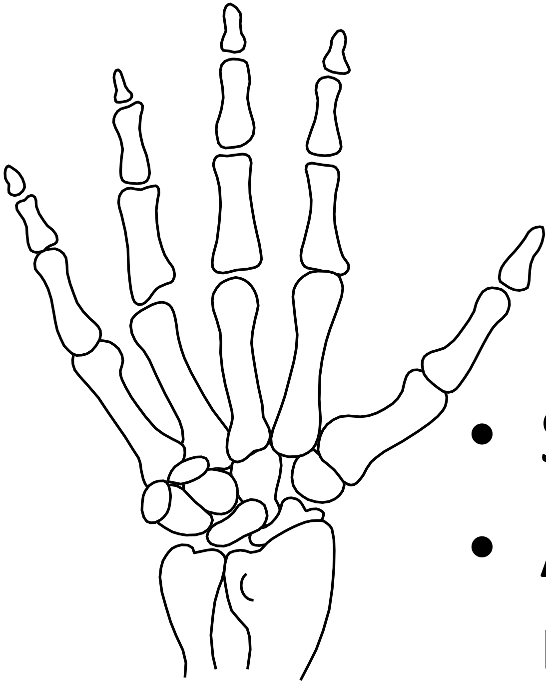
Chapter 6

The Skeletal System: Bone Tissue

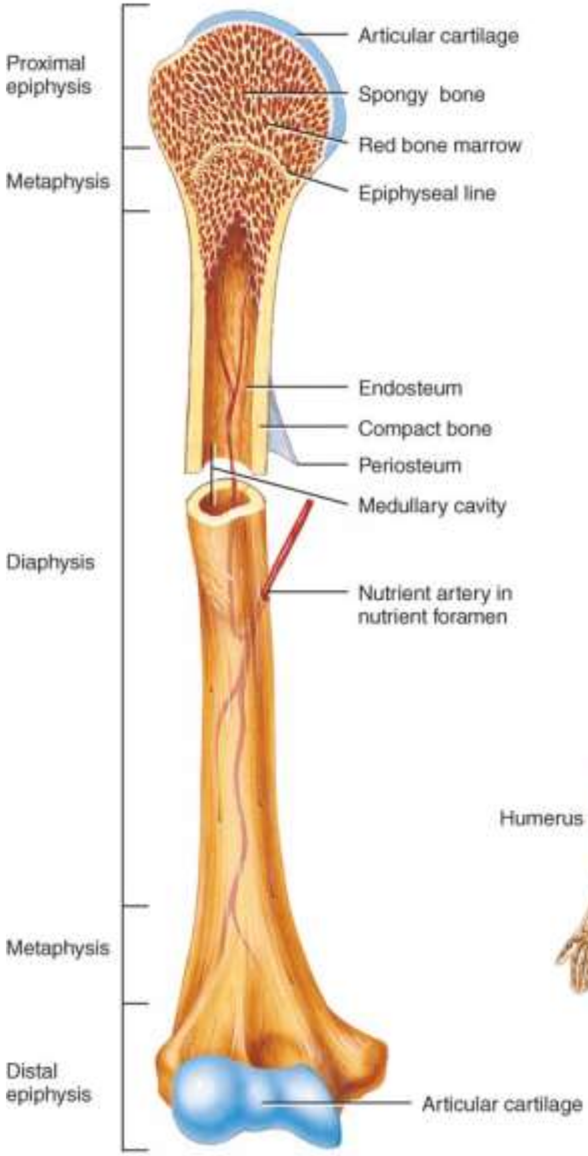
INTRODUCTION

- Bone is made up of several different tissues working together: bone, cartilage, dense connective tissue, epithelium, various blood forming tissues, adipose tissue, and nervous tissue.
- Each individual bone is an organ; the bones, along with their cartilages, make up the skeletal system.

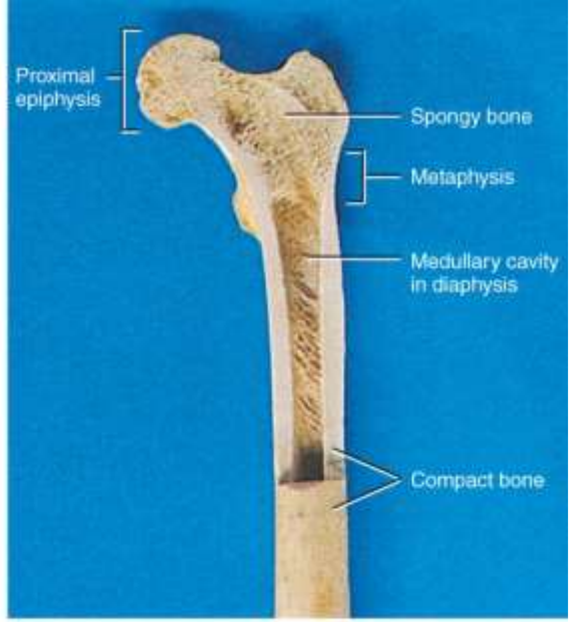


Functions of Bone

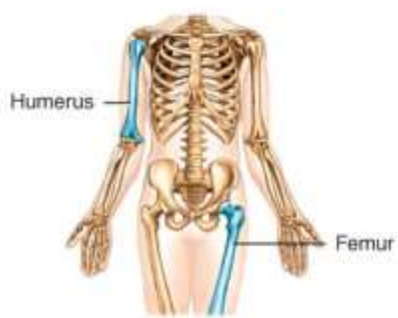
- Supporting & protecting soft tissues
- Attachment site for muscles making movement possible
- Storage of the minerals, calcium & phosphate -- mineral homeostasis
- Blood cell production occurs in red bone marrow (hemopoiesis)
- Energy storage in yellow bone marrow



(a) Partially sectioned humerus (arm bone)



(b) Partially sectioned femur (thigh bone)

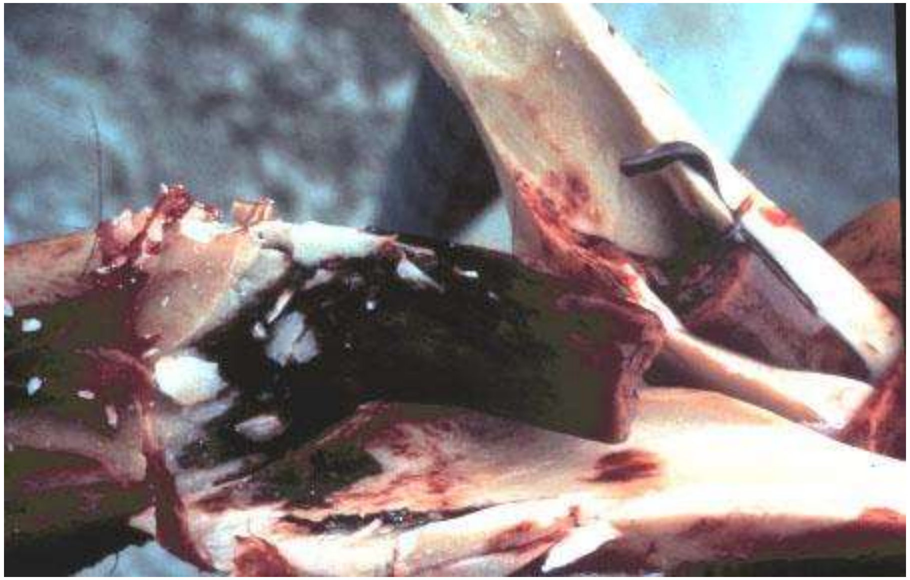


Anatomy of a Long Bone

- <u>diaphysis</u> = shaft
- <u>epiphysis</u> = one end
- <u>*metaphyses*</u> - area between diaphysis and epiphysis and include the *epiphyseal plate* in growing bones.
- <u>Endosteum</u> = lining of marrow cavity
- <u>Periosteum</u> = tough membrane covering bone but not the cartilage
- <u>Articular cartilage</u> over joint surfaces acts as friction reducer & shock absorber
- <u>Medullary cavity</u> = marrow cavity

Changes in Bone Marrow

Bone marrow in healthy individual



Bone marrow in unhealthy individual

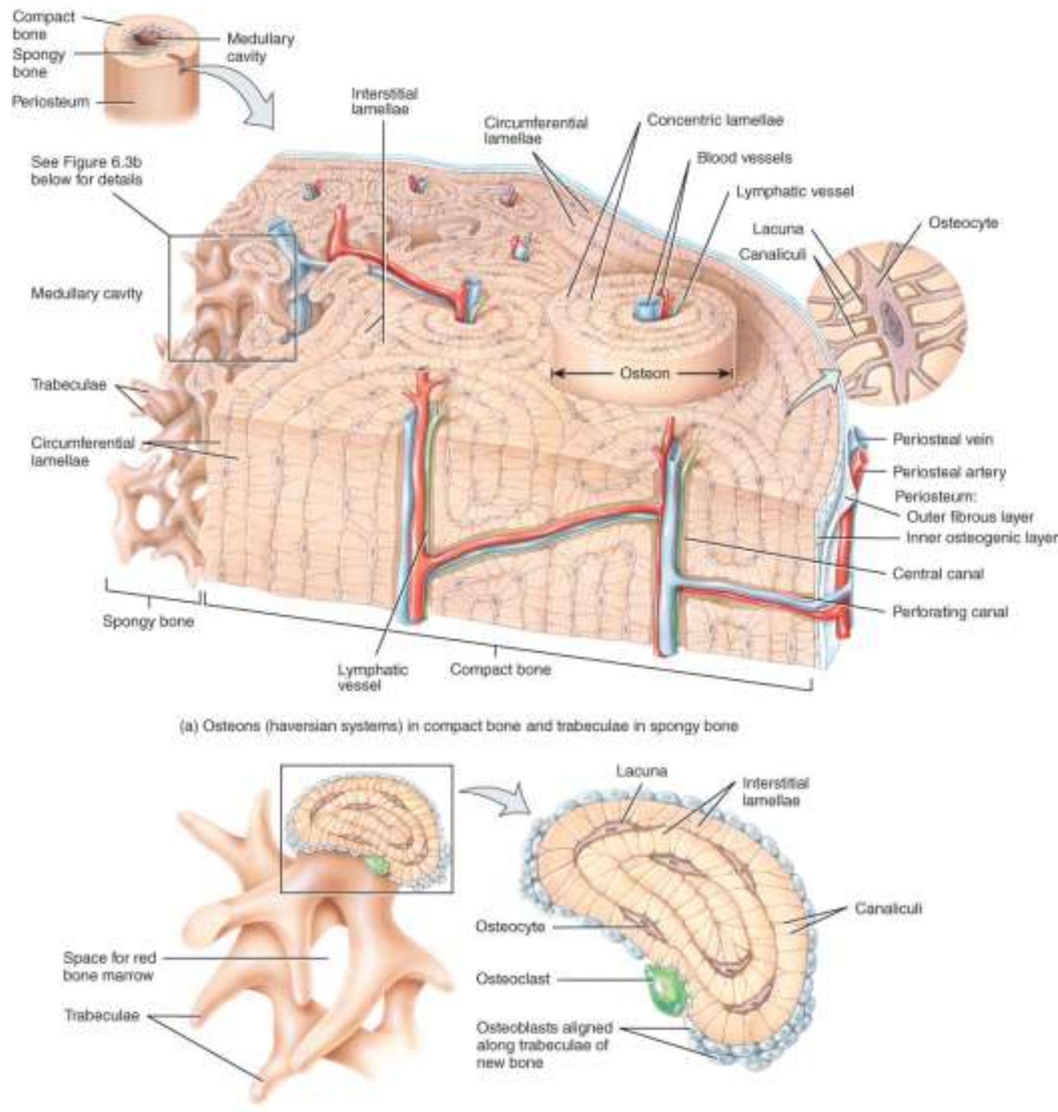
Marrow reconversion – changing of bone marrow from yellow to red
Reasons:

- Increased demand for red blood cells (e.g. blood loss)
- Physiologic stress – high athletic activity
- High altitude

Histology of Bone

- A type of connective tissue as seen by widely spaced cells separated by matrix

- 4 types of cells in bone tissue



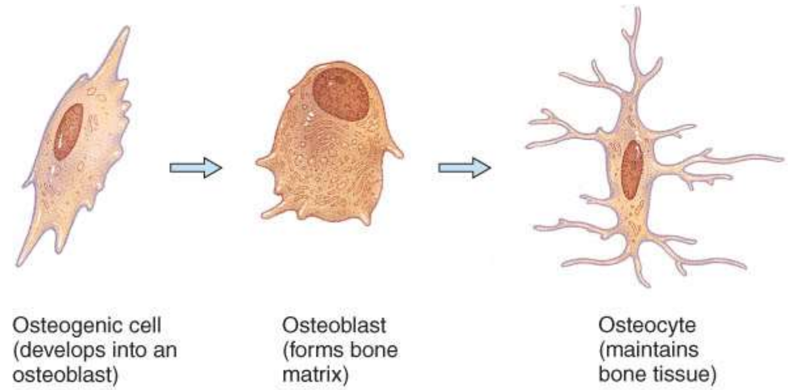
(a) Osteons (haversian systems) in compact bone and trabeculae in spongy bone

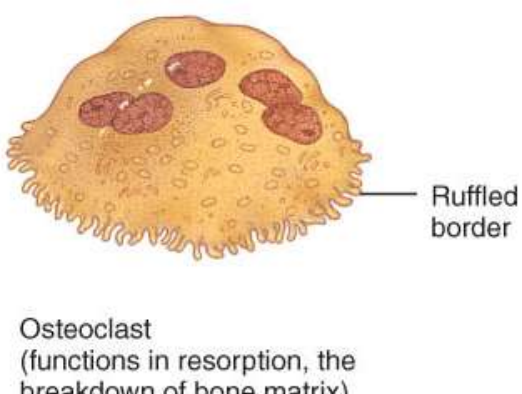
(b) Enlarged aspect of spongy bone trabeculae

(c) Details of a section of a trabecula

Bone Cells

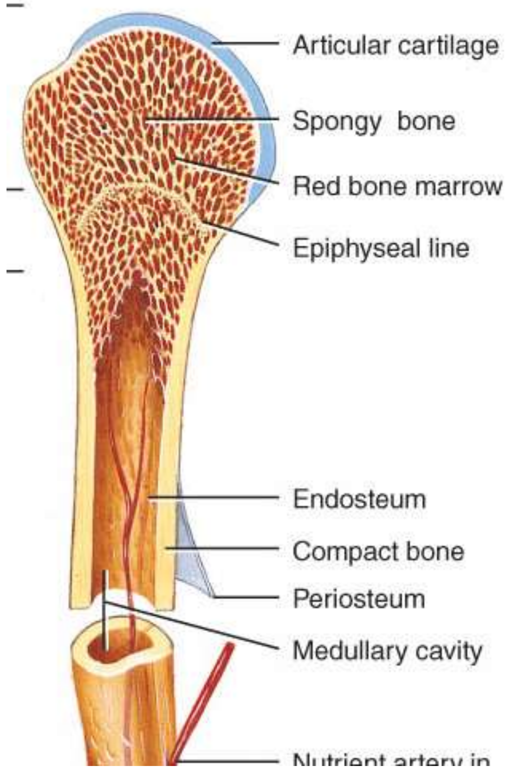
1. Osteoprogenitor/osteogenic cells --
   - undifferentiated cells
   - can divide to replace themselves & can become osteoblasts
   - found in inner layer of periosteum and endosteum
2. Osteoblasts--form matrix & collagen fibers but can't divide
3. Osteocytes ---mature cells that no longer secrete matrix
4. Osteoclasts---- huge cells from fused monocytes (WBC)
   - function in bone resorption at surfaces such as endosteum

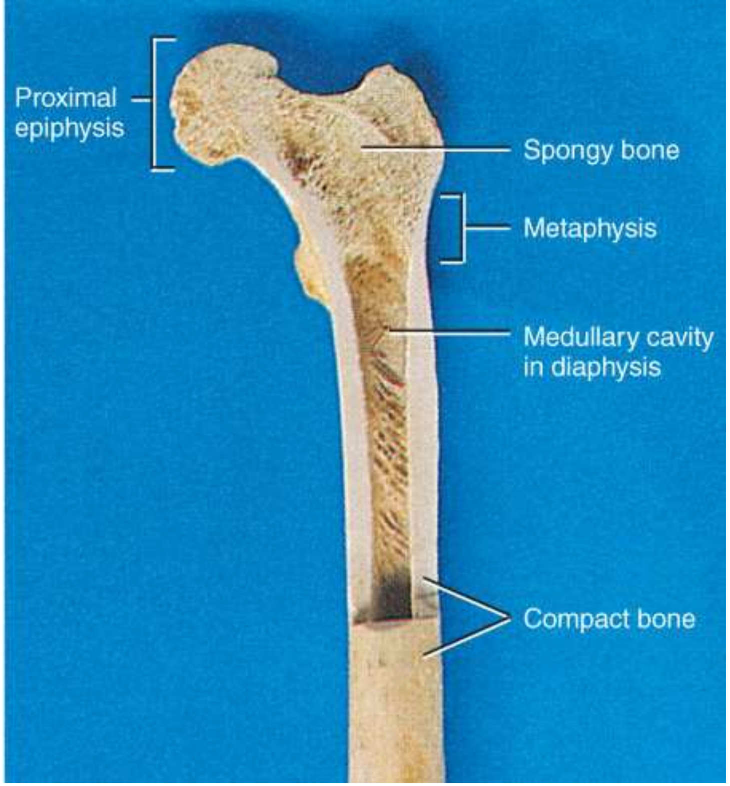




Matrix of Bone

- Inorganic mineral salts provide bone's hardness
  - hydroxyapatite (calcium phosphate and calcium hydroxide) & calcium carbonate
- Organic collagen fibers provide bone's flexibility
  - their tensile strength resists being stretched or torn
  - remove minerals with acid & rubbery structure results
- Bone is not completely solid since it has small spaces for vessels and red bone marrow
  - spongy bone has many such spaces
  - compact bone has very few such spaces



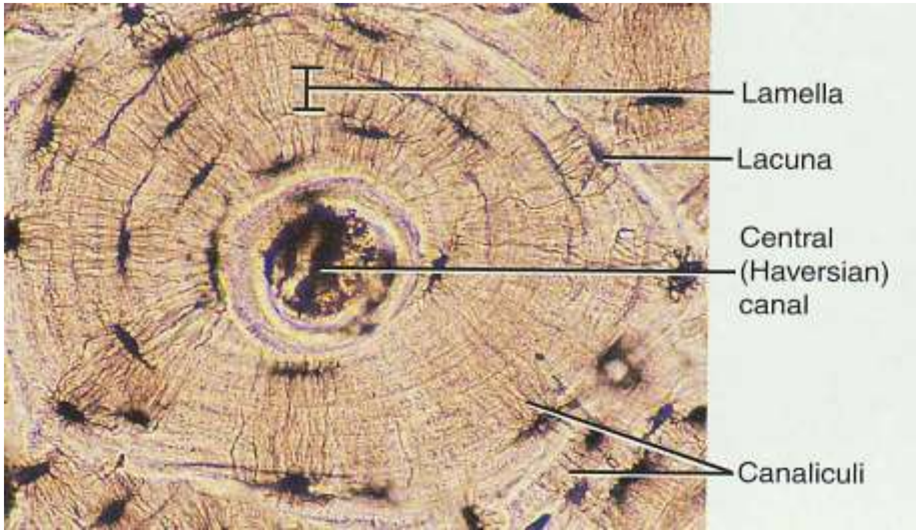


Compact or Dense Bone

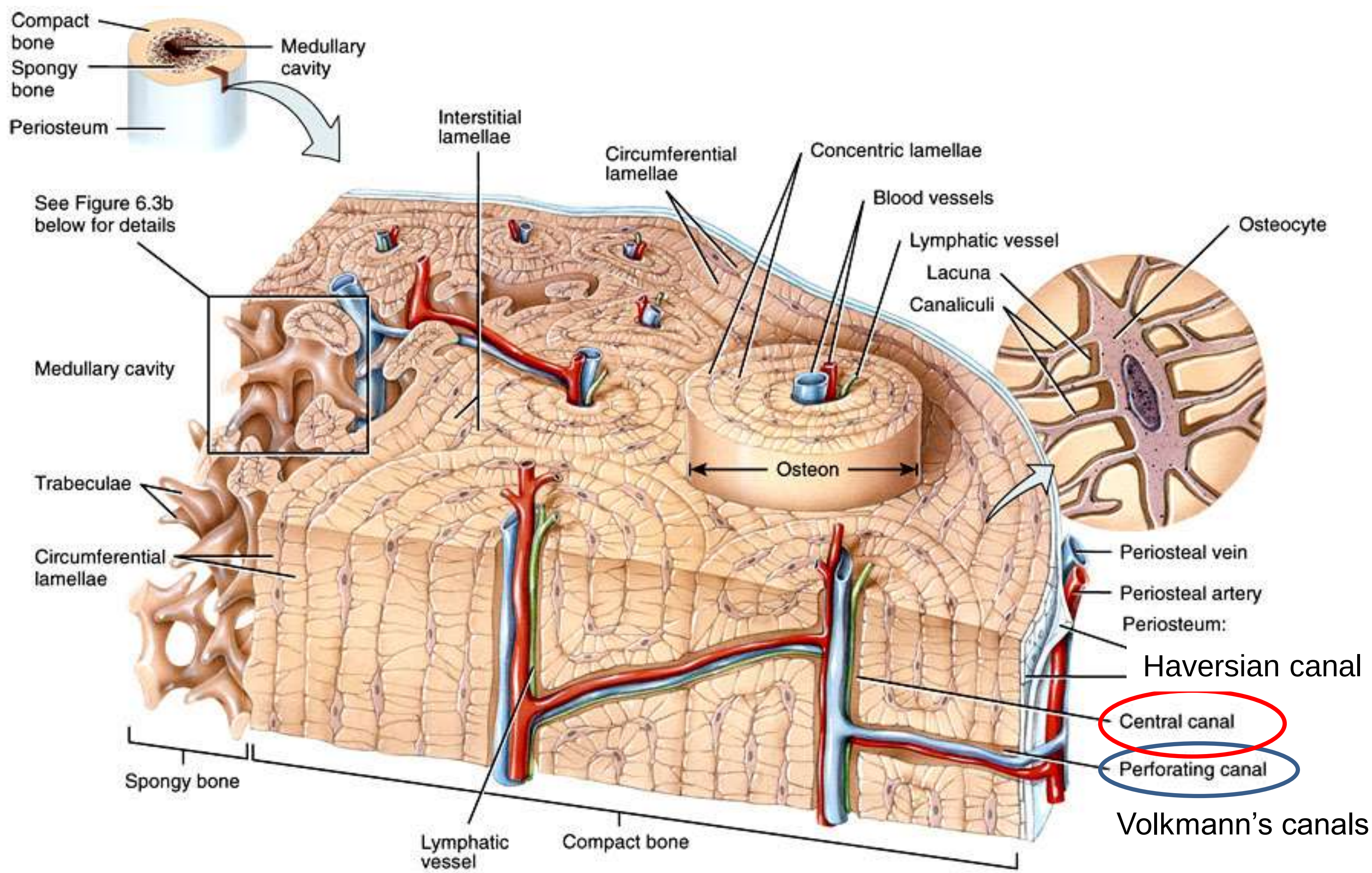
- Looks like solid hard layer of bone
- Makes up the shaft of long bones and the external layer of all bones
- Resists stresses produced by weight and movement

Histology of Compact Bone

- **Osteon** is concentric rings (**lamellae**) of calcified matrix surrounding a vertically oriented blood vessel
- **Osteocytes** are found in spaces called **lacunae**
- Osteocytes communicate through **canaliculi** filled with extracellular fluid that connect one cell to the next cell



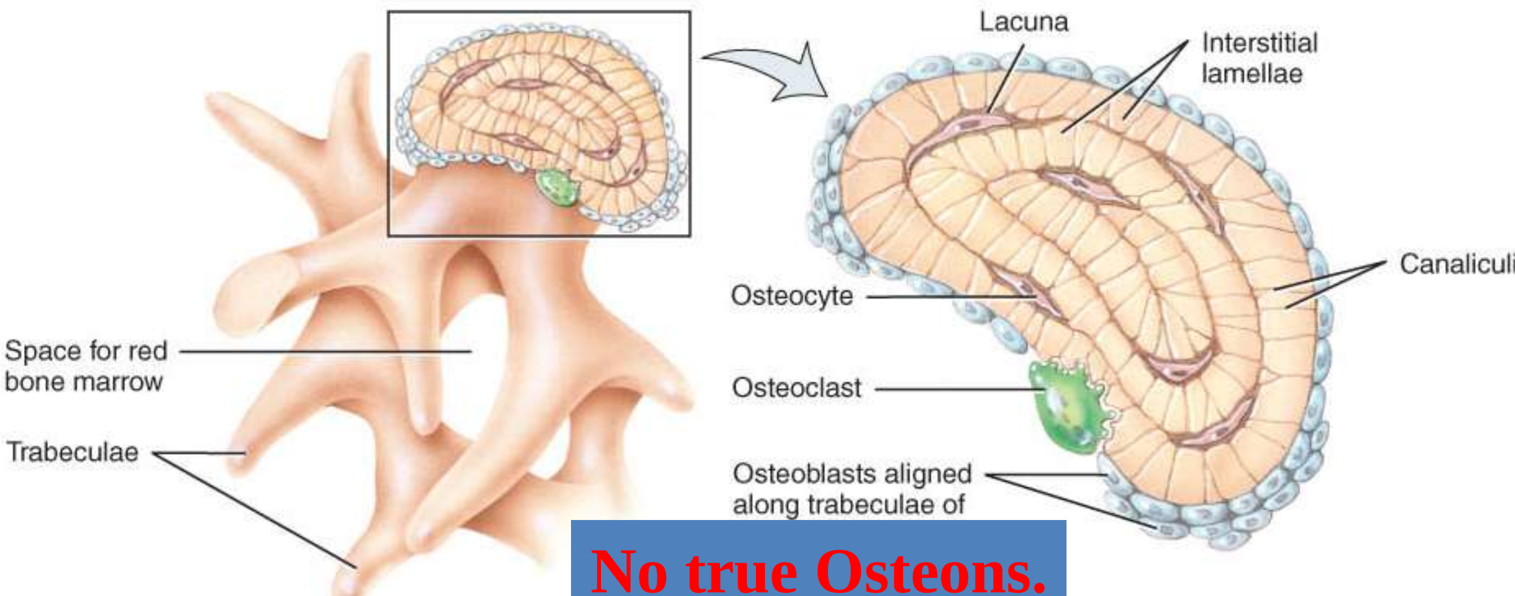
Histology of Compact Bone



(a) Osteons (haversian systems) in compact bone and trabeculae in spongy bone

Spongy Bone

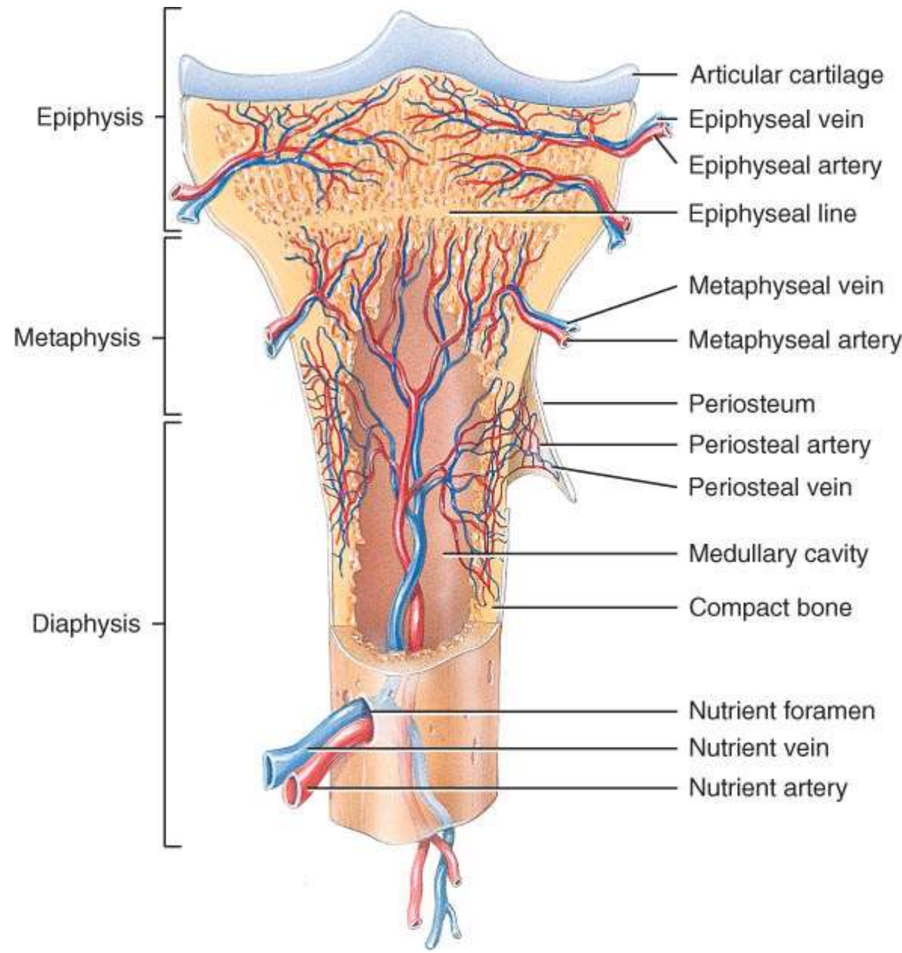
- Latticework of thin plates of bone called **trabeculae** oriented along lines of stress
- Spaces in between these struts are filled with red marrow where blood cells develop
- Found in ends of long bones and inside flat bones such as the hipbones, sternum, sides of skull, and ribs.



No true Osteons.

Blood and Nerve Supply of Bone

- Periosteal arteries
  - supply periosteum
- Nutrient arteries
  - enter through nutrient foramen
  - supplies compact bone of diaphysis & red marrow
- Metaphyseal & epiphyseal arterie.
  - supply red marrow & bone tissue of epiphyses



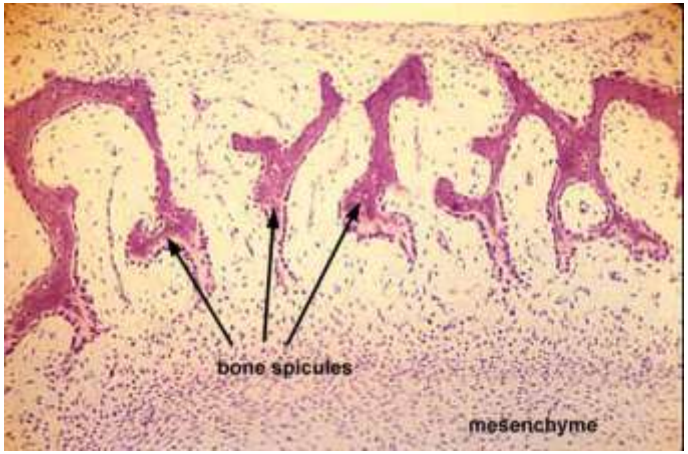
BONE FORMATION

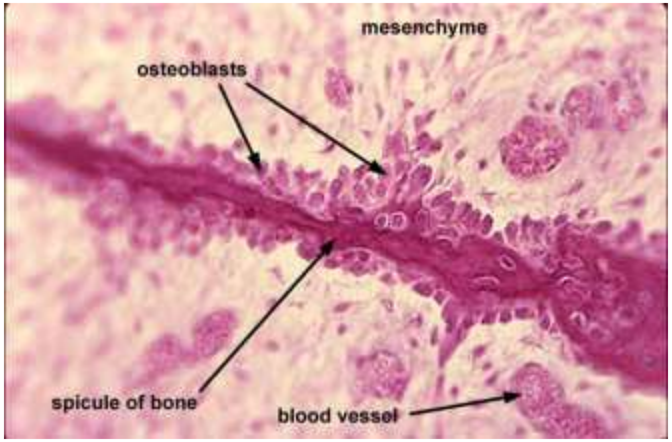
- All embryonic connective tissue begins as mesenchyme.
- Bone formation is termed *osteogenesis*
- Two types of ossification occur.
  1. ***Intramembranous ossification*** is the formation of bone directly from or within fibrous connective tissue membranes.

  2. ***Endochondrial ossification*** is the formation of bone from hyaline cartilage models.

Intramembranous Ossification

- Intramembranous ossification forms the flat bones of the skull and the mandible.
- Steps:
  1. An ossification center forms from mesenchymal cells as they convert to osteoblasts and lay down osteoid matrix.
  2. The matrix surrounds the cell and then calcifies as the osteoblast becomes an osteocyte.
  3. The calcifying matrix centers join to form bridges of trabeculae that constitute spongy bone with red marrow between.
  4. On the periphery the mesenchyme condenses and develops into the periosteum.





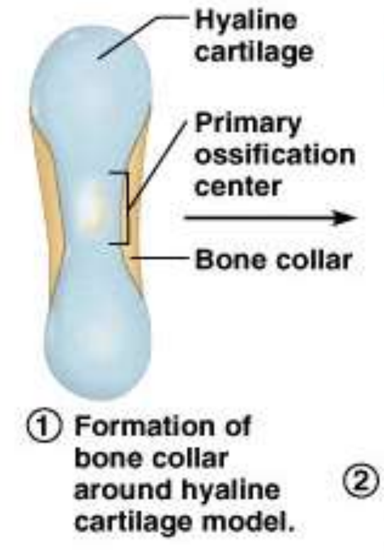
Endochondral Ossification

- *Endochondral ossification* involves replacement of a hyaline cartilage model of the skeleton by bone. This process forms all bones except some bones of the skull and clavicles
- Endochondral ossification begins late in 2nd month of human development and continues until early adulthood (i.e. when the growth plate closes).

Stage 1 in Endochondral Ossification

- A wide band of bone (bone collar) begins to form around the diaphysis of the hyaline cartilage model of the bone.

- This will lead to the **formation of the primary ossification** center where bone will first start to form.



Stage 2 in Endochondral Ossification

Because hyaline cartilage is avascular, the bone collar prevents nutrients from being passed to chondrocytes in the center and the cartilage matrix deteriorates **forming a space (cavitation).**

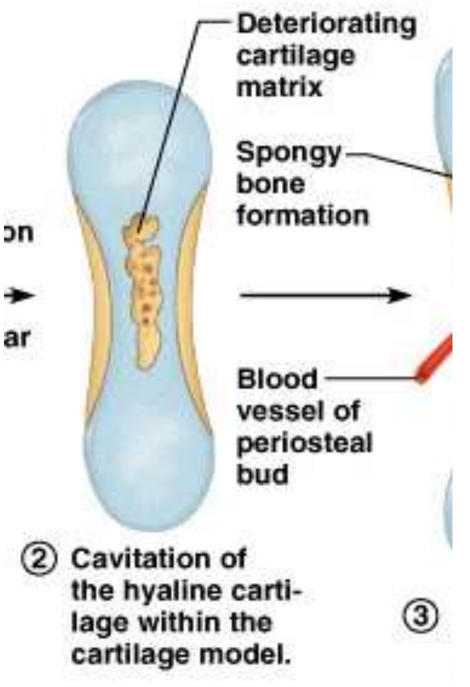


Figure 6.10

Stage 3 in Endochondral Ossification

- **Blood vessels penetrate** the bone collar and enter the central cavity.
- With the addition of blood vessels, **osteoblasts also enter the cavity and start forming spongy bone.**

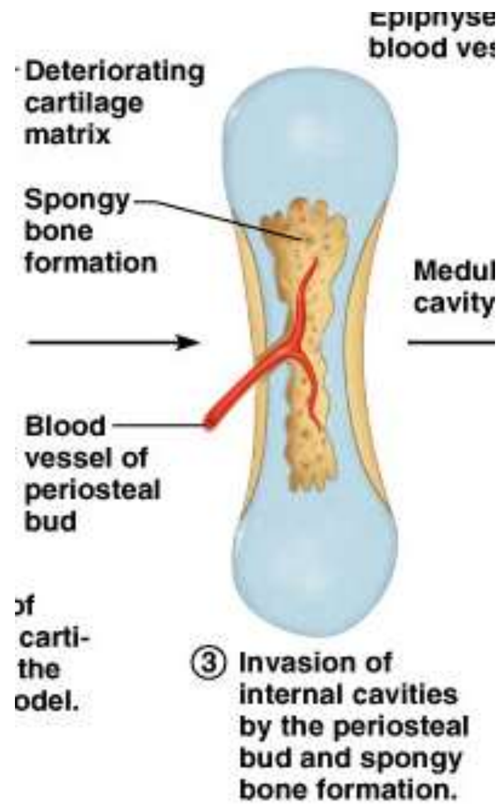
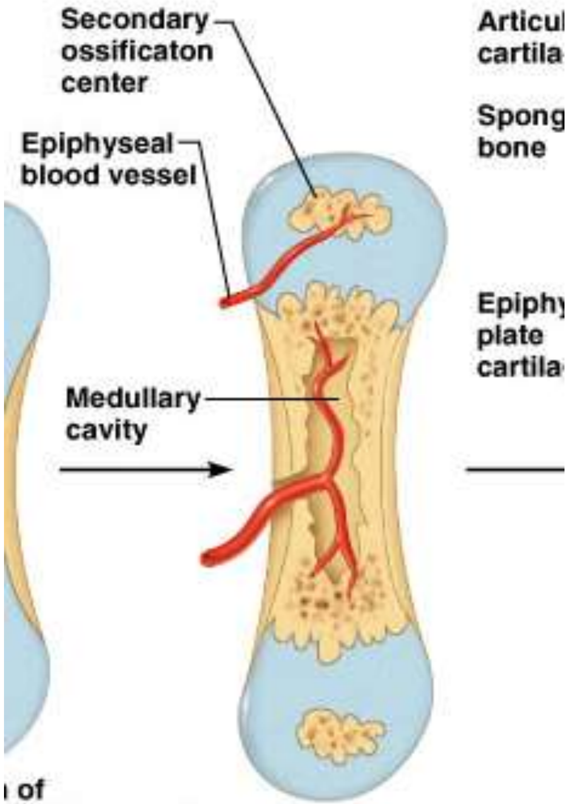


Figure 6.10

Stage 4 in Endochondral Ossification

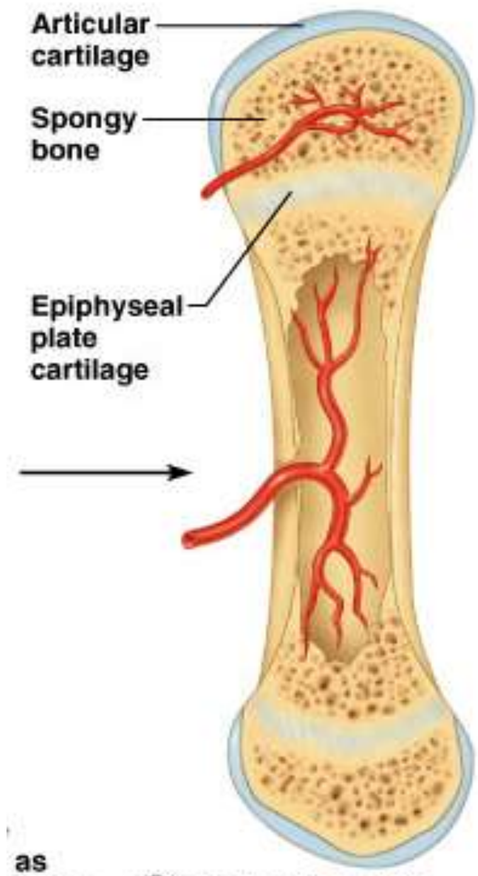
- The formation of bone from cartilage (ossification) **continues** with **spongy bone being converted into compact bone**.
- A distinct **medullary cavity forms**.
- Other blood vessels penetrate the epiphysis of the cartilage model, again bringing osteoblasts with them, allowing for **secondary ossification centers to form** at both end of the bone.



④ Formation of the medullary cavity as ossification continues; appearance of secondary ossification centers in the epiphyses in preparation for stage 5.

Stage 5 in Endochondral Ossification

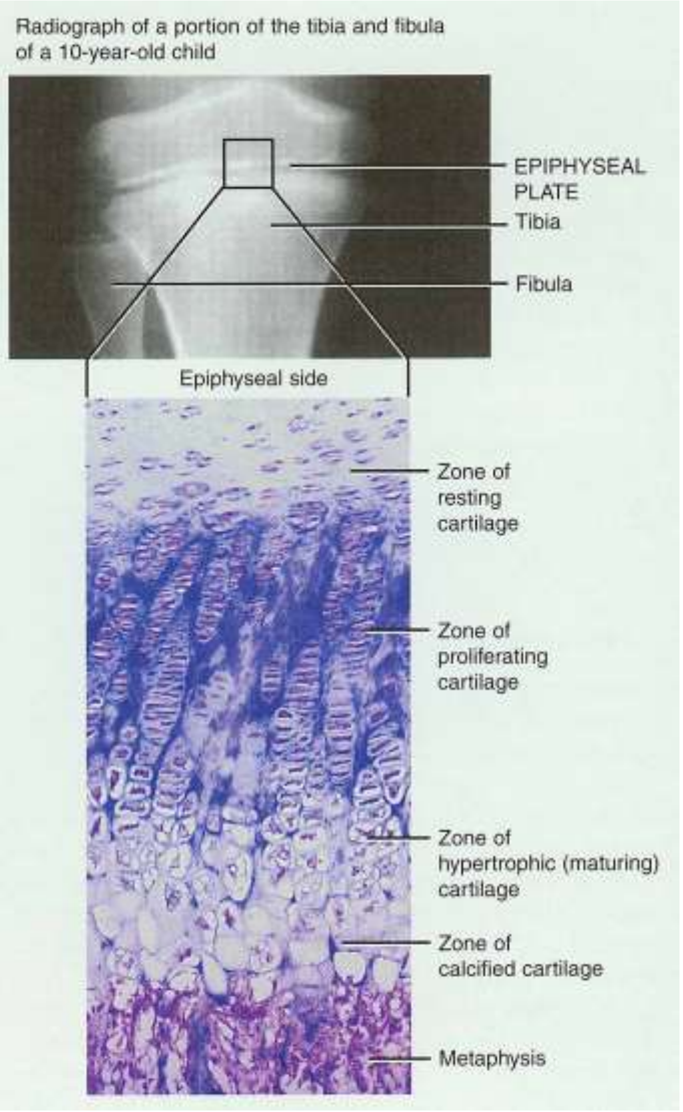
- The process continues until the only remaining cartilage is the epiphyseal plate (growth plate).
- Eventually, due to increased estrogen levels, the epiphyseal plate will close and growth in length will stop.



5 Ossification of the epiphyses; when completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.

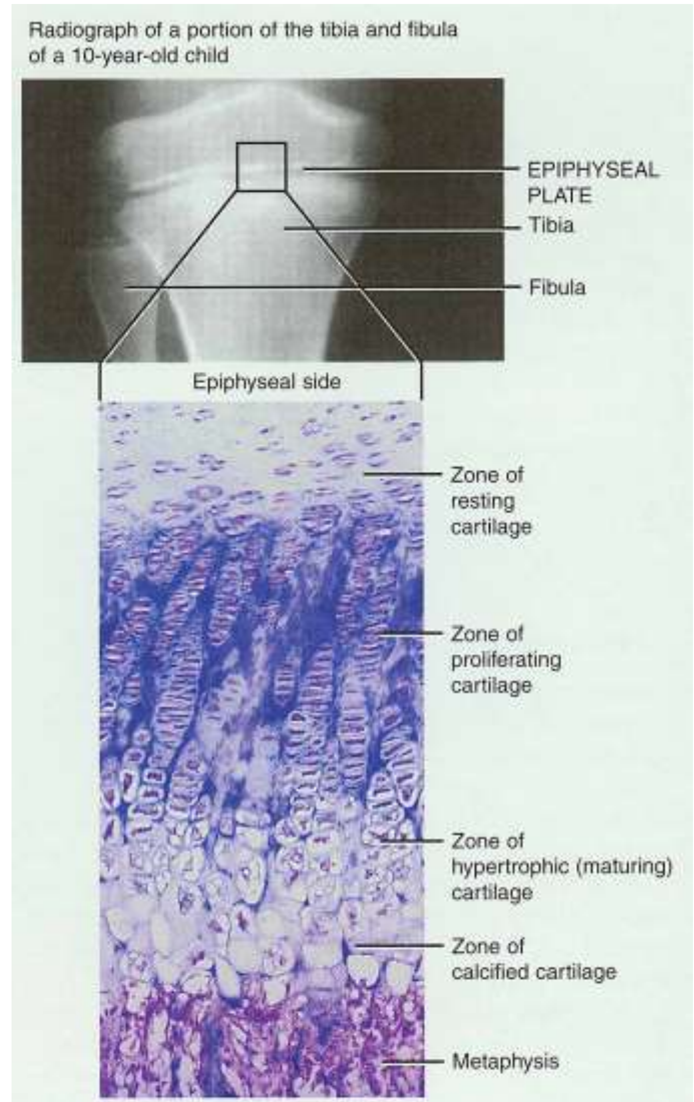
Bone Growth in Length

- Epiphyseal plate or cartilage growth plate
  - cartilage cells are produced by mitosis on epiphyseal side of plate
  - cartilage cells are destroyed and replaced by bone on diaphyseal side of plate
- Between ages 18 to 25, epiphyseal plates close due to elevated estrogen levels.



Zones of Growth in Epiphyseal Plate What is happening at each one?

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

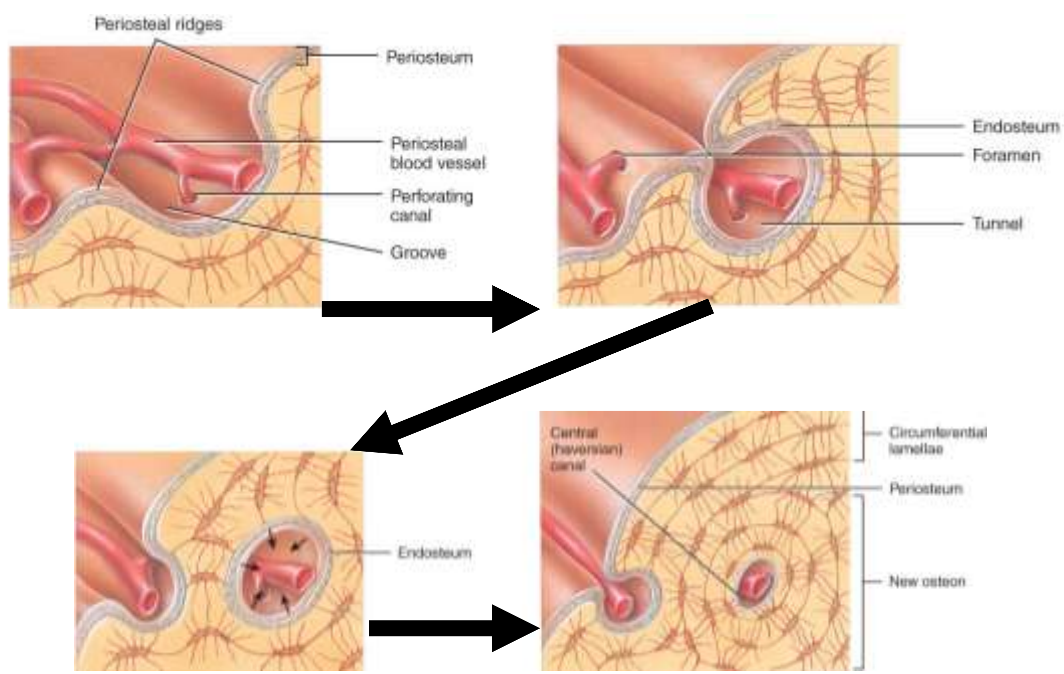


Bone Growth in Width

- Appositional growth = growth in width
- Appositional growth occurs at the bone's surface

How does that happen?

- Periosteal cells differentiate into osteoblasts and form bony ridges and then a tunnel around periosteal blood vessel.
- Concentric lamellae fill in the tunnel to form an osteon.



Factors Affecting Bone Growth

- Nutrition
  - adequate levels of minerals and vitamins
    - calcium and phosphorus, vitamin C (collagen formation)
- Sufficient levels of specific hormones
  - during childhood need **insulinlike growth factor**
    - promotes cell division at epiphyseal plate
    - need hGH (growth), thyroid (T3 &T4) and insulin
  - sex steroids at puberty
    - What role do they play?

Hormonal Abnormalities

- Oversecretion of hGH can produces significant effects:
  - Gigantism
  - Acromegaly
- Both men or women that lack estrogen receptors on cells grow taller than normal
    - estrogen is responsible for closure of growth plate

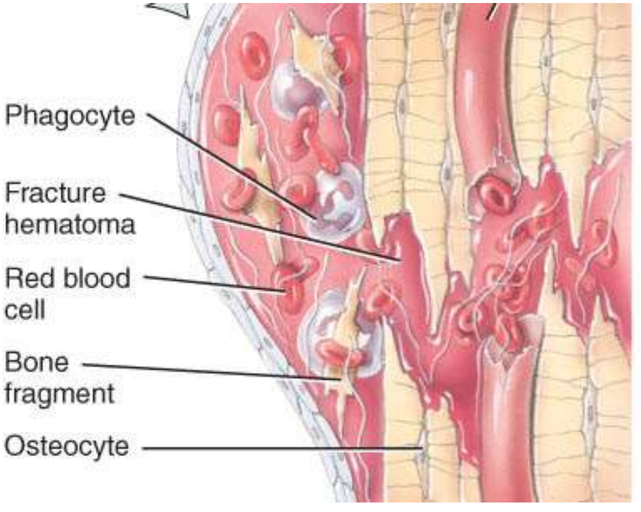
Bone Remodeling

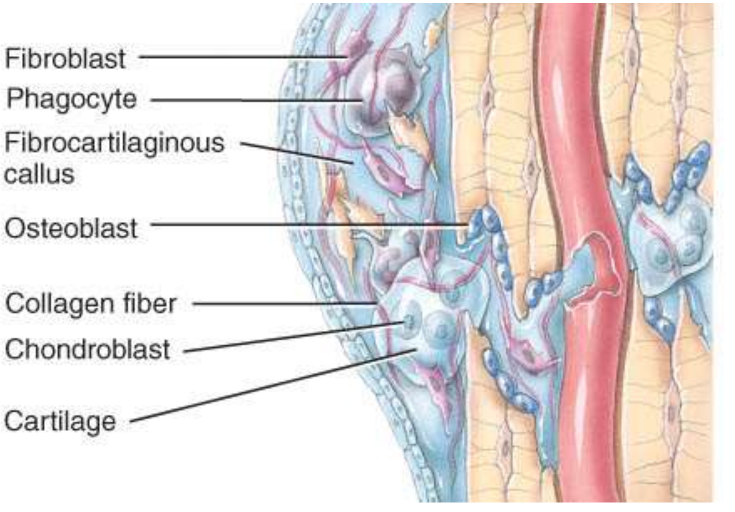
- *Remodeling* is the ongoing replacement of old bone tissue by new bone tissue.
  - Old bone is constantly destroyed by <u>osteoclasts</u> as they carve out small tunnels, and new bone is constructed by <u>osteoblasts</u> as they form osteons and spongy bone.
- Continual redistribution of bone matrix along lines of mechanical stress
  - distal femur is fully remodeled every 4 months

Fractures

- Named for shape or position of fracture line
- Common types of fracture
  - greenstick -- partial fracture
  - impacted -- one side of fracture driven into the interior of other side
  - closed -- no break in skin
  - open fracture --skin broken
  - comminuted -- broken ends of bones are fragmented
  - Pott's -- distal fibular fracture
  - Colles's -- distal radial fracture
  - stress fracture -- microscopic fissures from repeated strenuous activities

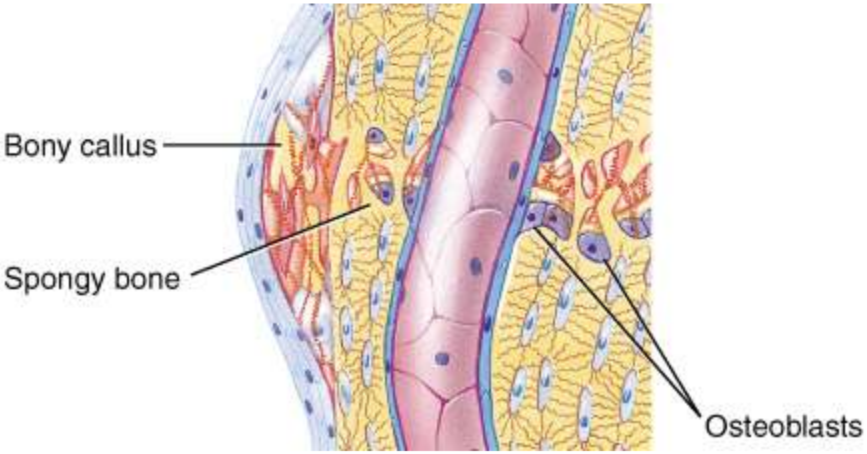
Repair of a Fracture

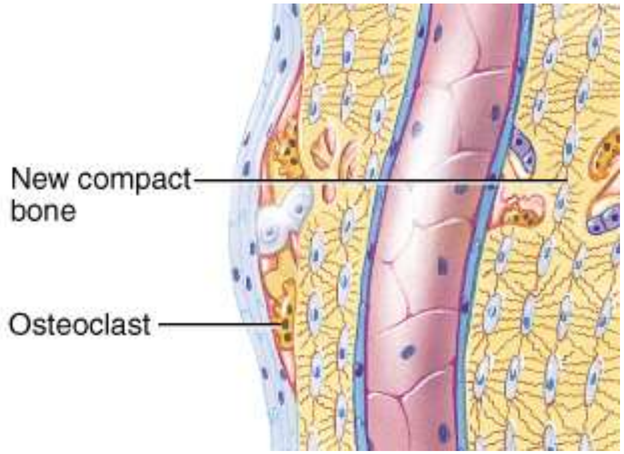




- Formation of fracture hematoma
  - damaged blood vessels produce clot in 6-8 hours, bone cells die
  - inflammation brings in phagocytic cells for clean-up duty
- Formation of fibrocartilagenous callus formation

Repair of a Fracture



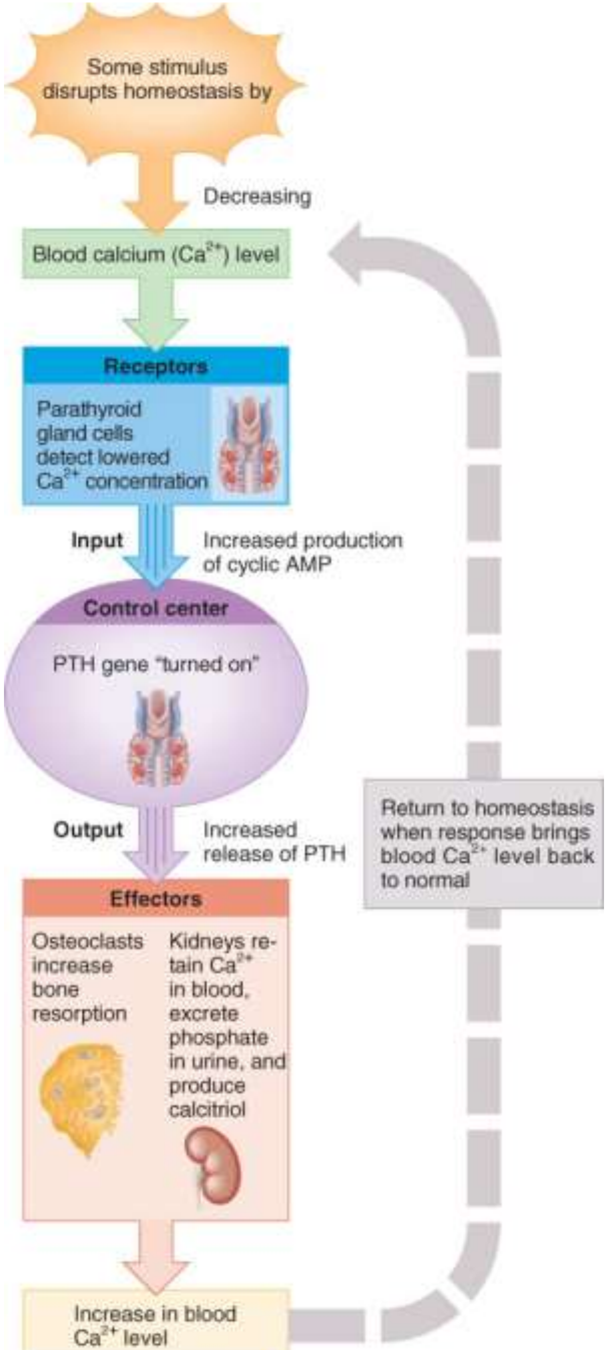


- Formation of bony callus
  - lasts 3-4 months
- Bone remodeling

Calcium Homeostasis & Bone Tissue

- Skeleton is a reservoir of Calcium & Phosphate
- Calcium ions involved with many body systems
  - nerve & muscle cell function
  - blood clotting
  - enzyme function in many biochemical reactions

- The storage and release of calcium is primarily controlled by two hormones: calcitonin and parathyroid hormone.



Hormonal Influences

- Parathyroid hormone (PTH) is secreted if Ca^{2+} levels falls
  - osteoclast activity increased, kidney retains Ca^{2+} and produces calcitriol
- Calcitonin hormone is secreted from thyroid if Ca^{2+} blood levels get too high
  - inhibits osteoclast activity
  - increases bone formation by osteoblasts

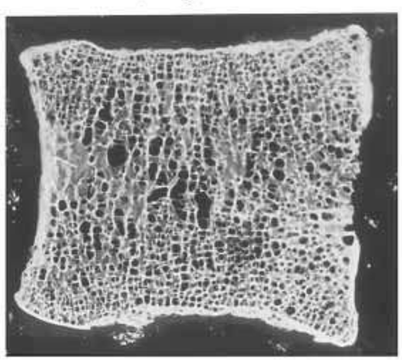
EXERCISE AND BONE TISSUE

- Within limits, bone has the ability to alter its strength in response to mechanical stress by increasing deposition of mineral salts and production of collagen fibers.
  - Weight-bearing activities, such as walking or moderate weightlifting, help build and retain bone mass.

AGING AND BONE TISSUE

- Of two principal effects of aging on bone, the first is **demineralization** which may result in osteoporosis.
  - rapid in women 40-45 as estrogens levels decrease
    - Estrogen reduces the number of osteoclasts, increases the activity of osteoblasts and speeds up the absorption of calcium
  - in males, begins after age 60
- The second is a decreased rate of protein synthesis
  - decrease in collagen production
  - bone becomes brittle & susceptible to fracture

L2, 37y.o. male



L2, 75y.o. female