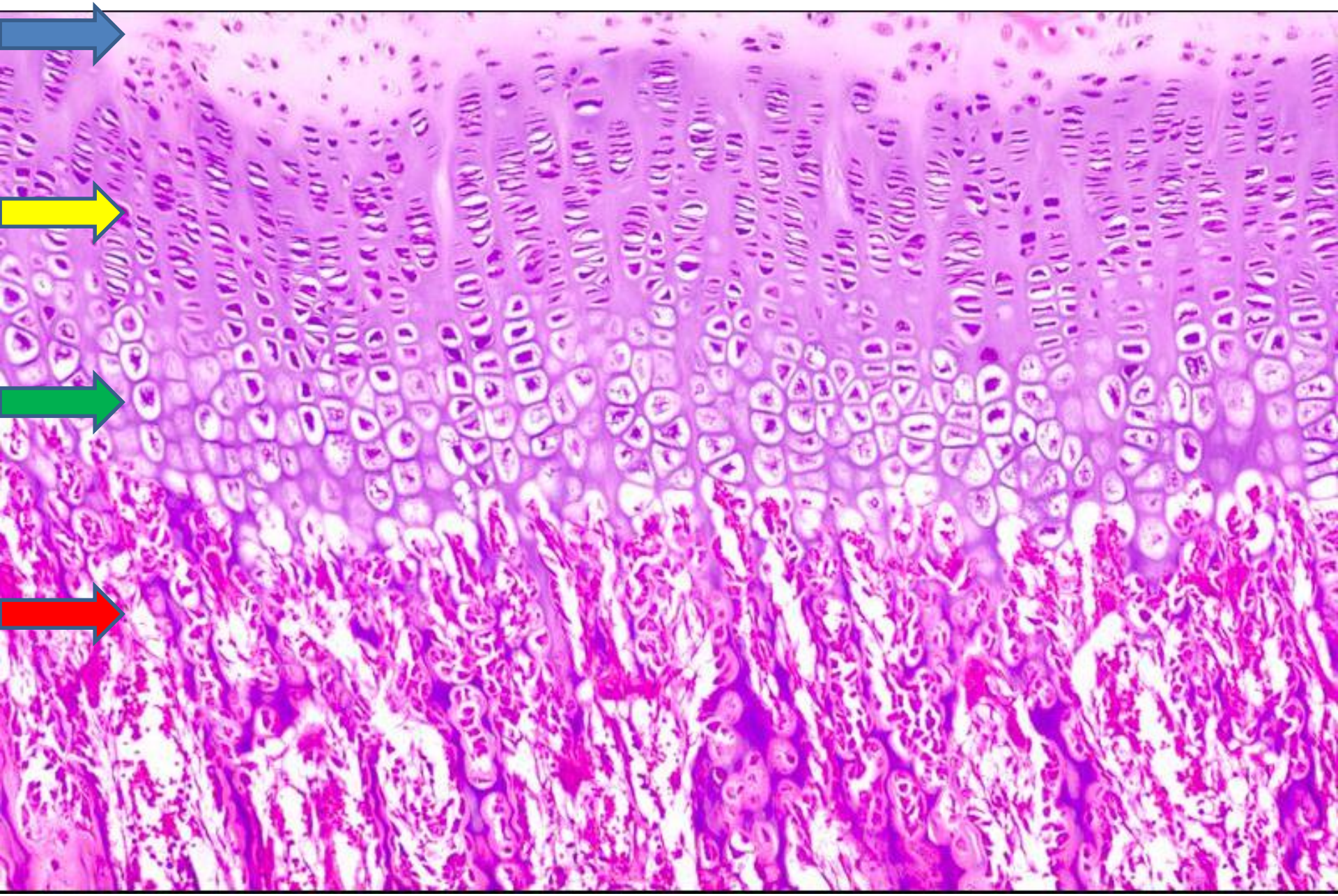
Ossification zone



Ossification zone



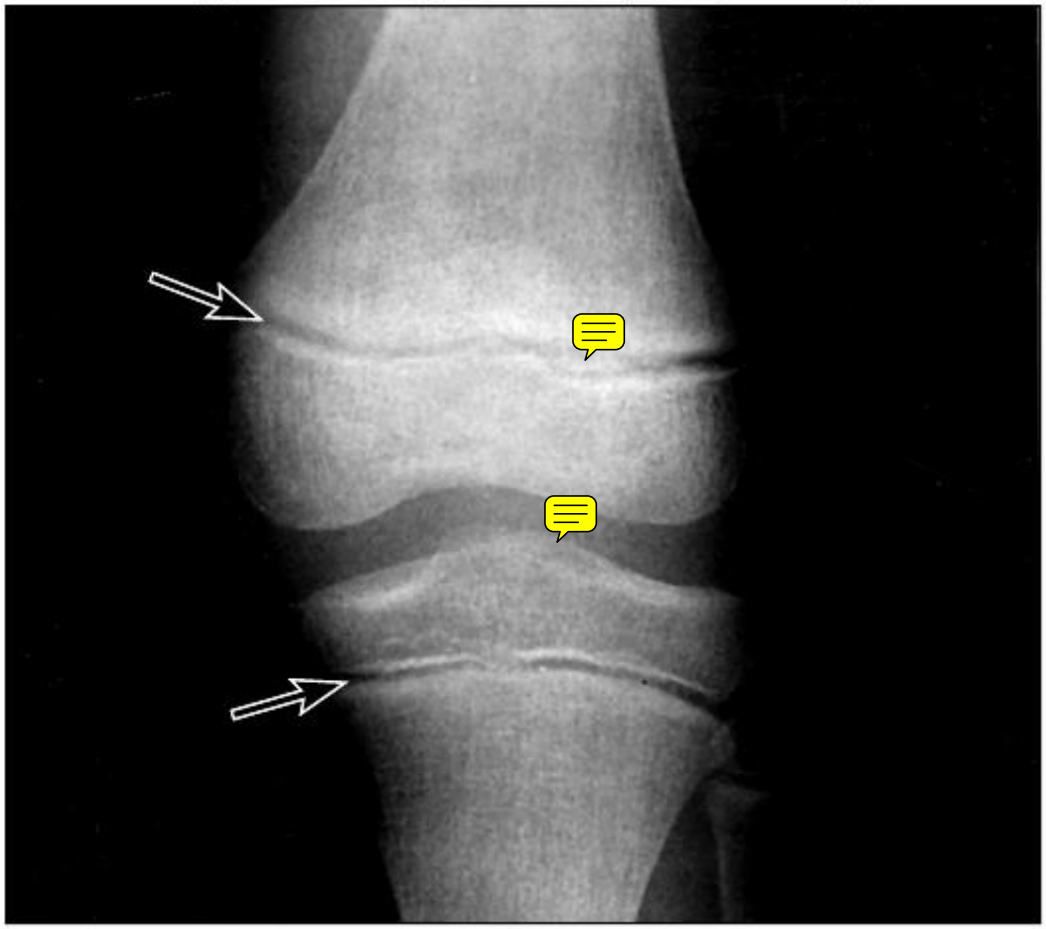




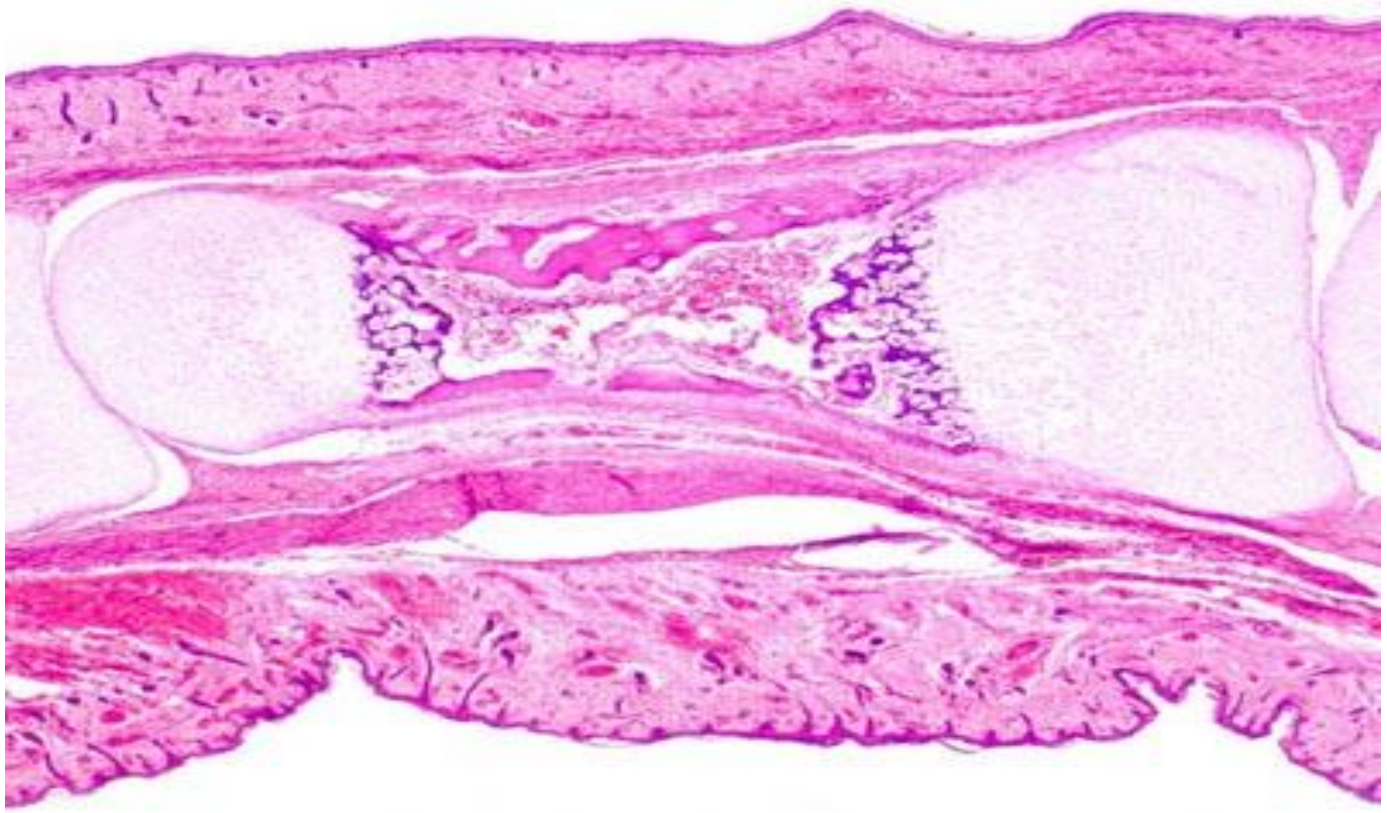
Hormonal Regulation of Bone Growth

- Growth hormone stimulates epiphyseal plate activity
- Thyroid hormone modulates activity of growth hormone
- Testosterone and estrogens (at puberty)
  - Promote adolescent growth spurts
  - End growth by inducing epiphyseal plate closure

Growth in the Epiphyseal Plate



What type of bone formation is taking place?



Clinical Application

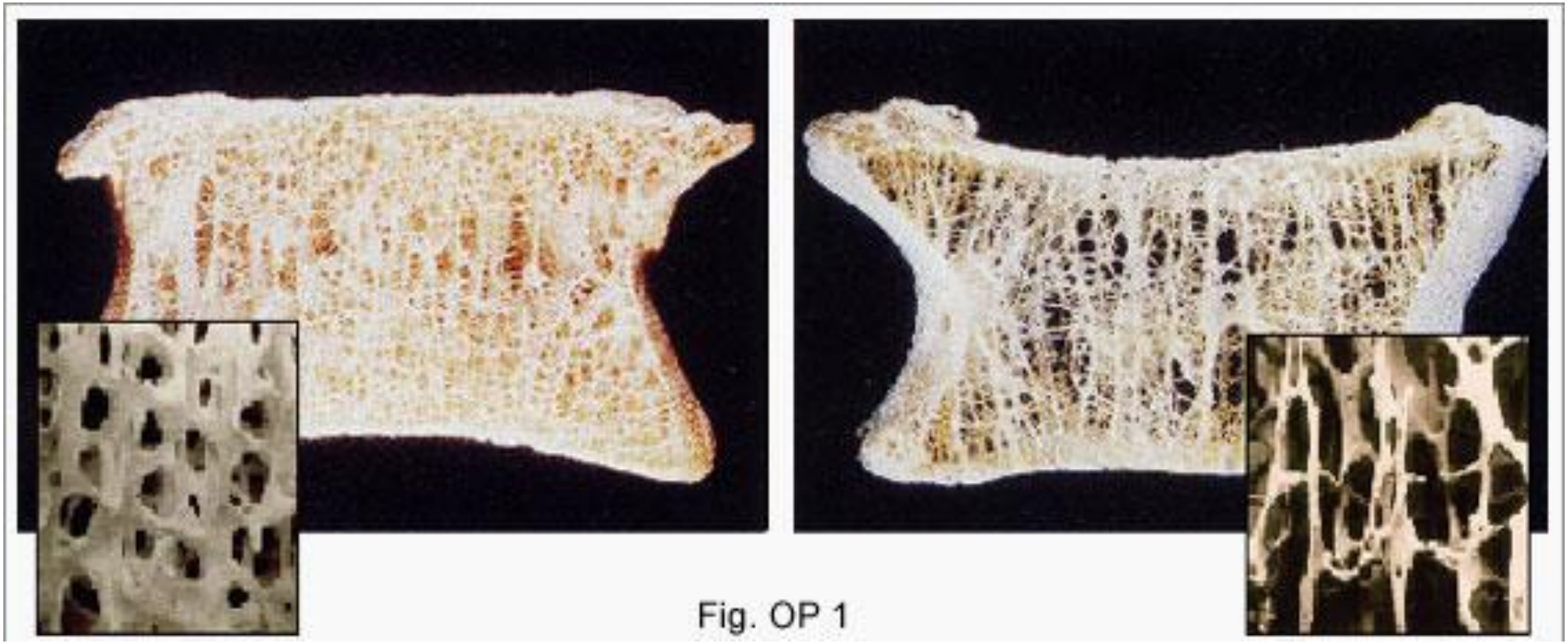


Fig. OP 1

Osteoporosis