Bone

Ossification

Bone ossification and callus formation

Objectives : Students must be able to identify:

.Types of ossifications and their cells .

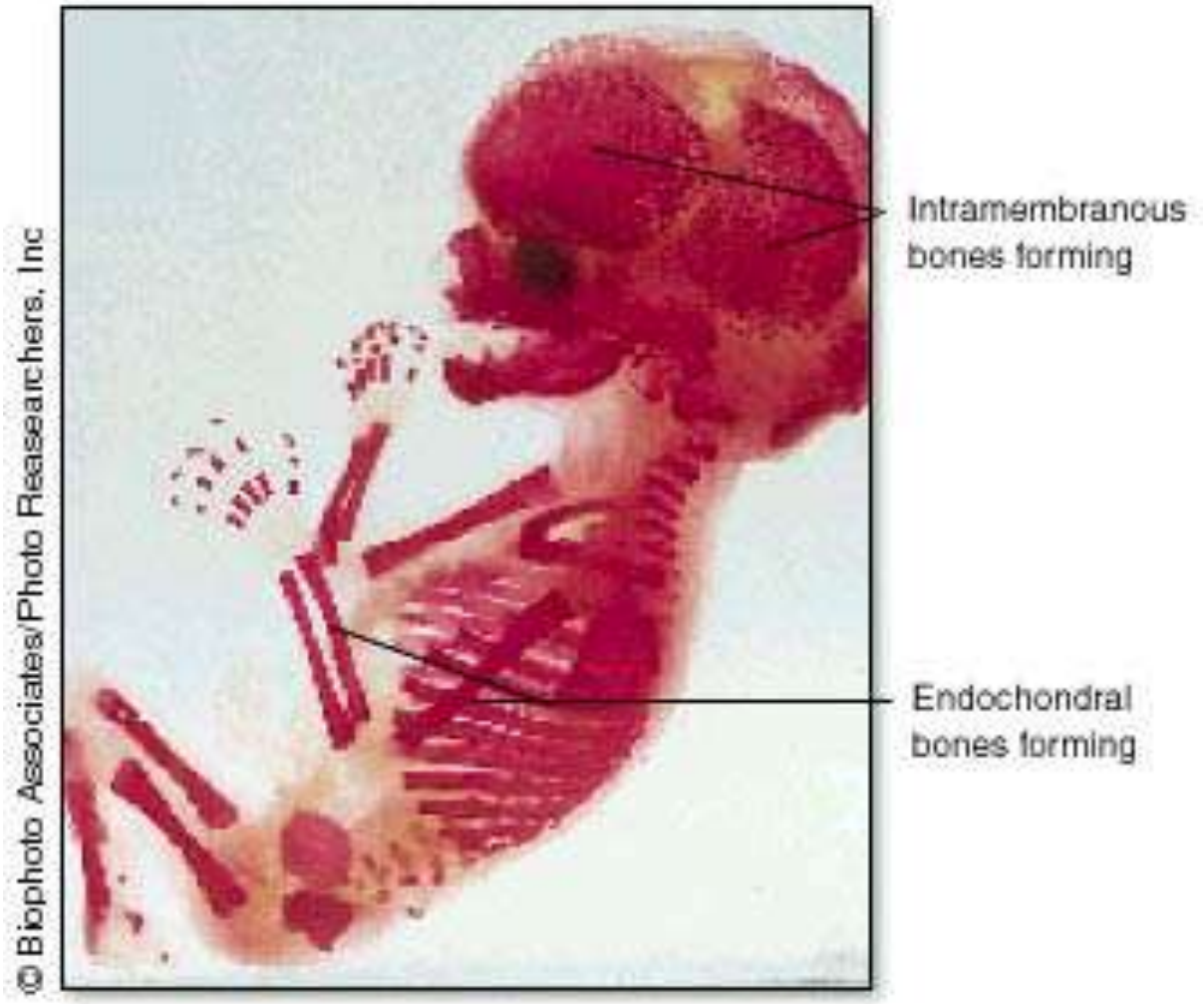
. Osteogenesis .

. Bone Fracture.

. callus formation (bone healing) .

. clinical disorders.

Ossification = Osteogenesis



Ossification = Osteogenesis

- Parts of the fetal skeleton form during the first few weeks after conception
- By the end of the 8th week, the skeletal pattern is formed : cartilage & connective tissue membranes

Bone Formation - Ossification

All embryonic CT begins as mesenchyme

- provides template for ossification

Two types of ossification:

Intramembranous ossification:

- bone forms directly from or within fibrous CT membranes

Endochondral ossification:

- bone forms from hyaline cartilage models

Intramembranous ossification

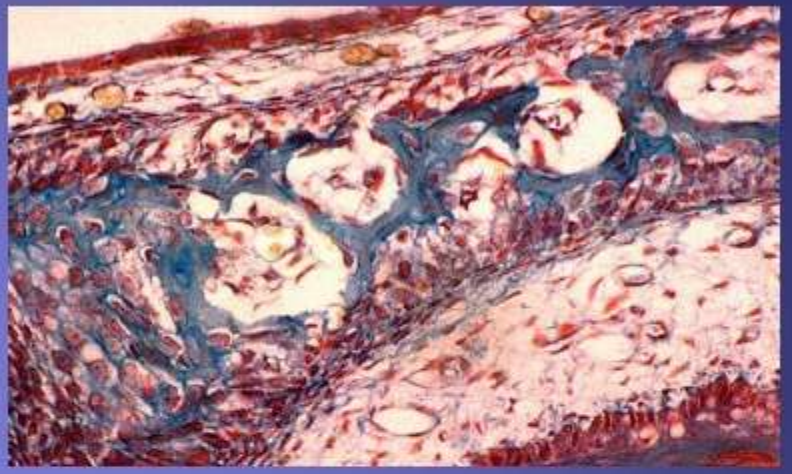
- Begins with osteoblast differentiation
- Dermal bones produced
- Begins at ossification center

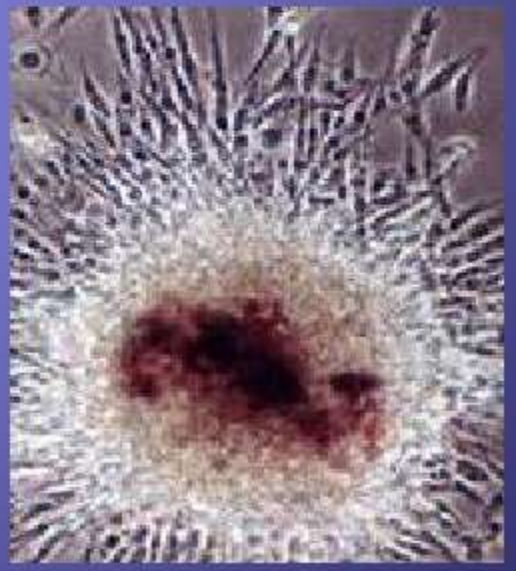
Intramembranous Ossification

Forms flat bones of skull & mandible

Ossification center: forms from mesenchyme that become osteoprogenitor cells

- change into osteoblasts that deposit matrix
- matrix surrounds osteoblasts that calcify to form osteocytes





Osteoblast depositing new bone matrix

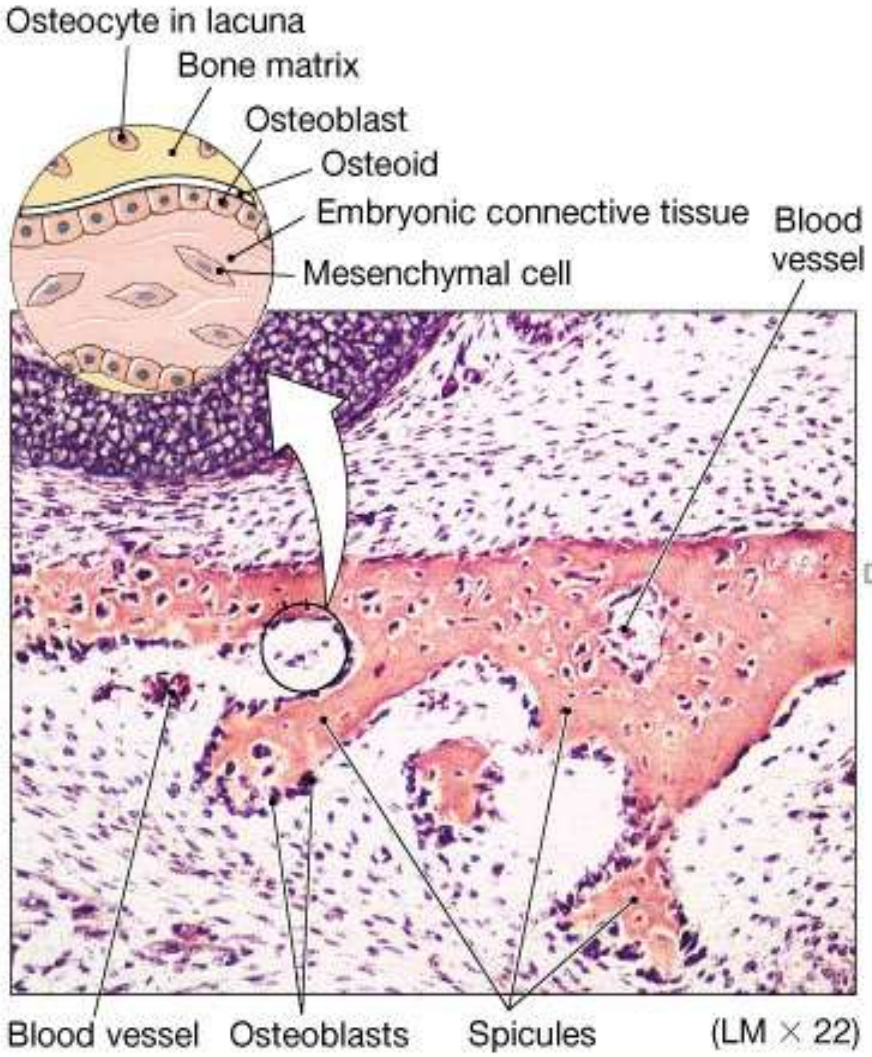
Intramembranous Ossification, cont.

Calcifying matrix centers join to form bridges of trabeculae, becoming spongy bone with red marrow

Mesenchyme on the bone surface condenses into periosteum

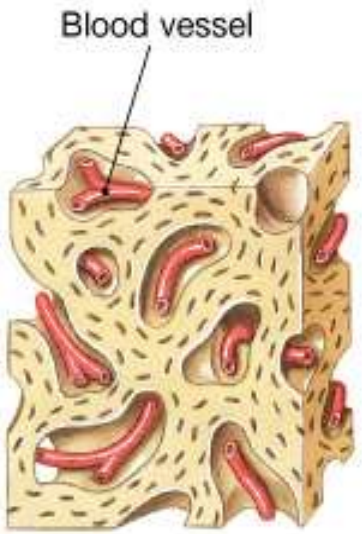
Compact bone replaces superficial layers of spongy bone

Intramembranous Ossification



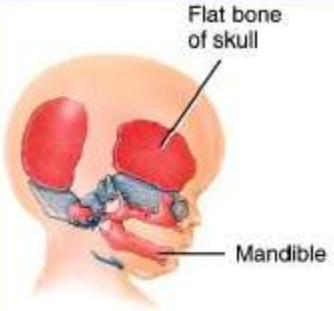
STEP 1:
Mesenchymal cells aggregate, differentiate, and begin the ossification process. The bone expands as a series of spicules that spread into surrounding tissues.

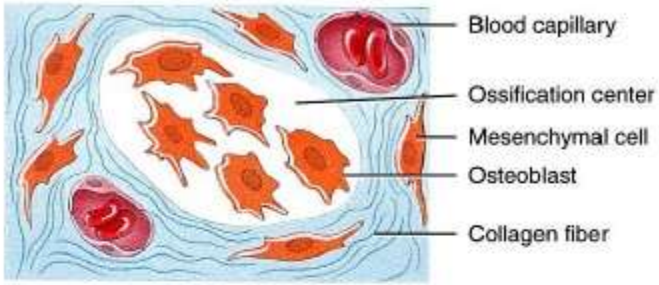
STEP 2:
As the spicules interconnect, they trap blood vessels within the bone.



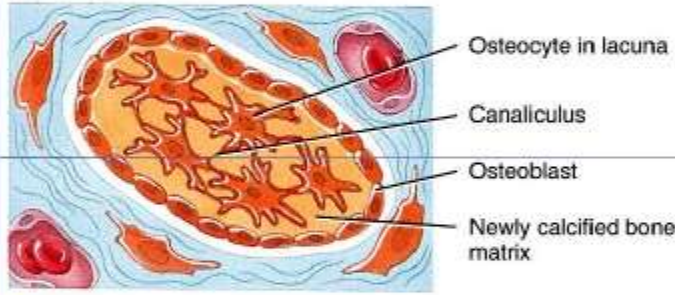
STEP 3:
Over time, the bone assumes the structure of spongy bone. Areas of spongy bone may later be removed, creating marrow cavities. Through remodel-ing, spongy bone formed in this way can be converted to compact bone.

Intramembranous Ossification

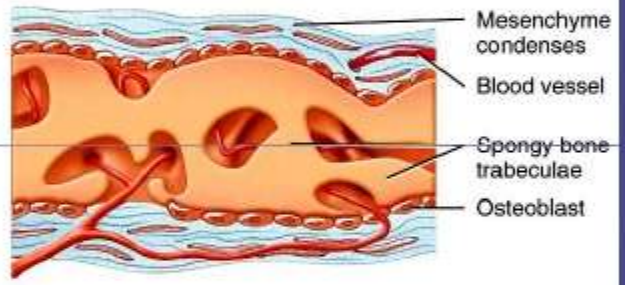




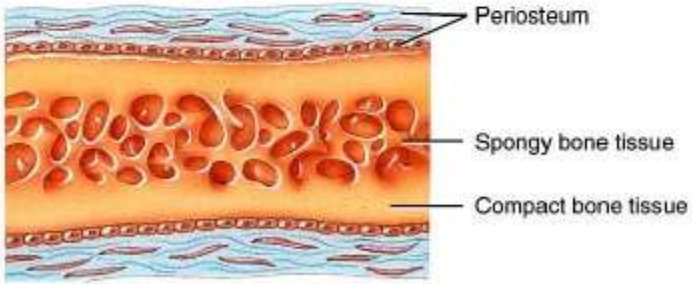
1 Development of ossification center



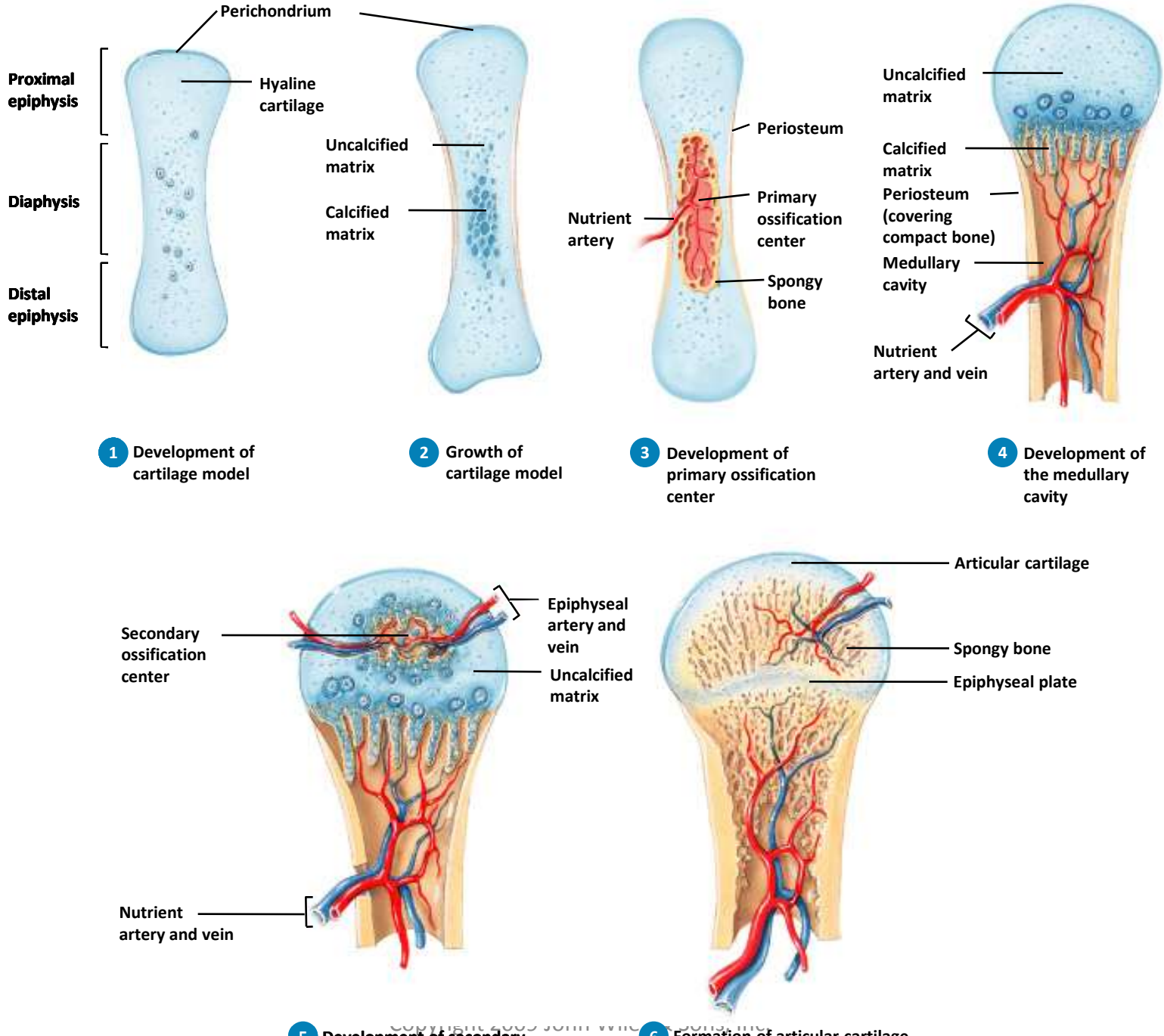
2 Calcification



3 Formation of trabeculae



4 Development of the periosteum



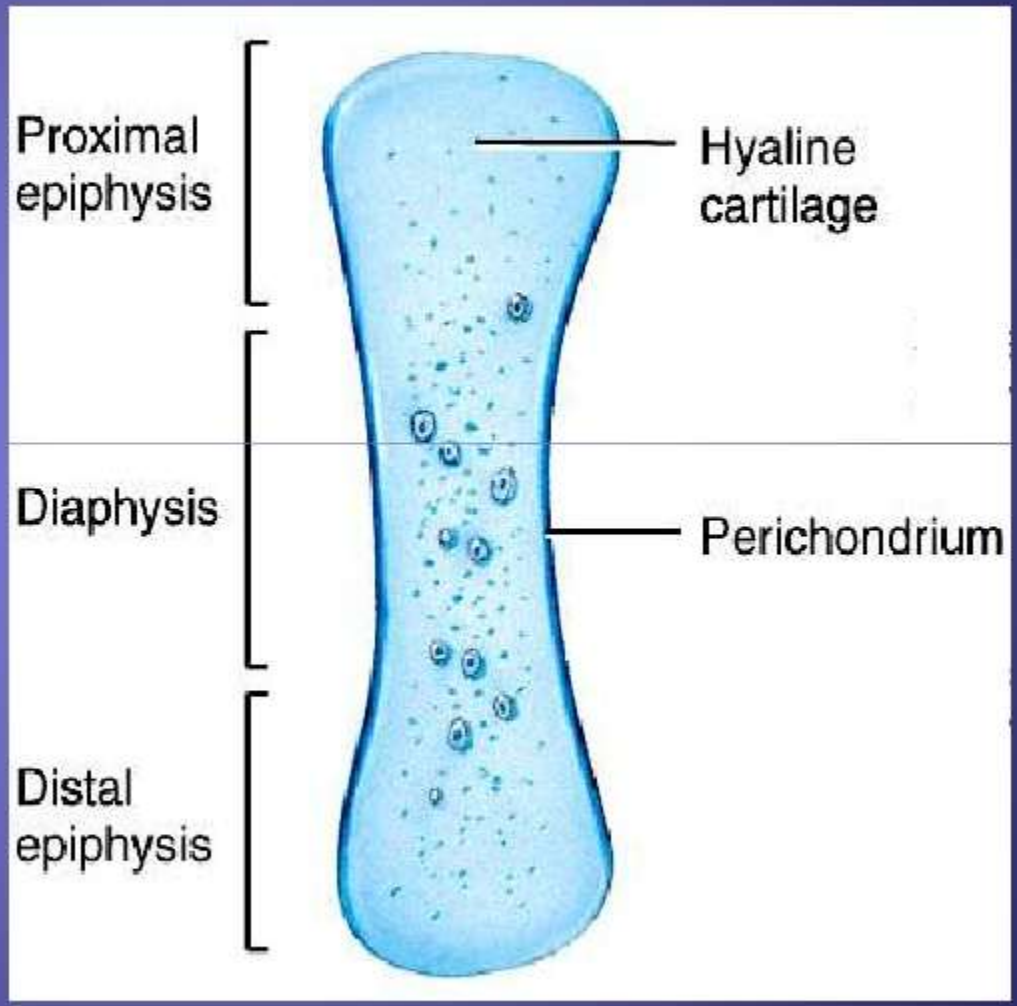
Endochondral ossification

- Cartilage model gradually replaced by bone
  - Increasing bone length
- Growth occurs by interstitial & Appositional
- Appositional growth increases bone diameter
- Stages of 0ssification are:
- 1. proliferation
- 2. hypertrophy
- 3. calcified zone
- 4. chondrocyte die
- 5. ossification zone epiphyseal plate : connect the two epiphyses and diephysis and responsible for the growth in length of the bone


Endochondral Ossification
Long bone
100 um

1. Development of Cartilage Model

Mesenchyme forms cartilage model of bone during development



Growth of the cartilage template

- Two mechanisms:
- Appositional growth -------→ by chondroblasts new cartilage is added on the surface by recruiting chondroblasts from the inner layer of the perichondrium
- Interstitial growth -------→ by chondrocytes

new cartilage is formed within the cartilaginous template by chondrocytes dividing and producing additional matrix

2. Growth of Cartilage Model

Chondrocytes divide and matrix forms

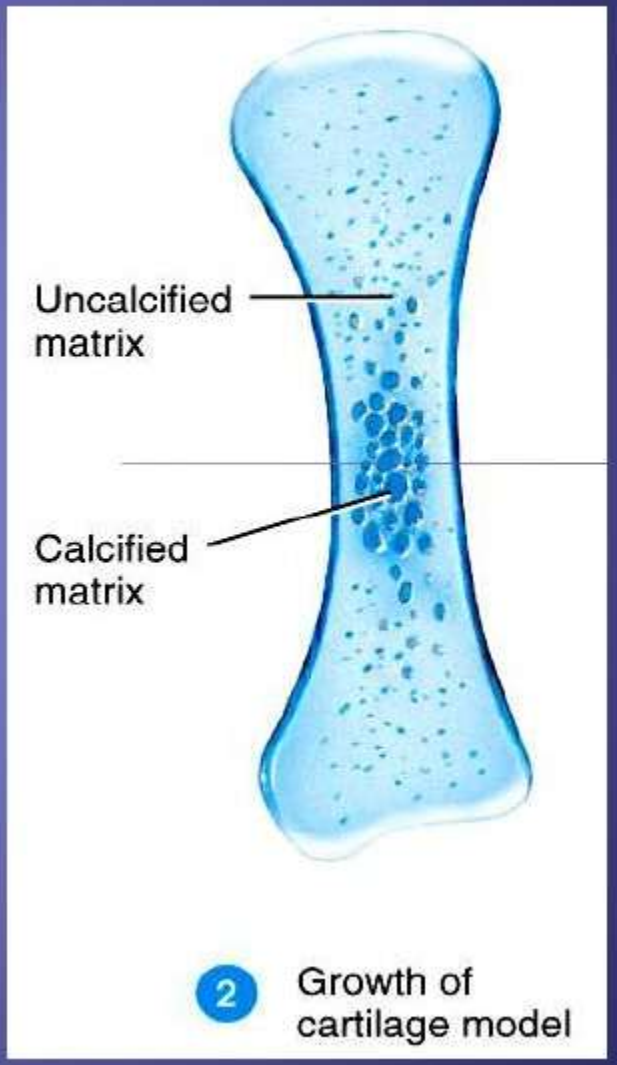
- **Interstitial growth**: in length

New matrix forms on periphery by perichondrium

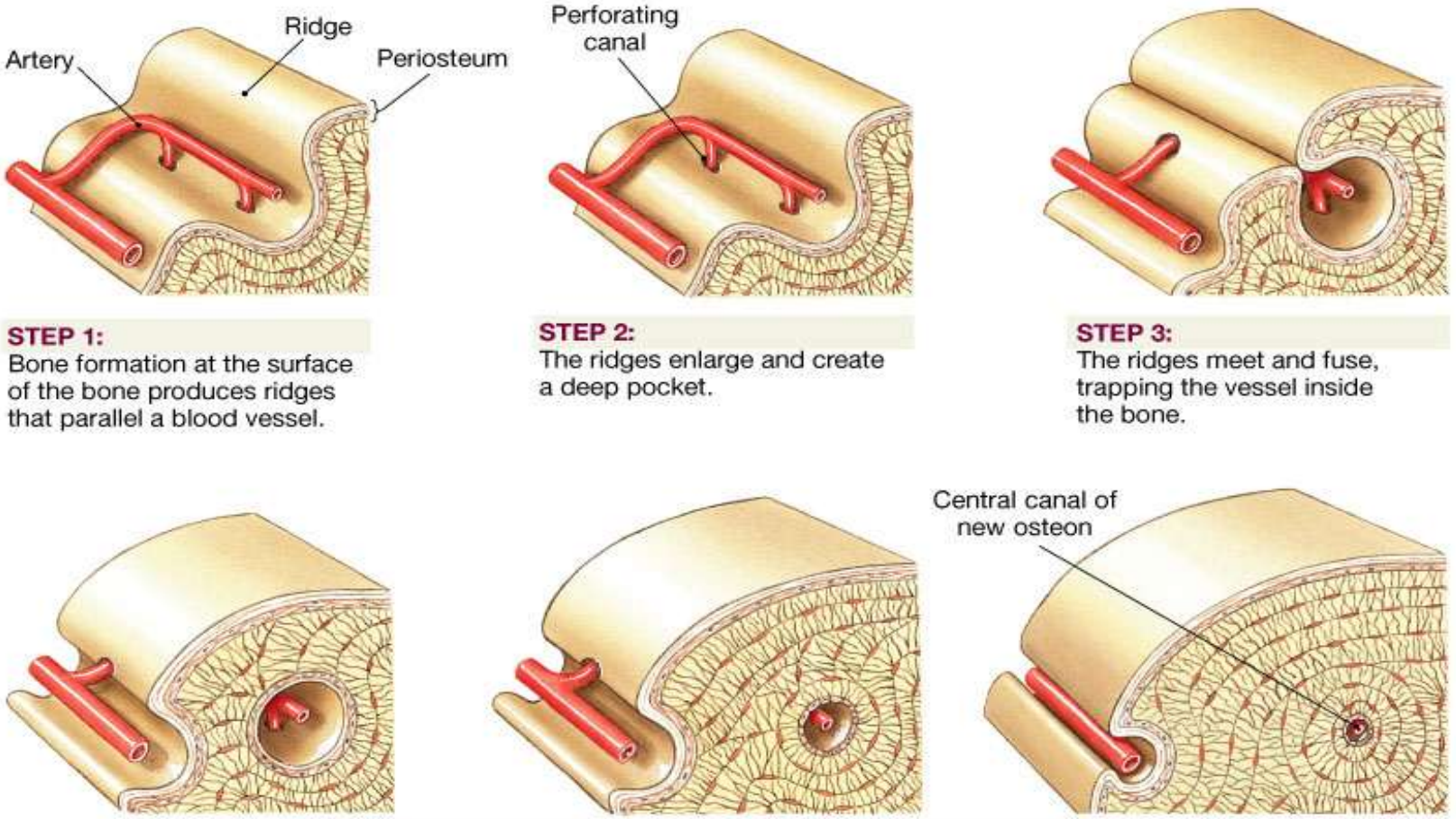
- **Appositional growth**: in width

Cells in mid-region burst & lower pH

- triggers calcification
- destroys chondrocytes



Appositional Bone Growth



STEP 1:
Bone formation at the surface of the bone produces ridges that parallel a blood vessel.

STEP 2:
The ridges enlarge and create a deep pocket.

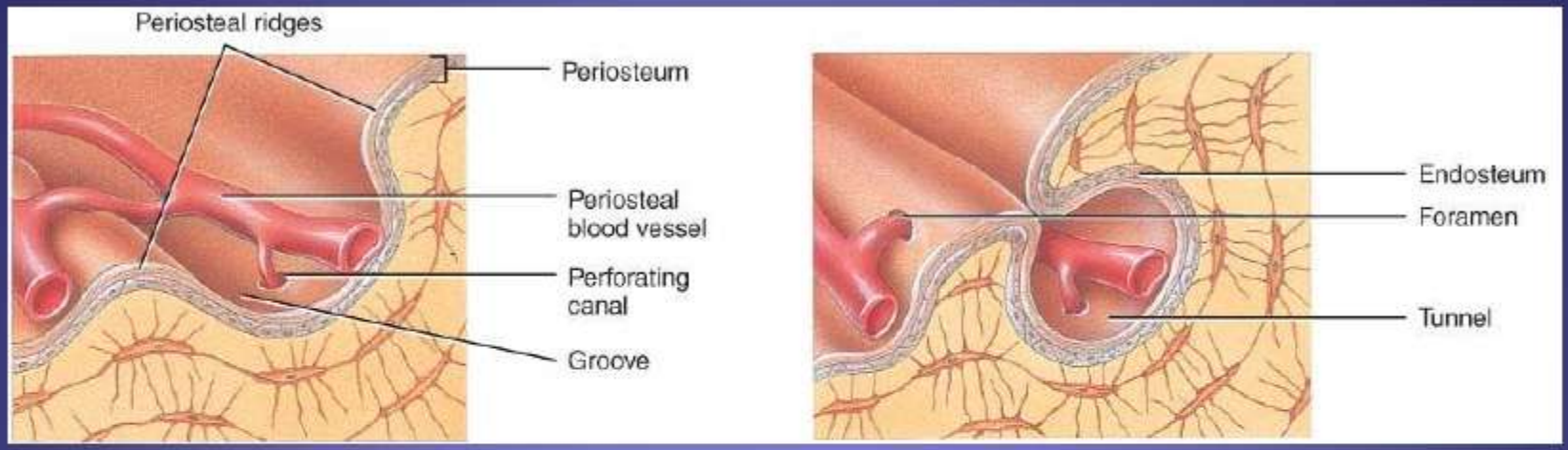
STEP 3:
The ridges meet and fuse, trapping the vessel inside the bone.

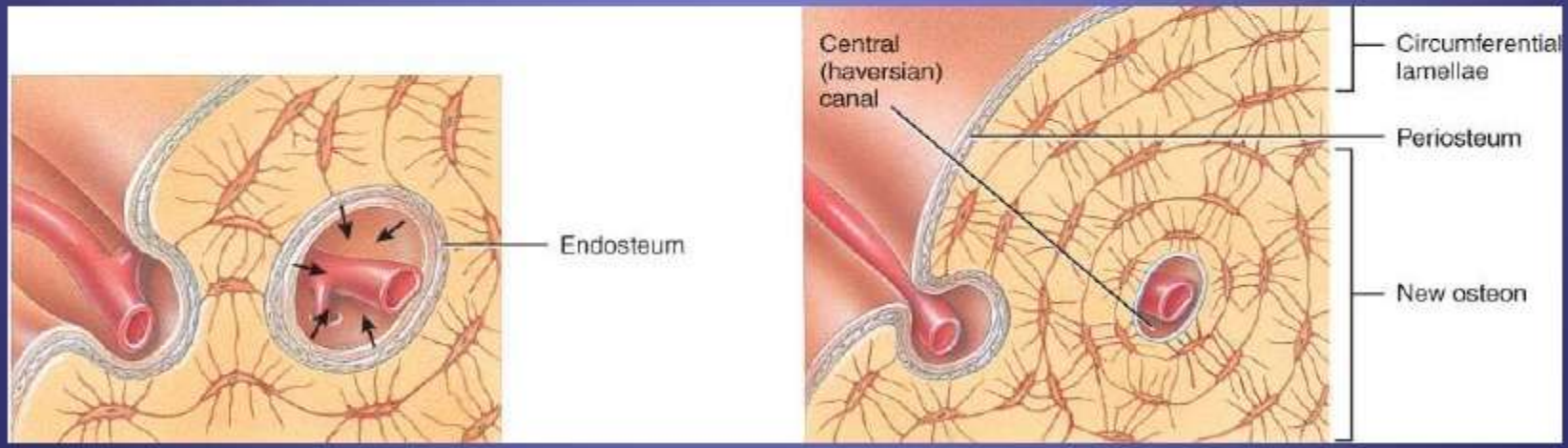
STEPS 4–6:
Bone deposition then proceeds inward toward the vessel, creating a typical osteon. Meanwhile, additional circumferential lamellae are deposited and the bone continues to increase in diameter. As it does, additional blood vessels will be enclosed.

(a) Steps in appositional bone growth

Figure 6.10a

Appositional Growth





Appositional Bone Growth animation

Appositional Bone Growth

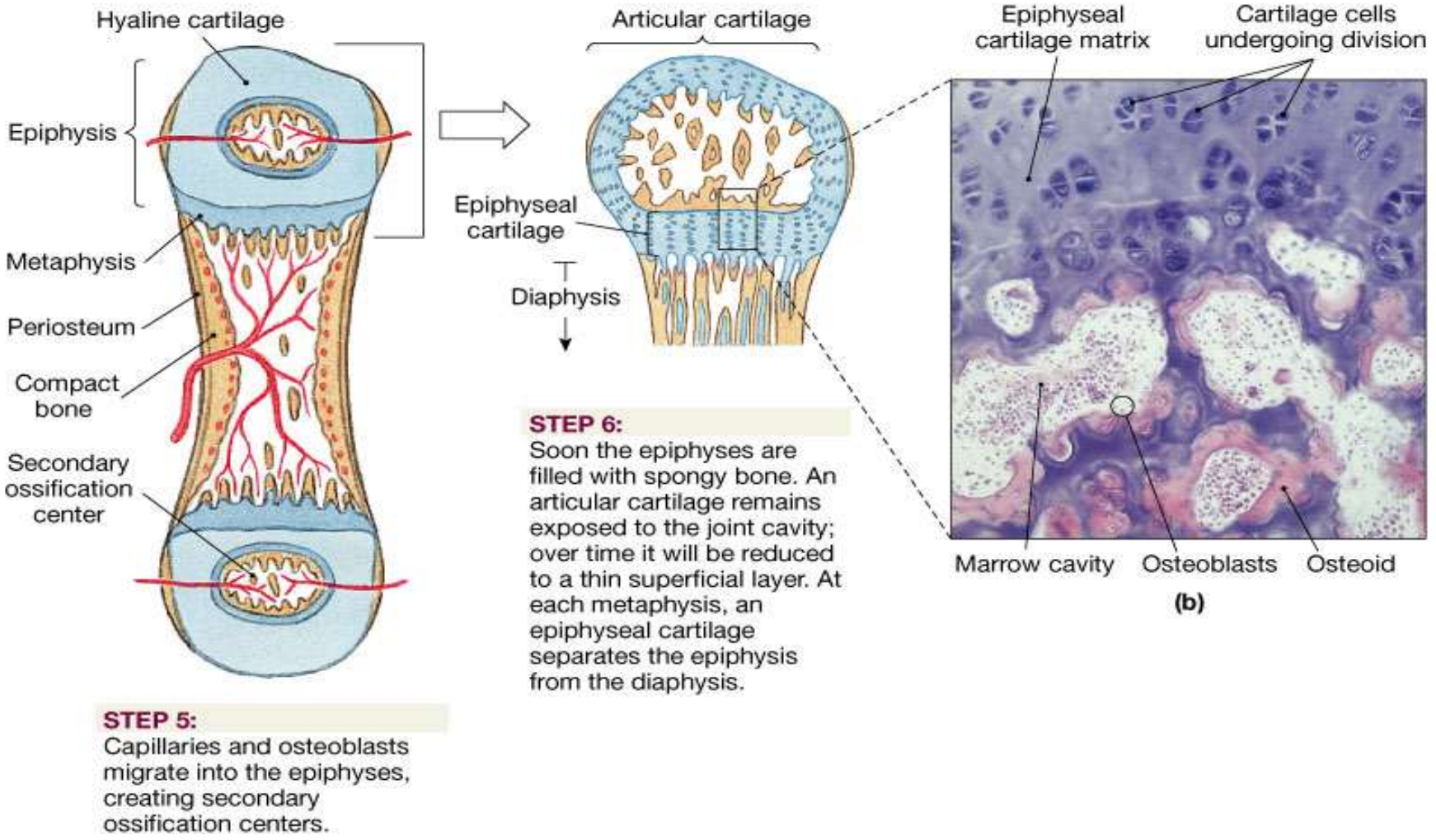


Figure 6.10b

Interstitial Growth

4 Zones of Epiphyseal Plate:

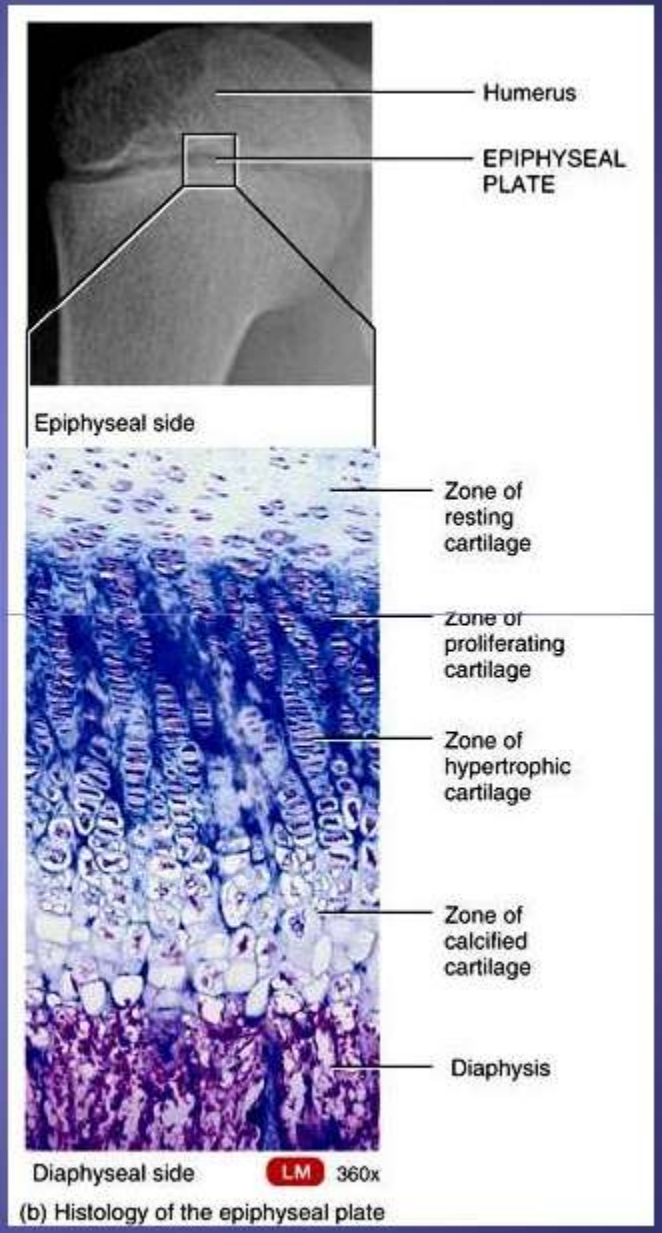
- Zone of resting cartilage
- Zone of proliferating cartilage
- Zone of hypertrophic cartilage
- Zone of calcified cartilage

Chondrocytes are produced by mitosis on the epiphyseal side of plate

Will be replaced by bone on the diaphyseal side of plate

Plate closes between ages 18-25

- chondrocytes stop dividing
- bone replaces cartilage (epiphyseal line)



(b) Histology of the epiphyseal plate

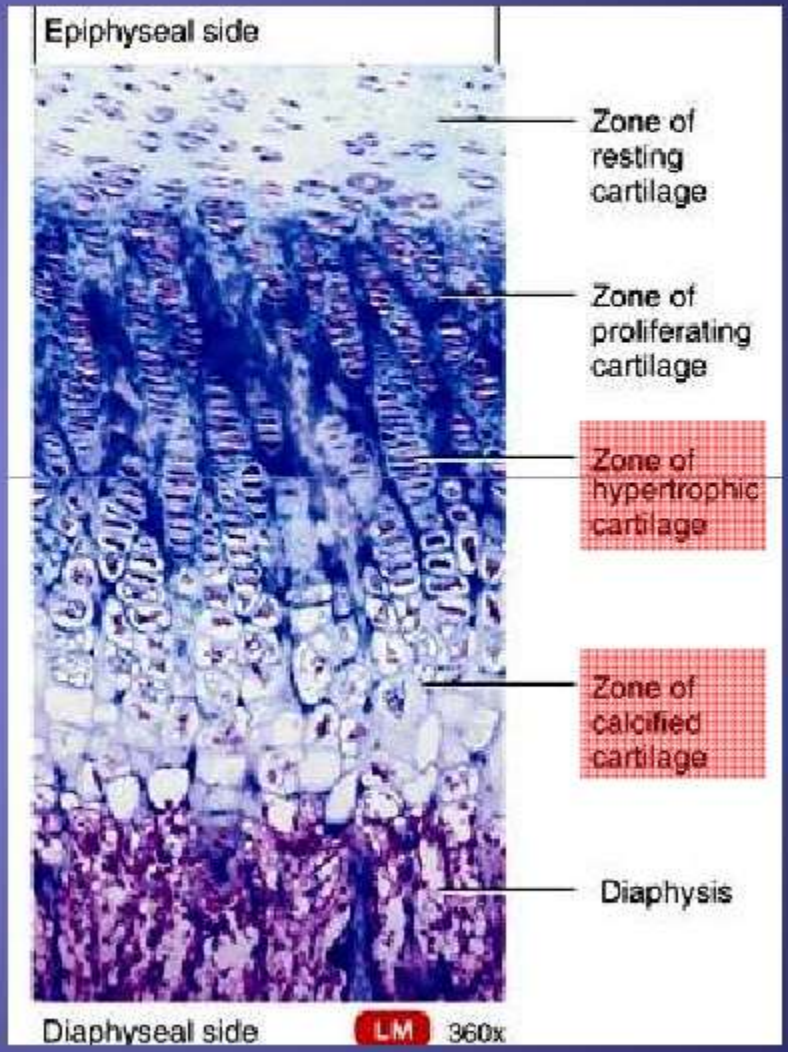
Zones of Growth, cont.

Zone of hypertrophic cartilage

- cells enlarge & remain in columns

Zone of calcified cartilage

- thin zone of mostly dead cells
- osteoclasts remove matrix
- osteoblasts & capillaries build bone over calcified cartilage



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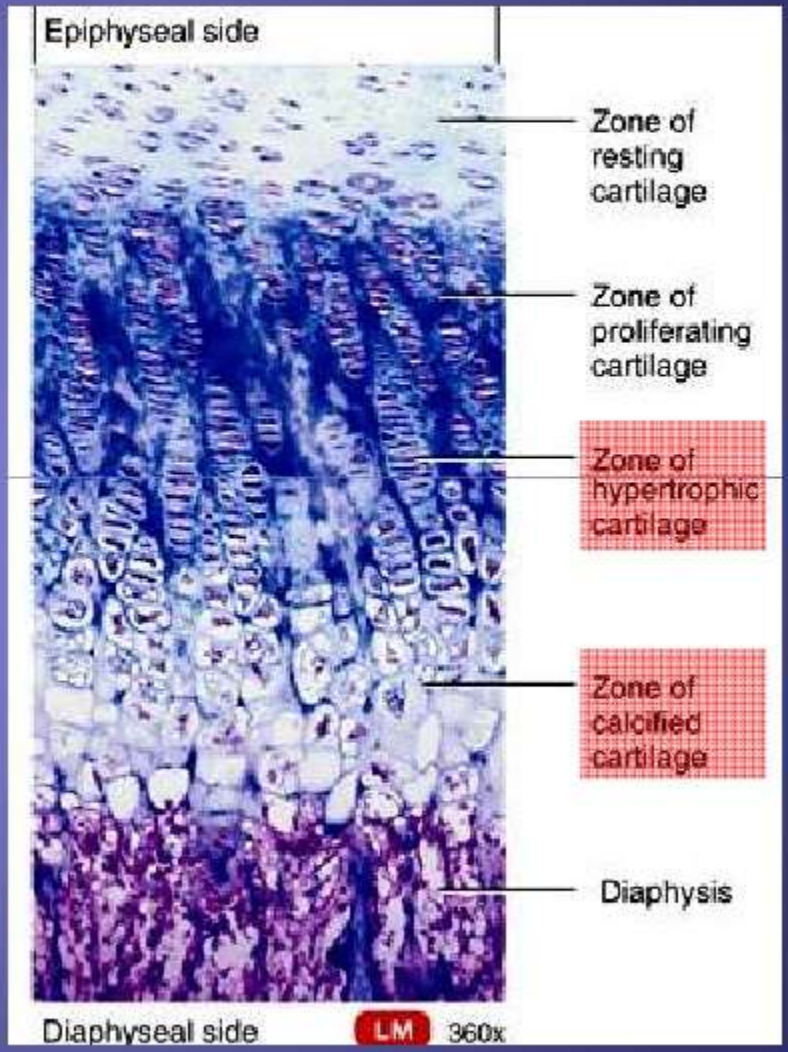


- oseopetrosis : a disease caused by a defect in osteoclast function that results in overgrowth , thickening , and hardening of bones.
- Obesity imposes significant strain on the articular cartilage , accelerating its degeneration , joint problems are far more frequent in obesity individuals.
- Chondroplastic dwarfism : results from the chondrocytes in multiplication and hypertrophy zones fail to multiply, the long bone grow slowly and stop growing early

Bone Fracture

- There are three processes involved in the healing of fractures - inflammatory, reparative and remodelling phases or 6 stages - the hematoma stage, inflammatory stage, formation of granulation tissue, soft and 'hard' callus formation, and remodelling.
- Their duration depends on age, health and nutritional status.
- Hematoma Stage: Hemorrhage, clot formation - within hours to days.
- Inflammatory Stage: Begins within 48 hours, inflammatory cells appear.

Organization and resorption of

- Granulation Tissue: From 2 days. Presence of - 12 mesenchymal cells, fibroblasts, new capillaries.
- Soft Callus: One week to several months. Callus grows and bridges the fracture site; cartilage and trabecular bone laid down.
- Hard Callus: One week to several months. When callus has sealed the bone ends. Trabecular bone.
- Remodelling: Continues for several months. Reorganization of bon.

Stages in the Healing of a Bone Fracture

- Hematoma formation
  - Torn blood vessels hemorrhage
  - A mass of clotted blood (hematoma) forms at the fracture site
  - Site becomes swollen, painful, and inflamed

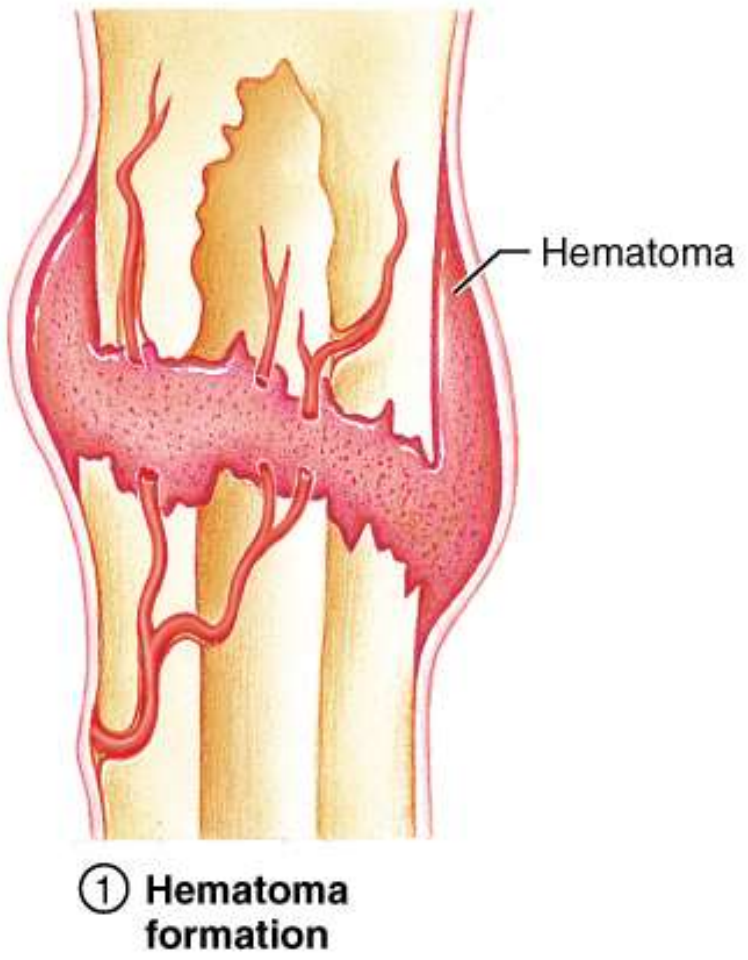
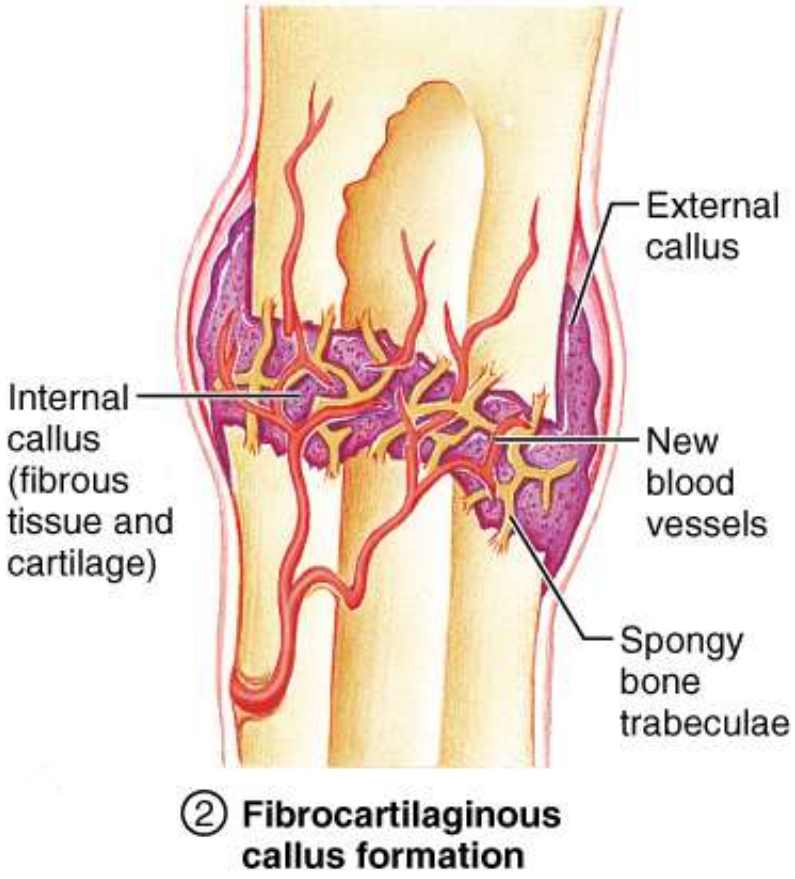


Figure 6.13.1

Stages in the Healing of a Bone Fracture

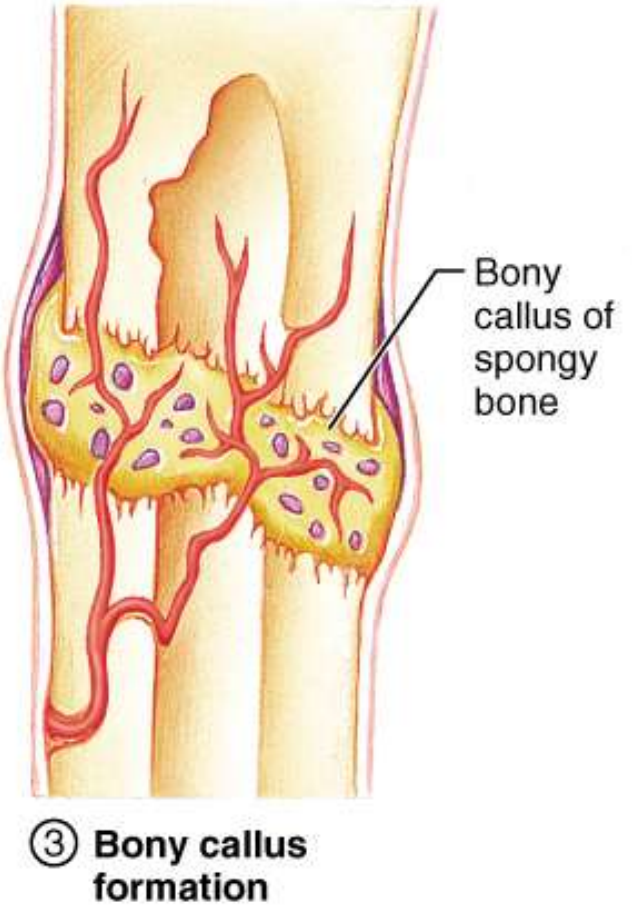
Fibrocartilaginous callus formsGranulation tissue (soft callus) forms a few days after the fracture
- Capillaries grow into the tissue and phagocytic cells begin cleaning debris



Stages in the Healing of a Bone Fracture

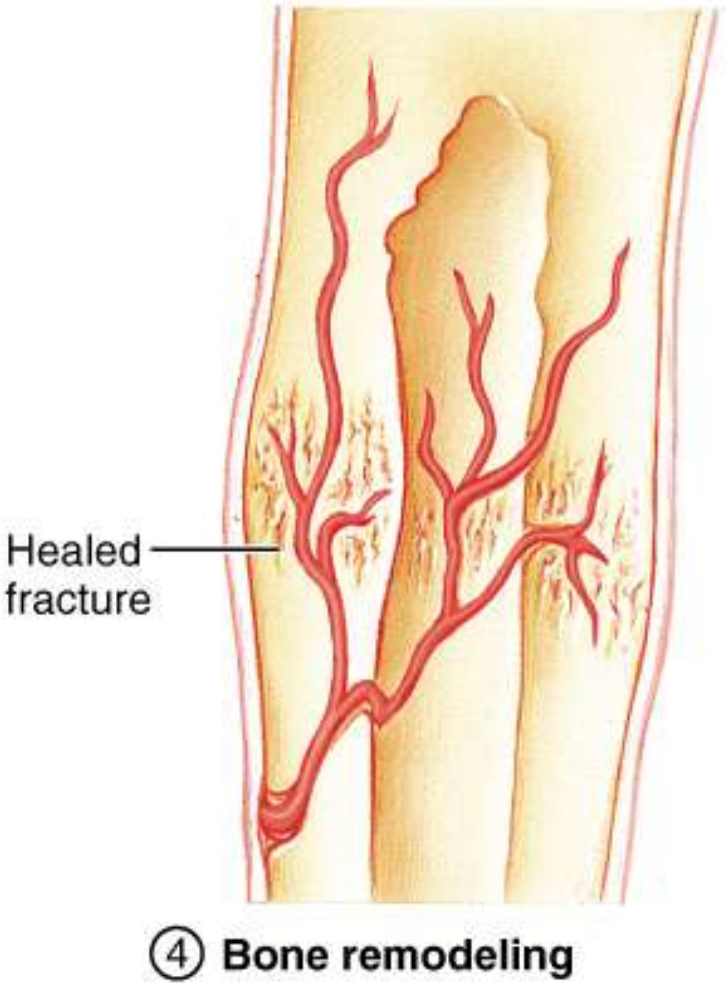
. Bony callus formation

- New bone trabeculae appear in the fibrocartilaginous callus
- Fibrocartilaginous callus converts into a bony (hard) callus
- Bone callus begins 3-4 weeks after injury, and continues until firm union is formed 2-3 months later

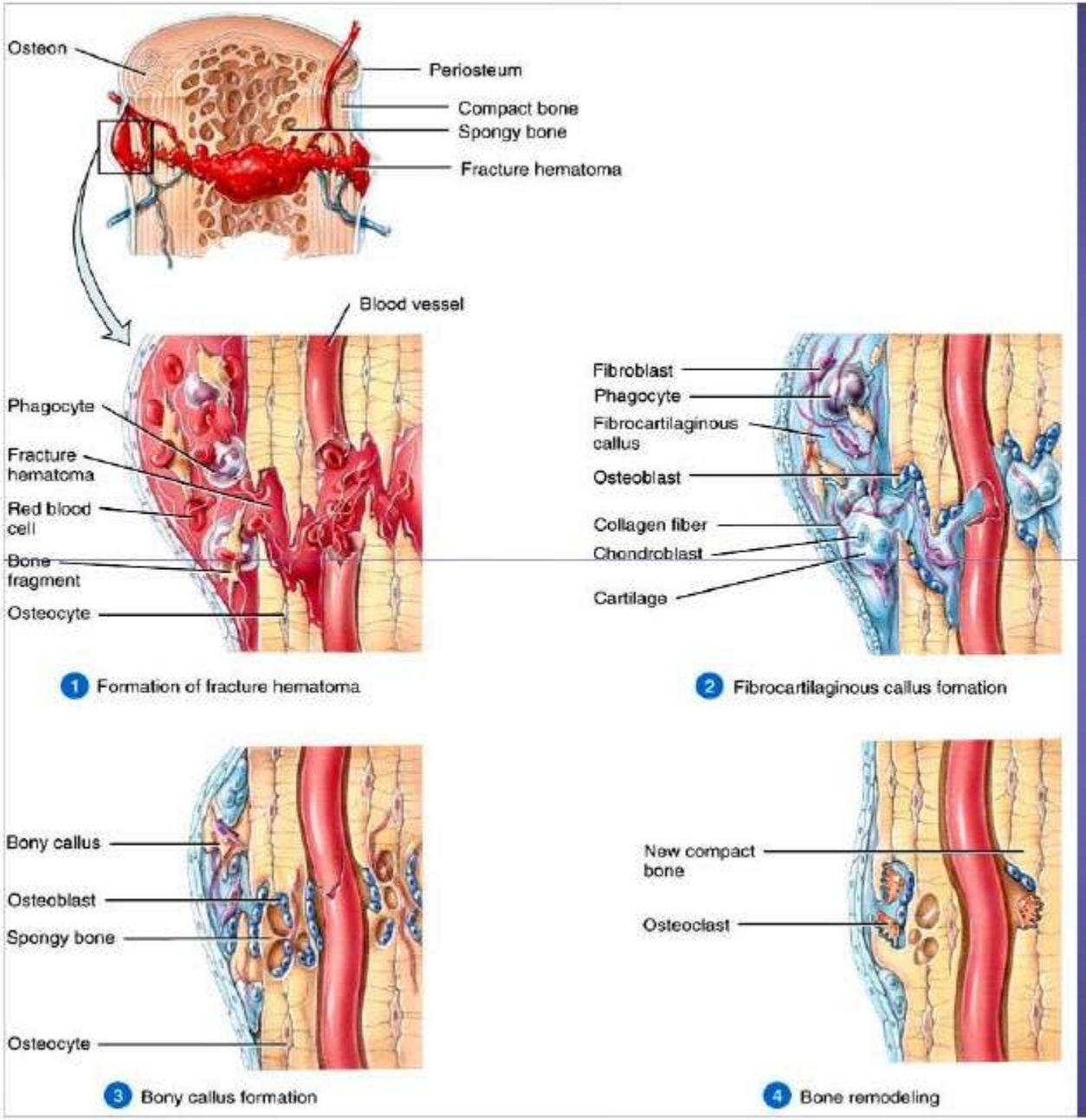


Stages in the Healing of a Bone Fracture

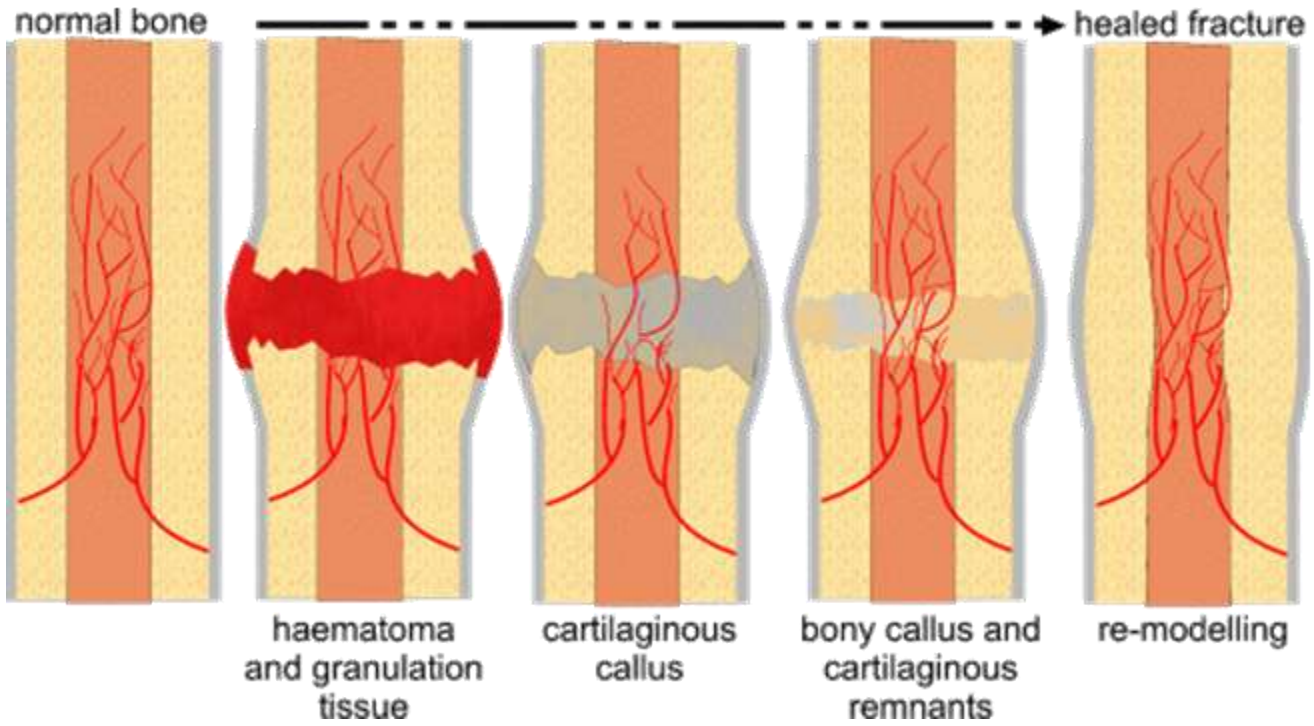
.Bone remodeling
- Excess material on the bone shaft exterior and in the medullary canal is removed
- Compact bone is laid down to reconstruct shaft walls



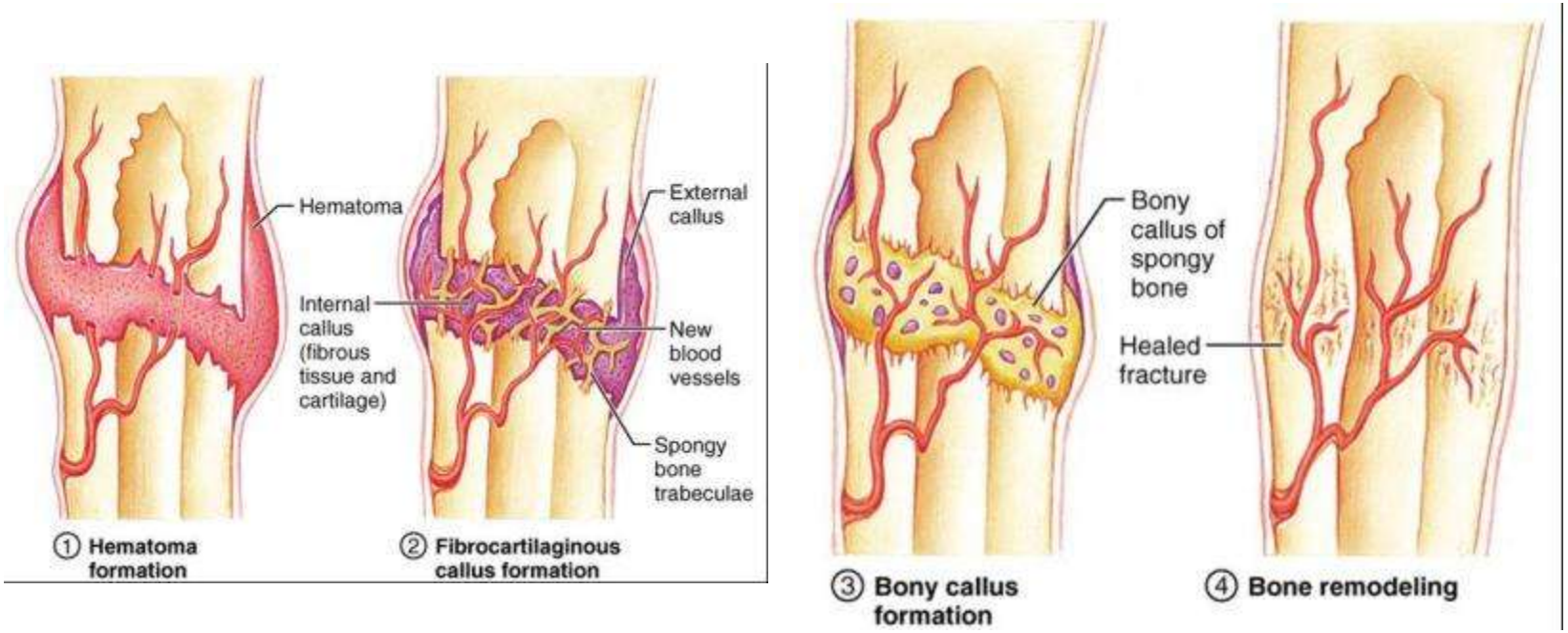
Fracture Repair



Repair of Bone - animation


normal bone
healed fracture
haematoma and granulation tissue
cartilaginous callus
bony callus and cartilaginous remnants
re-modelling

How does a broken bone heal?



1. Blood flow increases to the area of the break. This allows nutrients and oxygen to help the healing process.

2. As bone becomes deposited, it grows stronger, and eventually remodels itself.

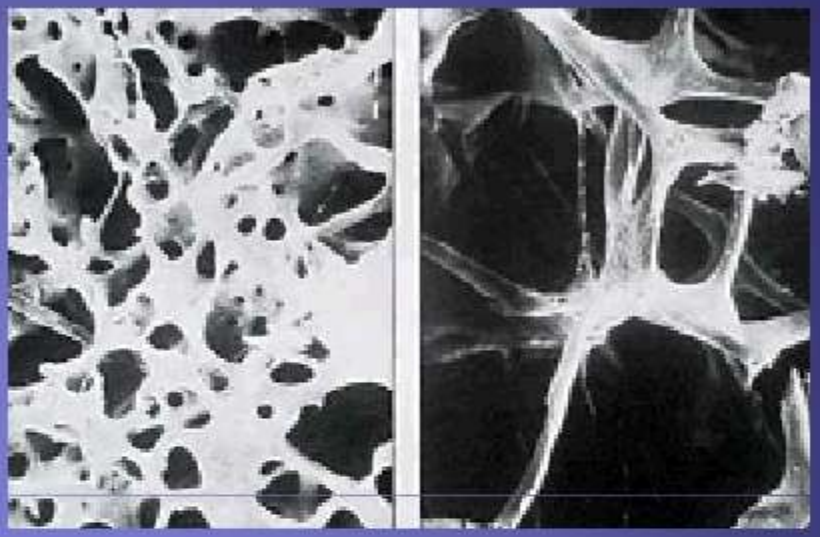
Aging & Bone Tissue

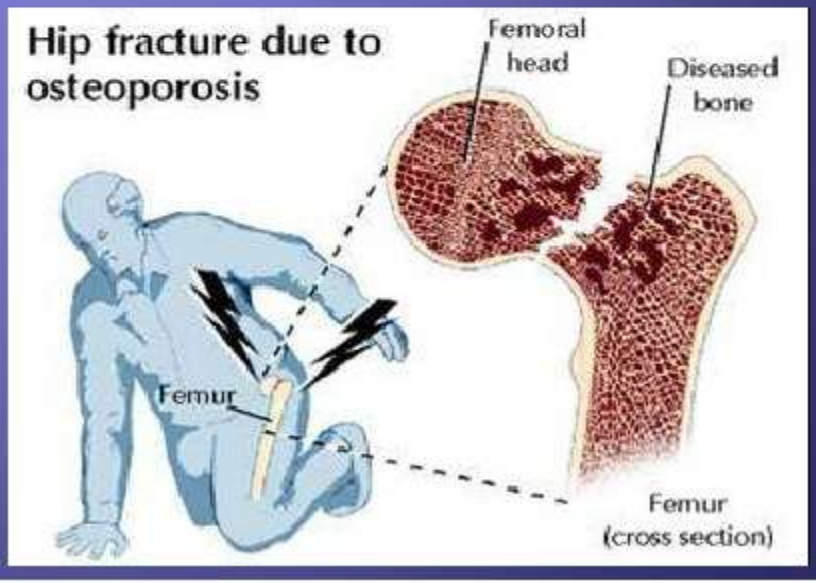
The loss of Ca^{+2} from bone matrix (demineralization)

- may result in osteoporosis
- rapid in women age 40-45 (when estrogen levels decrease)
- begins after age 60 in men

Decreased rate of protein synthesis

- less collagen production
- less growth hormone
- brittle bones more likely to fracture





SEM 30x

(a) Normal bone

SEM 30x

(b) Osteoporotic bone

Aging Bone Animation

Red Marrow

:

- Forms **Erythrocytes**:
- Forms **Leucocytes**:
- Forms **Thrombocytes**:

:

Red color is due to hemoglobin

Location:

- Skull
- Sternum
- Clavicles
- Vertebrae
- Pelvis
- Ribs

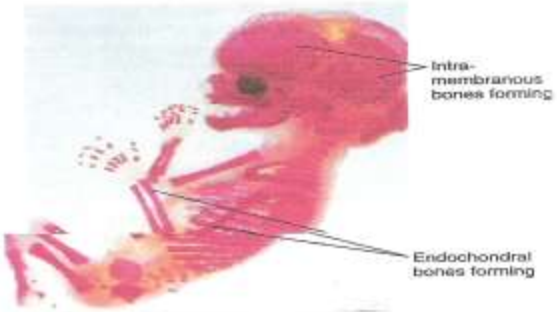
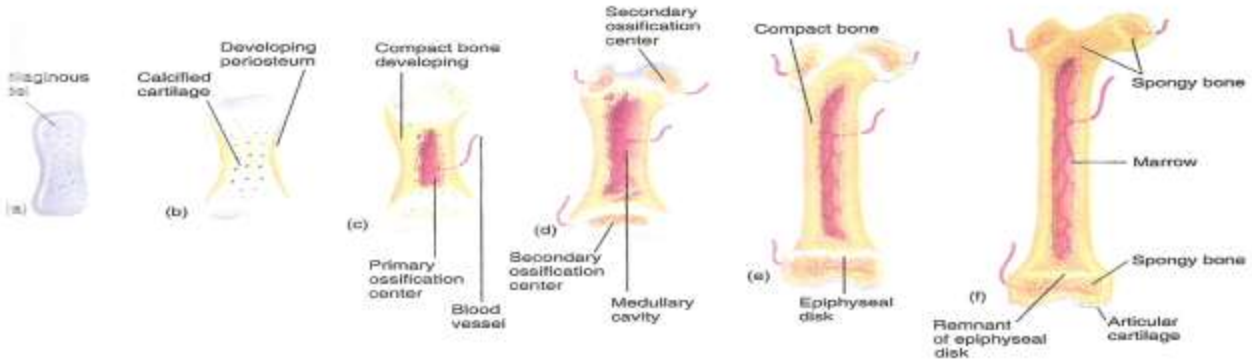


Figure 7.4
Note the stained, developing bones of this fourteen-week fetus.



Clinical Forms

- . Rickets
- Arthritis
- Gouty Arthritis (GOUT)
- Osteoporosis
- Osteosarcoma

Rickets:

- **Vitamin D deficiency** in growing children
- Unable to absorb calcium and phosphate from gut
- Inorganic bone matrix (mineral salts) lacks calcium-
- Bones deform

Clinical Forms of Arthritis

- **Osteoarthritis**
  - Most common chronic arthritis
  - Probably related to normal aging processes
- **Rheumatoid arthritis**
  - An autoimmune disease – the immune system attacks the joints
  - Symptoms begin with bilateral inflammation of certain joints
  - Often leads to deformities

Gouty Arthritis (GOUT)

- Inflammation of joints is caused by a deposition of urate (URIC ACID) crystals from the blood
- Can usually be controlled with diet
- Hereditary as it runs in families.
- This is very painful!!

Osteoporosis……

Cause is related to calcium loss due to the following dietary and behavioral patterns……

- **High meat protein diets**
- **Phosphorylated soft drinks**
- **Smoking**
- **Lack of exercise**
- **High caffeine intake**

Treatment:

- **elimination of risk factors**
- **exercise**
- **calcium suppliments**
- **estrogen administration**

Osteosarcoma

- Most common and most malignant form of bone cancer
- Tumors arise beneath periosteum and elevate it as they grow
- Penetrate cortical bone
- Rapid spreading - cure rate is low

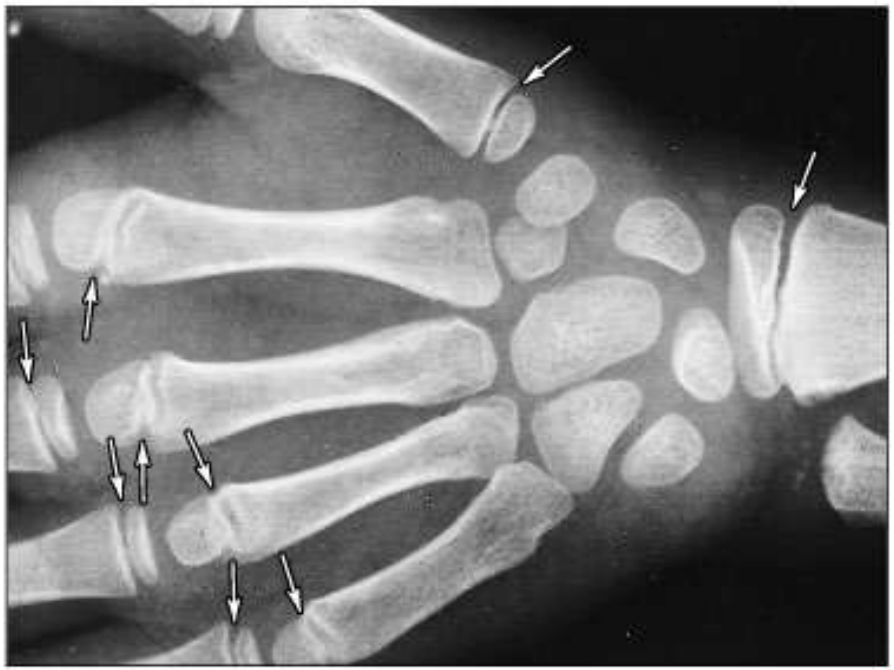
summary

. Bone formation by two different ways , intramembranous and endochondral ossification , and how calcium phosphate is deposited in the matrix .

. There are differences between cartilage and bone cells . Chondroplastic dwarfism and oseopetrosis are bone diseases .

. Bone fracture and formation of Soft and hard callus ,aging & bone tissue and some examples of disease.

Bone Growth at an Epiphyseal Cartilage



(a) Epiphyseal cartilages

(b) Epiphyseal lines

Figure 6.9