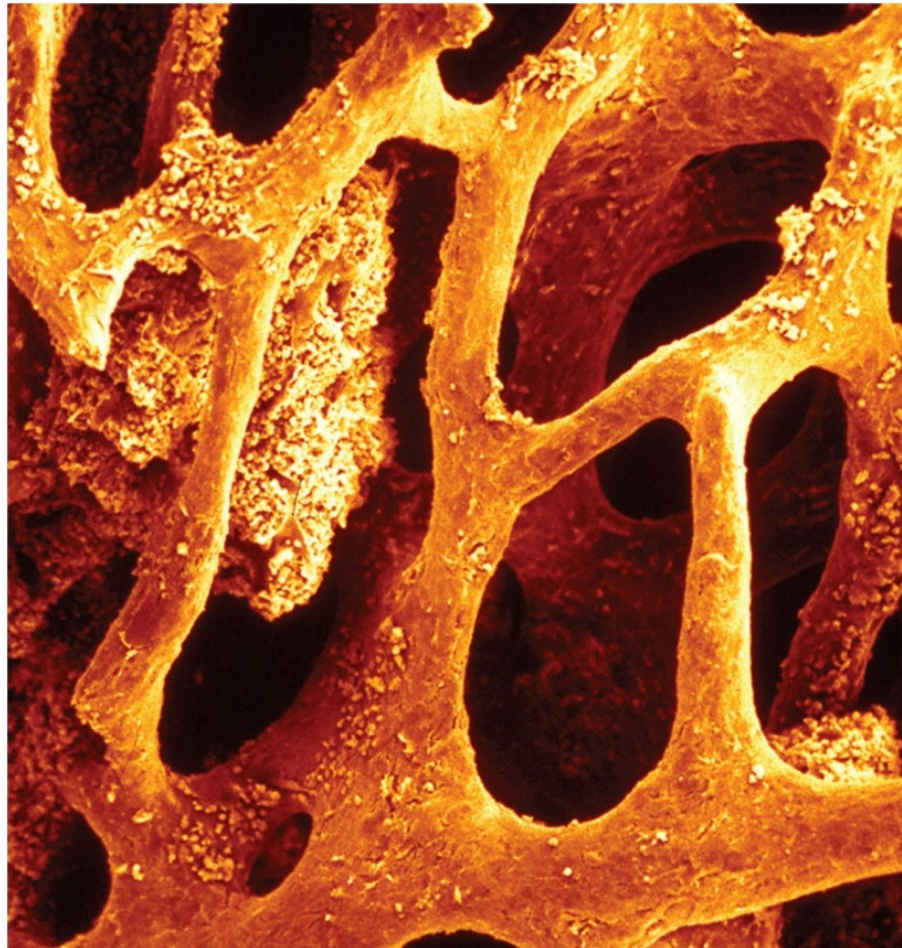


# Bone Tissue



# Functions of the Skeleton

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**support** – hold the body up, supports muscles, mandible and maxilla support teeth

**protection** – brain, spinal cord, heart, lungs

**movement** – limb movements, breathing, action of muscle on bone

**electrolyte balance** – calcium and phosphate ions

**acid-base balance** – buffers blood against excessive pH changes

**blood formation** – red bone marrow is the chief producer of blood cells



# Bone Is Osseous Tissue

---

Bone is also called an osseous tissue // it is a **type of connective tissue**.

Bone consists of **cells and a matrix**. The bone cells synthesize collagen fibers (protein) and excrete them by exocytosis.

An engineer would describe the non cellular matrix as a composite. This is made up of two different substances, calcium phosphate salt and collagen fibers. Each component has different characteristics but combined creates a new substance with properties superior to those of the original for a specific application.



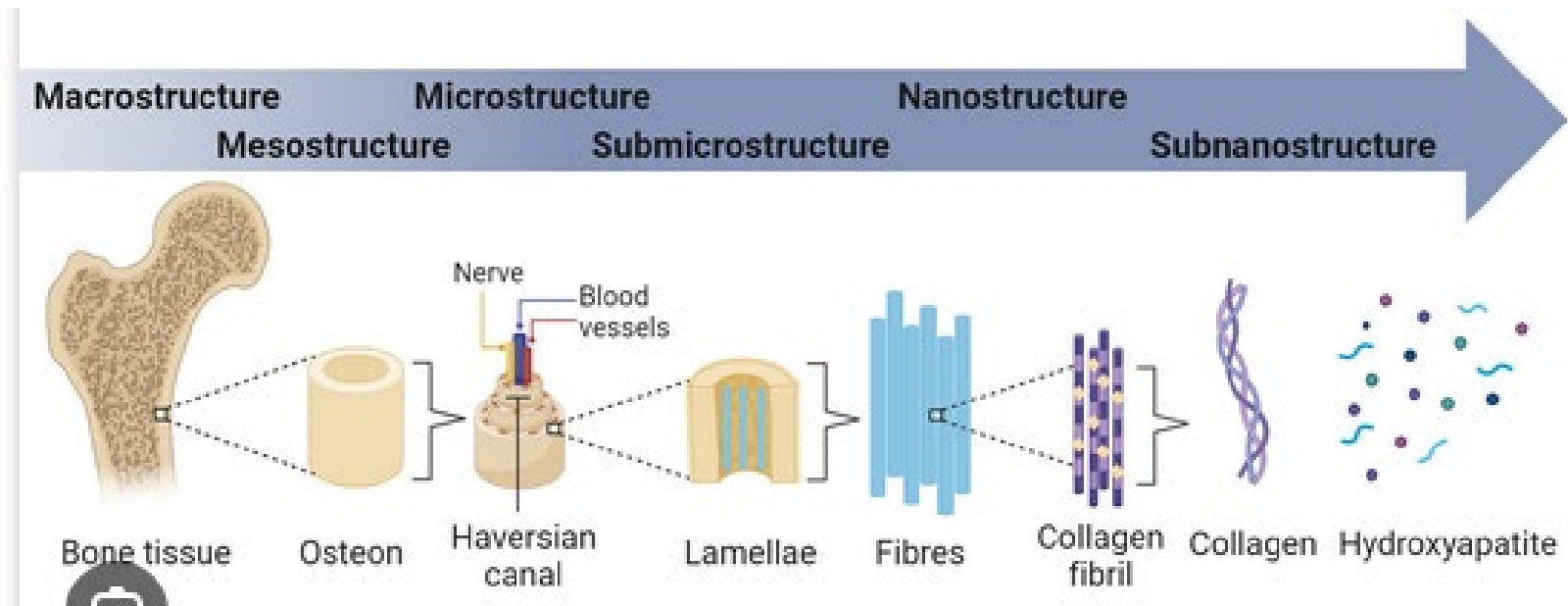


# Bone Is Osseous Tissue

Collagen fibers are **flexible** and calcium-phosphate crystals are **hard**. Bone matrix exhibits both characteristics.

Bone is one of the most metabolically active tissue in the body and constantly remodels itself in response to mechanical forces. // red bone marrow also produces all the blood's formed elements

Bone has many nerves and blood vessels, which attests to its sensitivity and metabolic activity



# Osseous Tissue

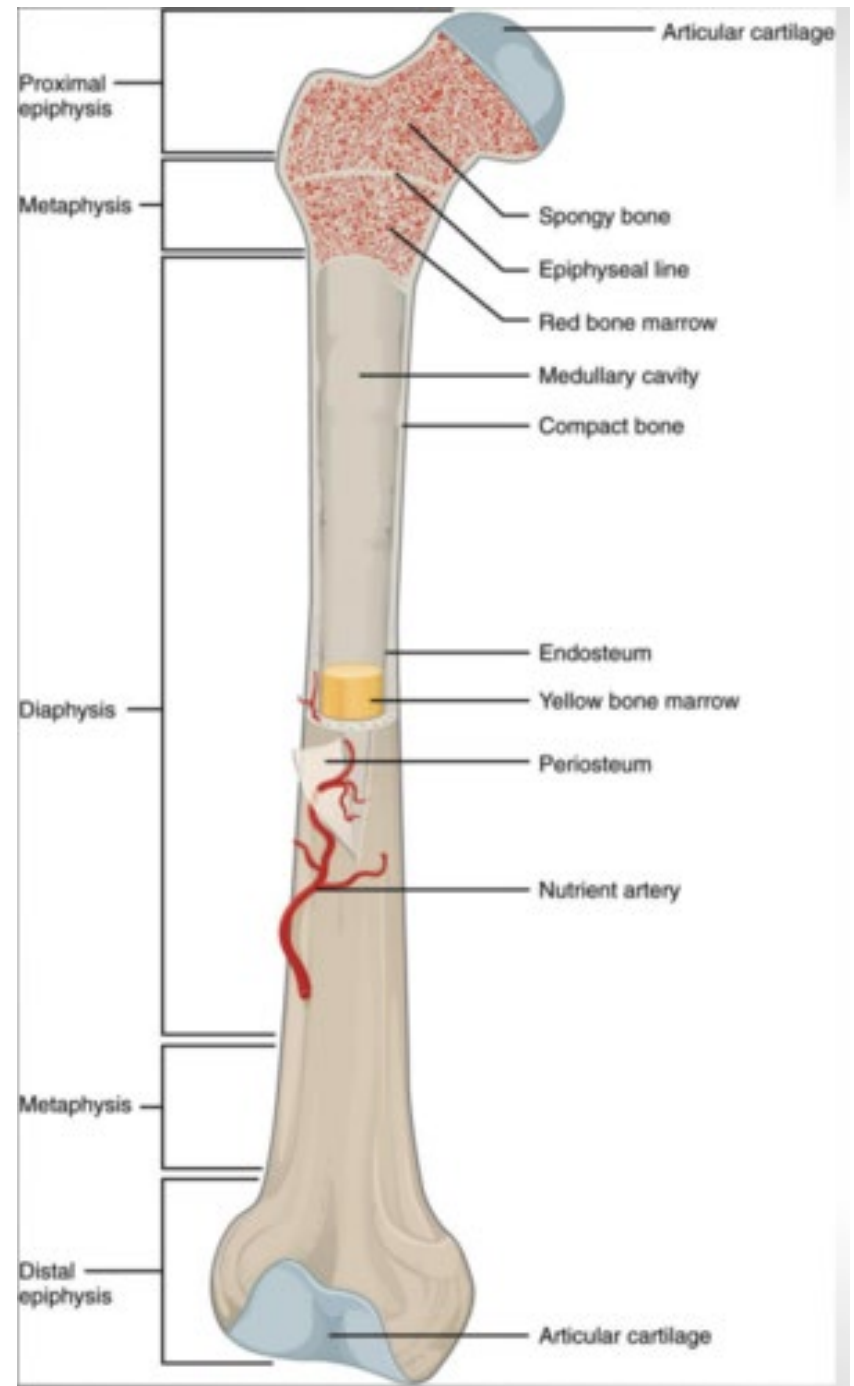
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Consist of.....

- bone (cells and matrix)
- compact and spongy bone
- bone marrow (red & yellow)
- cartilage
- adipose tissue
- nervous tissue
- fibrous connective tissue membranes
- blood vessels

# Structure of a Long Bone

(lab learning objective)



# General Features of Bones

---

Diaphysis (shaft) // cylinder of compact bone to provide leverage

Medullary cavity (marrow cavity) // space in middle of diaphysis

- contains bone marrow
- Yellow marrow = fat
- red marrow = hemopoetic = make formed elements of blood (blood cells)

Epiphyses // enlarged ends of a long bone // enlarged to strengthen joint and attach ligaments and tendons

Endosteum and periosteum are connective tissue membranes lining the medullary cavity and outer surface of the bone.

# General Features of Bones

---

## Nutrient foramina

- minute holes in the bone surface
- allows blood vessels to penetrate bone to distribute blood to osteons and medullary cavity

## Articular cartilage

- a layer of **hyaline cartilage**
- covers the joint surface where one bone meets another
- allows joint to move more freely and friction free



# General Features of Bones

---



- **Periosteum** // external sheath that covers bone
  - outer fibrous membrane = dense irregular
- some outer fibers (collagen fibers) continuous with the tendons that attach muscle to bone
- perforating (Sharpey's) fibers – fibers on inner surface of periosteum which penetrate into the bone matrix
- strong attachment and continuity from muscle to tendon to bone
  - inner osteogenic layer of bone forming cells // important to growth of bone and healing of fractures
  - not present on articular surfaces (hyalin cartilage)

# General Features of Bones

---



**Endosteum** // **connective tissue membrane lining marrow cavity**

Between membrane and bone there are osteogenic cells (osteoblast and osteoclast)

**Epiphyseal plate** (growth plate) // **area of hyaline cartilage that separates the marrow spaces of the epiphysis and diaphysis // enables growth in length**

**Epiphyseal line**

in adults, a bony scar that marks where growth plate used to be

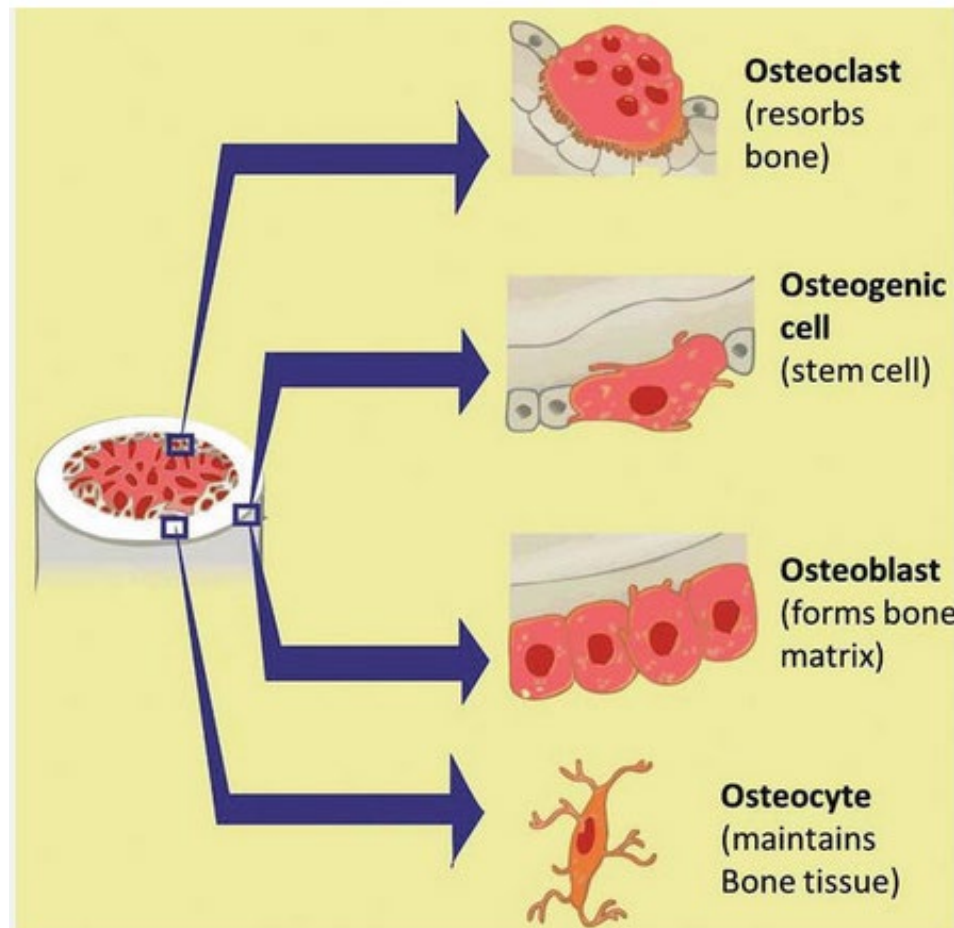
# Bone Cells



## Osteogenic vs Osteoblasts vs Osteoclast vs Osteocytes

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One of the key characteristics of osteoblasts, osteocytes, and osteoclasts is that **they do not undergo mitosis**. Only the osteogenic stem cells may undergo mitosis



# Osteoblasts

---



Osteoblasts lined up as single layer of cells under endosteum and periosteum (inner and outer connective tissue membranes)

Osteoblast produce bone matrix // synthesize extracellular fiber = collagen by exocytosis and calcium from blood completes matrix

The calcium phosphate crystals form within the collagen fibers // calcium phosphate blood concentration regulated by hormones

Stress and fractures stimulate osteogenic cells to multiply more rapidly and increase number of osteoblasts to reinforce or rebuild bone

# Osteoclasts



**Bone-dissolving cells** found on the bone's surface // just beneath the endosteum and periosteum // different origin from rest of bone cells

Osteoclasts develop from stem cells that give rise to blood cells /  
Osteoclasts are modified macrophage

Unusually large cells that formed from the fusion of several stem cells  
/ typically have 3 to 4 nuclei, may have up to 50

Ruffled border – side facing bone surface // several deep infoldings of the plasma membrane which increases surface area and resorption efficiency

Resorption bays (Howship lacunae) – pits on surface of bone where osteoclasts reside

Remodeling occurs from combined action of the bone-dissolving osteoclasts and the bone-depositing osteoblasts

# Osteocytes



Osteoblast become osteocyte after surrounded by matrix

**Osteocytes are trapped inside a cavity called the lacunae** – tiny cavities where osteocytes reside

**canaliculi** – little channels that connect lacunae between lamella

cytoplasmic processes from osteocytes “stream” into the canaliculi to connect osteocytes with the central canal (blood vessels)

contribute to homeostatic mechanism of bone density and calcium and phosphate ions

when stressed, produce biochemical signals that regulate bone remodeling

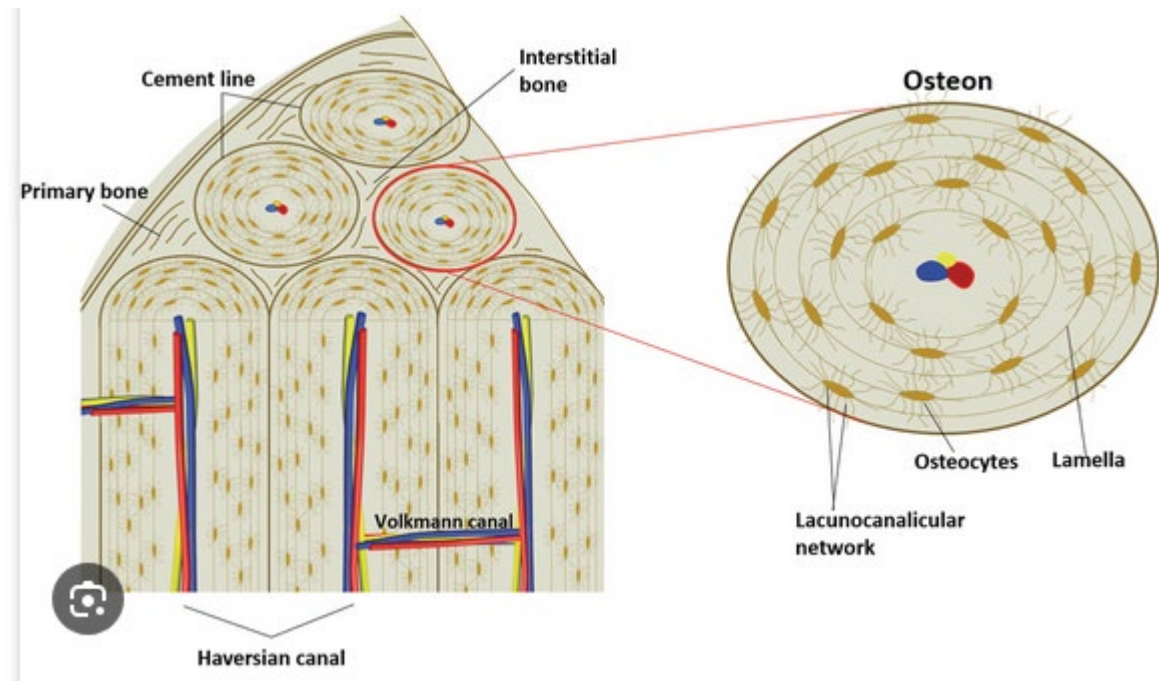
If lamella eroded back to the osteocyte, then it can once again regain functions of an osteoblast

# Compact vs Cancellous (Spongy) Bone

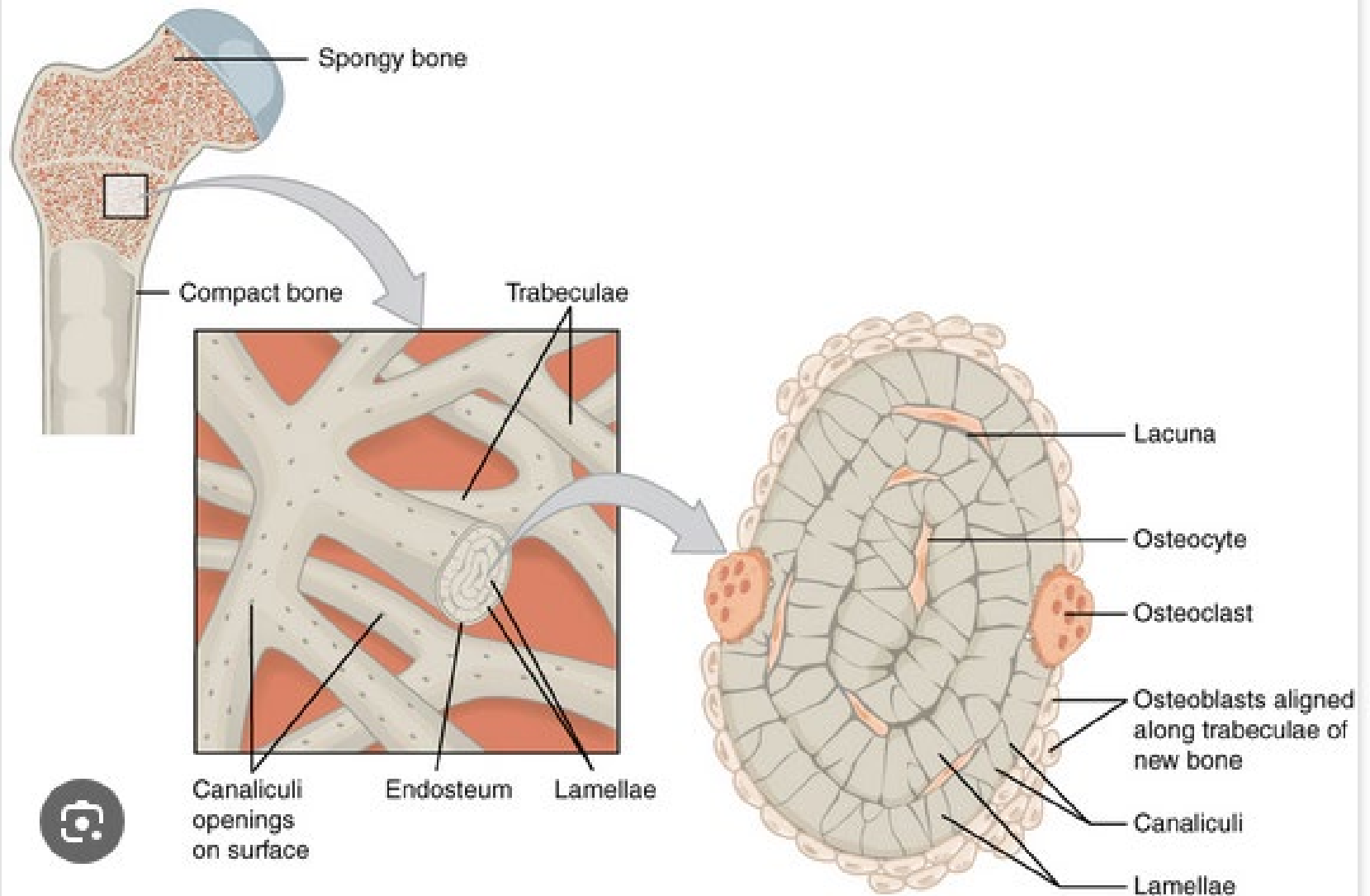
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The functional unit of compact and cancellous bone is the **osteon**

How the osteons are arranged will determine if the bone is compact or cancellous.



Osteon in compact bone



Osteon in spongy bone

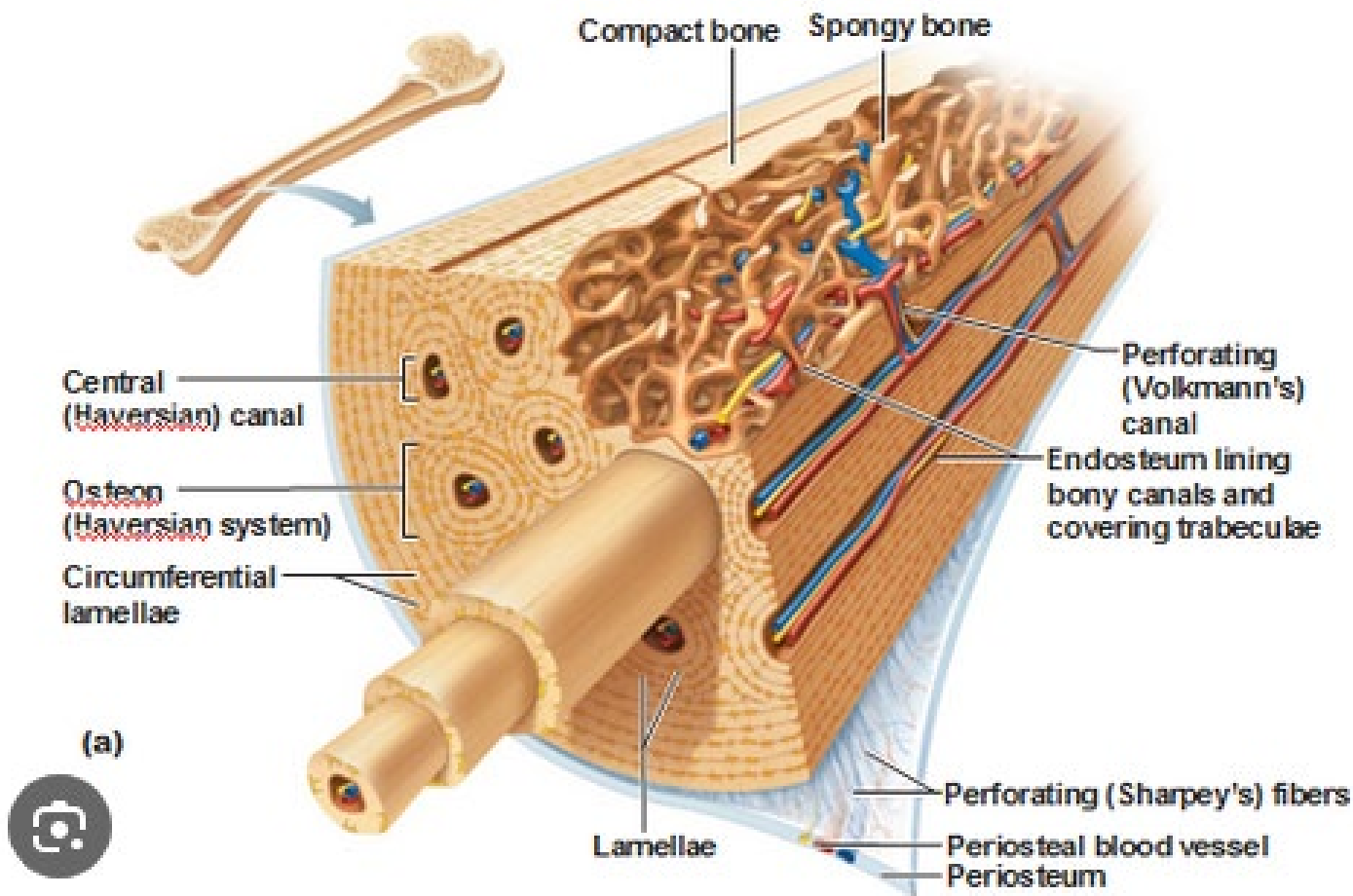


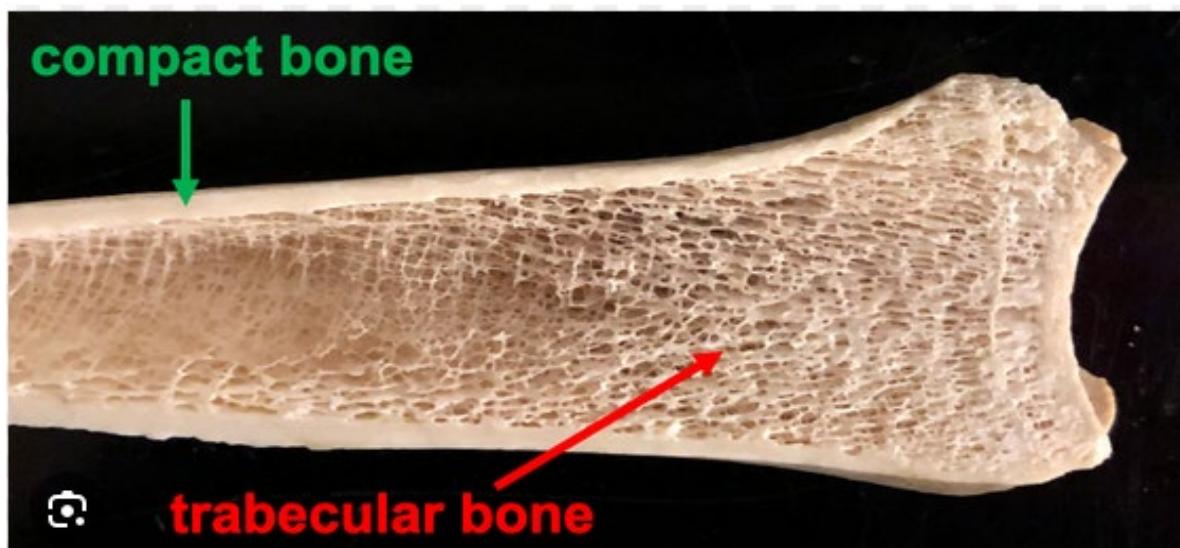
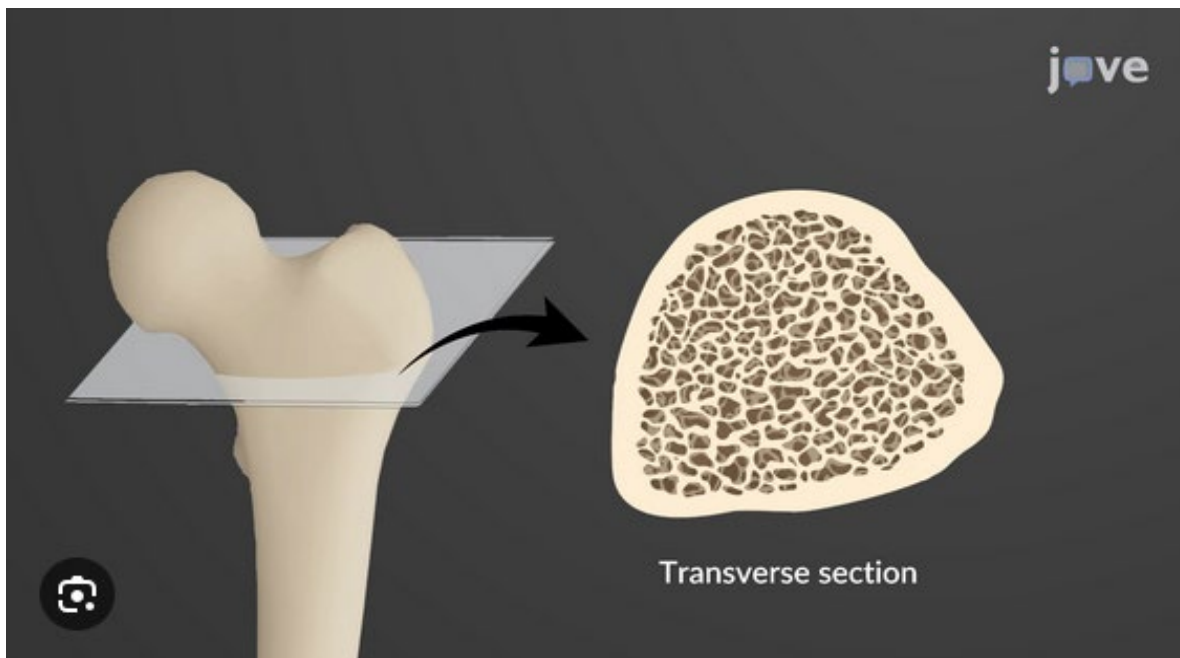
# Spongy Bone (Cancellous Bone)

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- sponge-like appearance // but as hard as compact bone
- spongy bone consists of:
  - slivers of bone called **spicules**
  - thin plates of bone called **trabeculae**
  - spaces filled with **bone marrow**
- fewer osteons and no central canals
- all osteocytes close to bone marrow
- provides strength with minimal weight // trabeculae develop along bone's lines of stress

# Microscopic Structure of Compact Bone





Trabecular bone = spongy bone

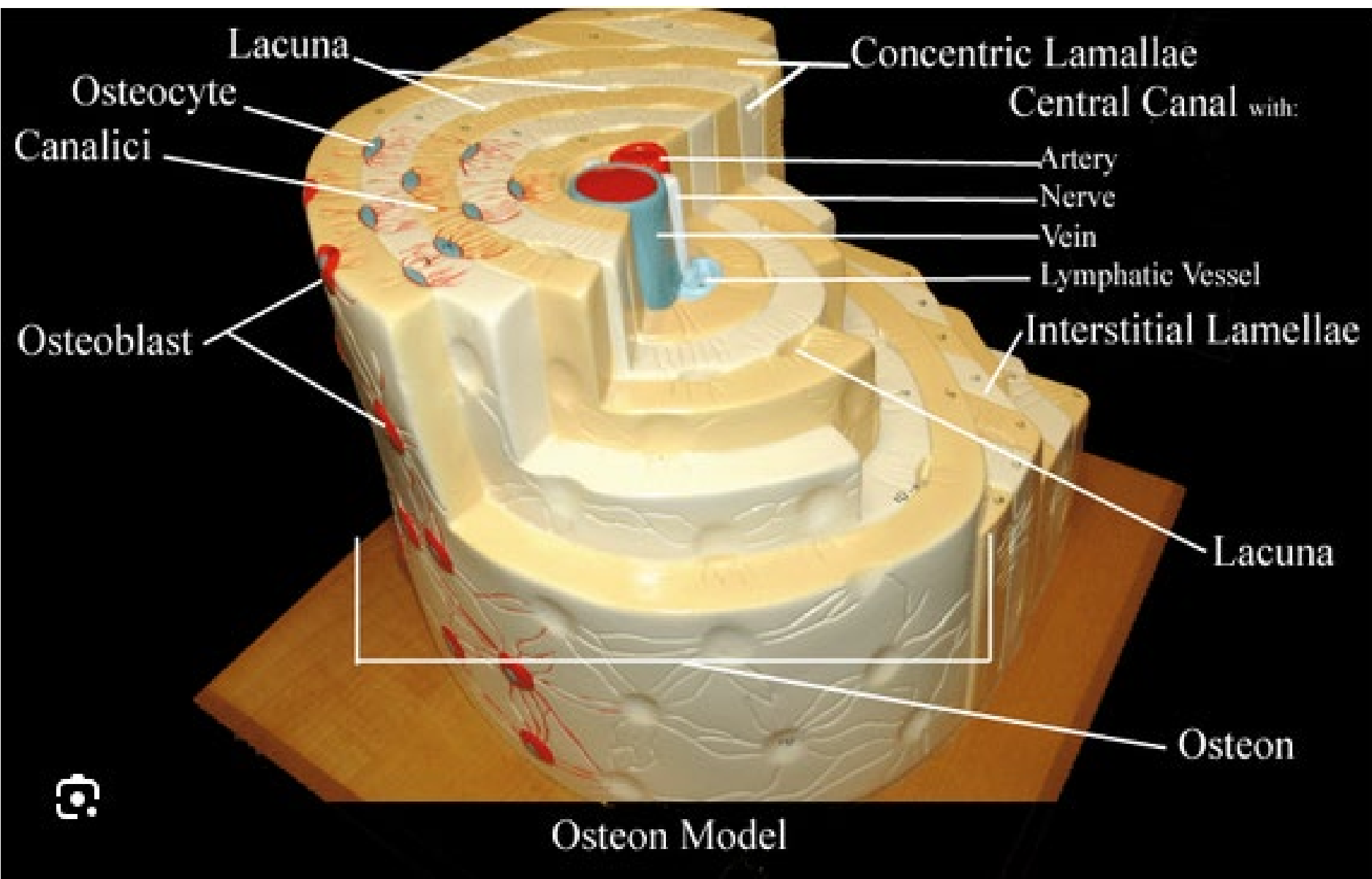
# Three Types of Lamellae in Compact Bone

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–concentric lamellae // forms matrix around central canal

–circumferential lamellae // inner and outer boundaries of dense bone // run parallel to bone surface

–interstitial lamellae // remains of old osteons // as bone is remodeled some osteons are “eroded” // the fragments of old osteons are referred to as interstitial lamellae



# Matrix Failed Homeostasis

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**Rickets** – soft bones due to deficiency of calcium salts

**Osteogenesis imperfecta** - brittle bone disease  
// excessively brittle bones due to lack of the protein fiber collagen

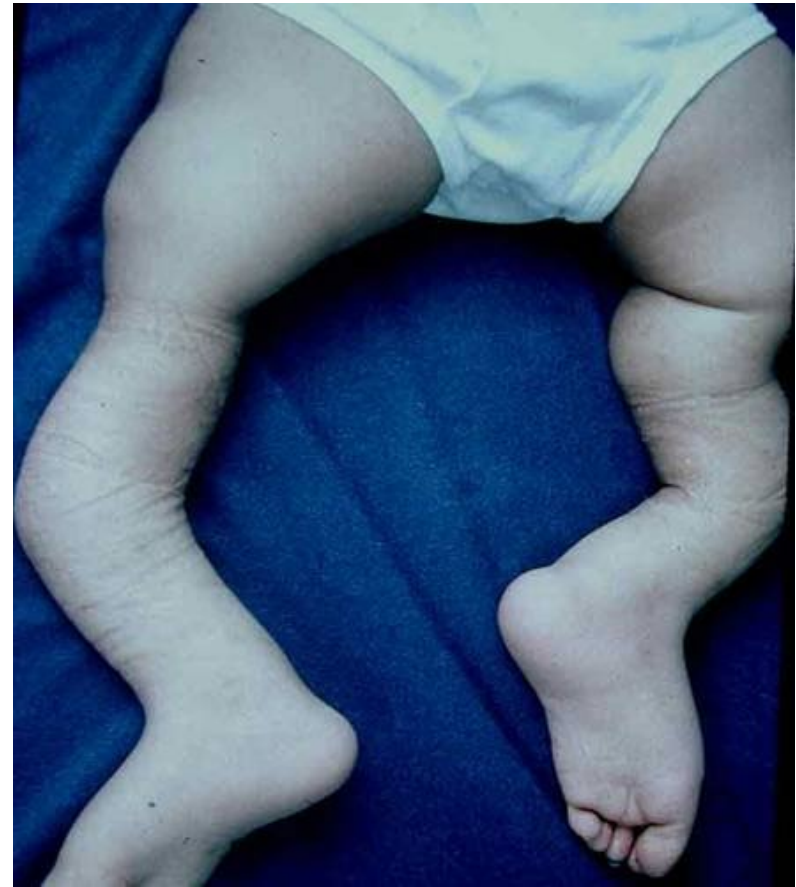
# Rickets

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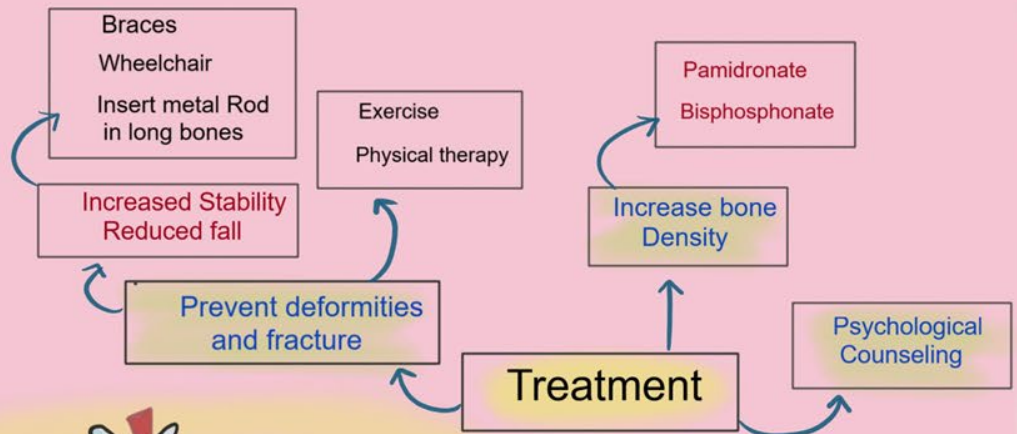
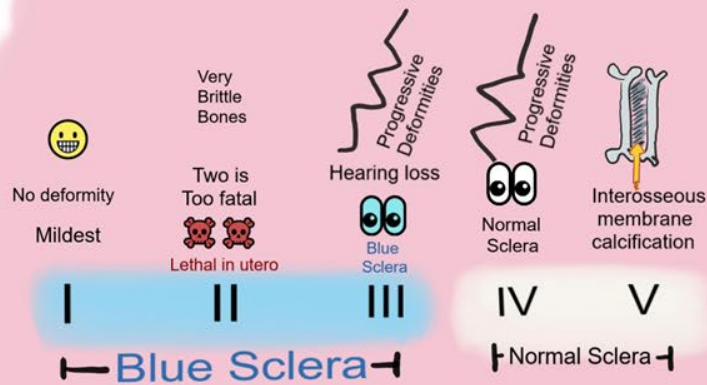


# Osteogenesis Imperfecta

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B One STD most affected  
Bone, Skin, Tendon, Dentin

Triple Helix synthesis  
Defect



Type I

Collagen defect

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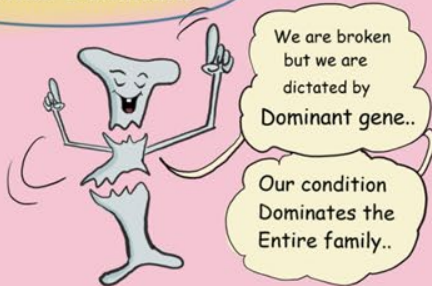


*Osteogenesis imperfecta*

Bone formation is  
Imperfect (reduced)

Creative-Med-Doses

Autosomal Dominant



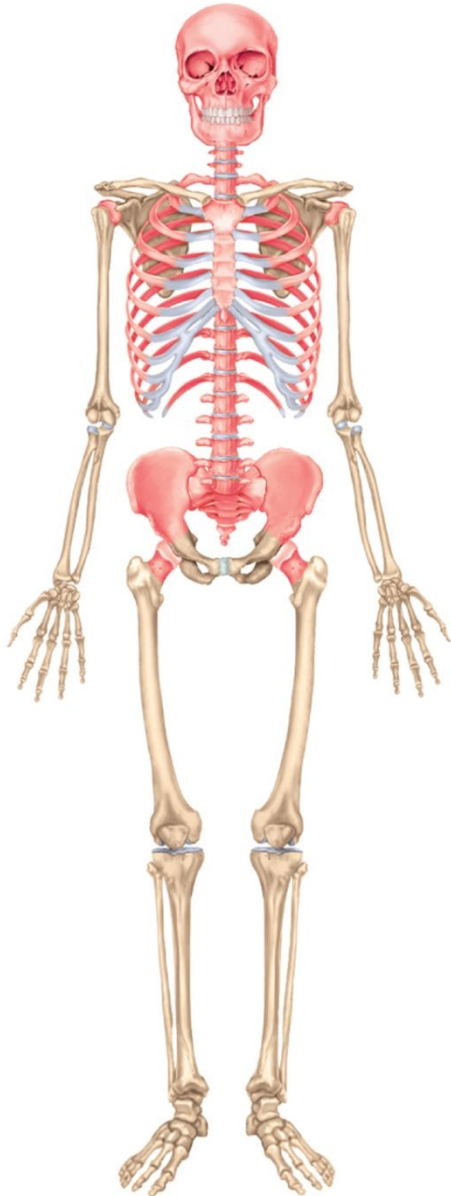
I lost my Looks..

Broken enough to get deformed..

Walk diligently..  
Coz I am Fragile..

Reduced Bone density  
Fragile bones  
Multiple fractures  
Deformities

# Bone Marrow



- bone marrow** – general term for soft tissue that occupies the marrow cavity of a long bone and small spaces amid the trabeculae of spongy bone

- red marrow (myeloid tissue)**

- in nearly every bone in a child

- hemopoietic tissue** - produces blood cells and is composed of multiple tissues in a delicate, but intricate arrangement that is an organ to itself

- in adults, found in **skull, vertebrae, ribs, sternum**, part of **pelvic girdle**, and **proximal heads of humerus and femur**

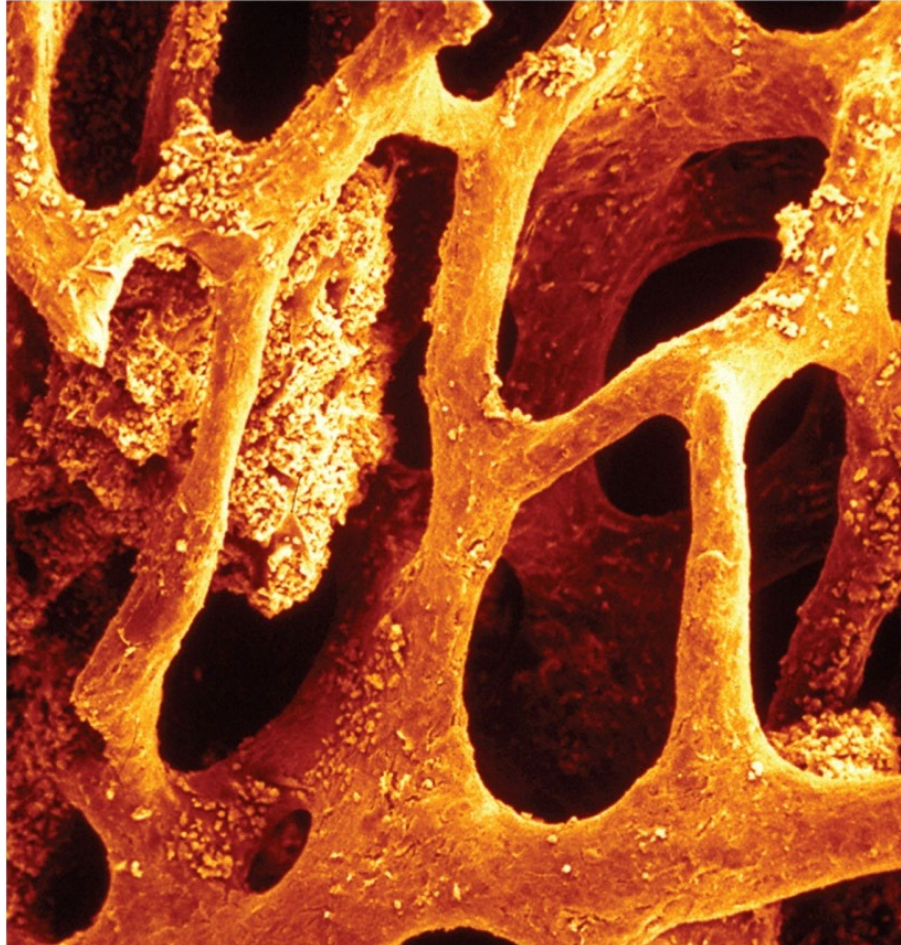
- yellow marrow** found in adults

- most red marrow turns into fatty yellow marrow

- no longer produces blood

## Chapter 7.2

# Bone Development



# Bone Development in Fetal Growth

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- **Ossification or osteogenesis** = the formation of new bone
- Bone grows differently during fetal-infant and adult stages
- **In fetal and infant bone growth occurs by:**
  - intramembranous ossification
  - endochondral ossification
- **In adults bone growth occurs by:**
  - interstitial ossification – increases length (stop at 20yr)
  - appositional ossification – increases diameter (continues throughout life)

# Intra-membranous Ossification

---

- these bones develop within a **fibrous membrane similar to the epidermis** of the skin (**dermal bones**)
  - mesenchyme** – embryonic connective tissue condenses into a layer of soft tissue with dense supply of blood capillaries
  - mesenchymal cells** differentiate into **osteogenic cells**
  - regions of mesenchyme become a network of soft sheets – **trabeculae**
  - osteogenic cells differentiate into **osteoblasts**
  - these cells deposit organic matrix – **osteoid tissue**



# Intramembranous Ossification

---

- as trabeculae grow thicker, calcium phosphate is deposited in the matrix
- mesenchyme close to the surface of a trabecula remains uncalcified // becomes denser and more fibrous, forming periosteum
- osteoblasts continue to deposit minerals // producing a honeycomb of bony trabeculae
  - some persist as permanent spongy bone
  - osteoclasts resorb and remodel others to form a marrow cavity in the middle of bone
- trabeculae at the surface continue to calcify until the spaces between them are filled in, converting spongy bone to compact bone
- gives rise to the sandwich-like arrangement of mature flat bone

# Endochondral Ossification

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- process in which bone develops from pre-existing hyaline cartilage model
  - beginning the 6<sup>th</sup> fetal week and ending in early 20's
  - most bones develop by this process
- mesenchyme develops into a body of hyaline cartilage in location of future bone
  - covered with fibrous perichondrium /// perichondrium produces chondrocytes initially, and later produces osteoblasts
  - osteoblasts form a bony collar around middle of cartilage model
  - former perichondrium is now considered to be periosteum

# Endochondral Ossification

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–**primary ossification center** - chondrocytes in the middle of the model enlarge

- matrix between lacunae are reduced to thin walls
- walls of this thin matrix ossify and block nutrients from reaching chondrocytes
- they die and their lacunae merge into a single cavity in the middle of the model

- blood vessels penetrate the bony collar and invade primary ossification center

–**primary marrow cavity** – forms from blood and stem cells filling hollow cavity



# Endochondral Ossification

---

- blood vessels penetrate the bony collar and invade **primary ossification center**

- **primary marrow cavity** – forms from blood and stem cells filling hollow cavity

- stem cells give rise to osteoblasts and osteoclasts

- osteoblasts line cavity and deposit osteoid tissue and calcify it

- forming temporary network of trabeculae

- wave of cartilage death progresses toward the ends

- osteoclasts follow the wave dissolving the cartilage remnants enlarging the marrow cavity

- **metaphysis** – region of transition from cartilage to bone at each end of primary marrow cavity

# Endochondral Ossification

---

- secondary ossification center – created by chondrocyte enlargement and death in the epiphyses
- become hollowed out by the same process generating a secondary marrow cavity in epiphyses
- cavity expands outward from the center in all directions

# Postpartum Bone Growth

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- During infancy and childhood, the hyaline epiphyses fill with spongy bone
- As bone matures the cartilage limited to the **articular cartilage** covering each joint surface, and to the **epiphyseal plate**
  - a thin wall of cartilage separating the primary and secondary marrow cavities
  - epiphyseal plate **persists through childhood** and adolescence
  - serves as a growth zone for bone elongation

# Postpartum Bone Growth

---

- By late teens to early twenties, all remaining cartilage in the epiphyseal plate is generally calcified
  - gap between epiphyses and diaphysis closes
  - primary and secondary marrow cavities unite into a single cavity
  - bone can no longer grow in length
  - epiphyseal line “remains” as shadow of old epiphyseal plate

# Bone Growth and Remodeling After Birth

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- ossification continues throughout life with the growth and remodeling of bones

- bones grow in two directions

- length (interstitial) – stops in early 20's

- width (appositional) – continues throughout

- elongation occurs at epiphyseal plate

- after it closes, bone can still remodel itself by changing the width and/or shape of long bones

# Bone Growth and Remodeling After Birth

---

- interstitial growth = bone elongation

- epiphyseal plate – a region of transition from cartilage to bone

- functions as growth zone where the bones elongate

- consists of typical hyaline cartilage in the middle

- with a transition zone on each side where cartilage is being replaced by bone

- metaphysis is the zone of transition facing the marrow cavity

# Bone Growth and Remodeling After Birth

---

- interstitial growth

- bones increase in length

- bone elongation is really a result of cartilage growth within epiphyseal plate

- epiphyses close when cartilage is gone forming the **epiphyseal line**

- length-wise growth is completed // occurs at different ages in different bones

# Bone Growth and Remodeling After Birth

---

- **Appositional Growth**

- bones increase in width throughout life

- the deposition of new bone at the surface

- osteoblasts on deep side of periosteum deposit osteoid tissue / become trapped as tissue calcifies

- **circumferential lamellae** = matrix in layers parallel to surface

- forms over surface

- osteoclasts under endosteum enlarge marrow cavity



# Bone Growth and Remodeling

---



- **Bone remodeling** occurs throughout life - 10% per year

–repairs microfractures, releases minerals into blood, reshapes bones in response to use and disuse

## –**Wolff's Law of Bone**

- architecture of bone determined by mechanical stresses placed on it and bones adapt to withstand those stresses
- remodeling is a collaborative and precise action of osteoblasts and osteoclasts
- bony processes grow larger in response to mechanical stress
- Tendons' pull on periosteum and matrix produce “stress” and osteoblasts and osteoclast respond to physical forces

# Dwarfism



- **Achondroplastic dwarfism**

- long bones stop growing in childhood // **normal torso, short limbs / more common**

- failure of cartilage growth in metaphysis

- spontaneous mutation produces mutant dominant allele



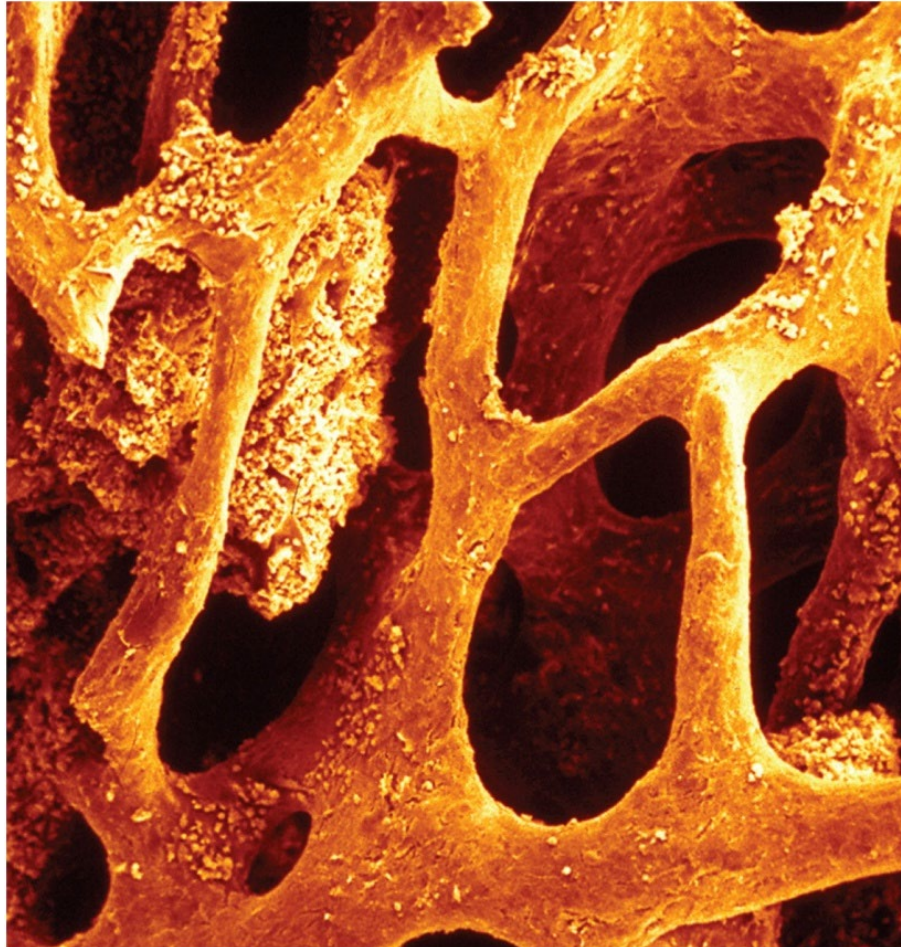
- **Pituitary dwarfism**

- lack of growth hormone

- normal proportions with short stature**

## Chapter 7.3

# Bone Fracture & Repair



# Fractures and Repair

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**Stress fracture** – break caused by abnormal trauma to a bone /// falls, athletics, and military combat

**Pathological fracture** – break in a bone weakened by some other disease // **bone cancer or osteoporosis** // **usually caused by stress that would not break a healthy bone**

**Fractures** classified by structural characteristics

- direction of fracture line
- break in the skin
- multiple pieces

**Uncomplicated fractures**

- normally take **8 - 12 weeks to heal**
- longer in elderly

# Stages of Healing Bone Fractures (#1)

Fracture results in hematoma followed by development of granulation tissue

- bleeding of a broken bone forms a clot – fracture hematoma // immune cells like neutrophils and macrophage enter area
- granulation tissue – soft fibrous mass is produced includes new capillary networks growing into hematoma
- cellular invasion // after about 48 hours after injury // chondrocytes enter area
- fibroblasts, osteoclasts, and osteogenic cells follow chondroblast enter area to further develop granulation tissue

## Stages of Healing Bone Fractures (#2)

**Soft callus formation ///** formed by fibroblasts and chondroblasts depositing collagen and fibrocartilage into granulation tissue

# Stages of Healing Bone Fractures (#3)

## Conversion to hard callus

osteoblasts produce a bony collar in 6 weeks called a hard callus

hard callus is cemented to dead bone around the injury site and acts as a temporary splint to join broken ends together

4 - 6 weeks for hard callus to form and immobilization is necessary

# Stages of Healing Bone Fractures (#4)

## Remodeling

hard callus persists for 3 – 4 months

osteoclasts dissolve fragments of broken bone

osteoblasts deposit spongy bone to bridge to gap between the broken ends, transformed gradually into compact bone that is thicker in fracture area

**–Note: Vitamin A, vitamin C, and vitamin D are required nutritional factors for growth and repair**



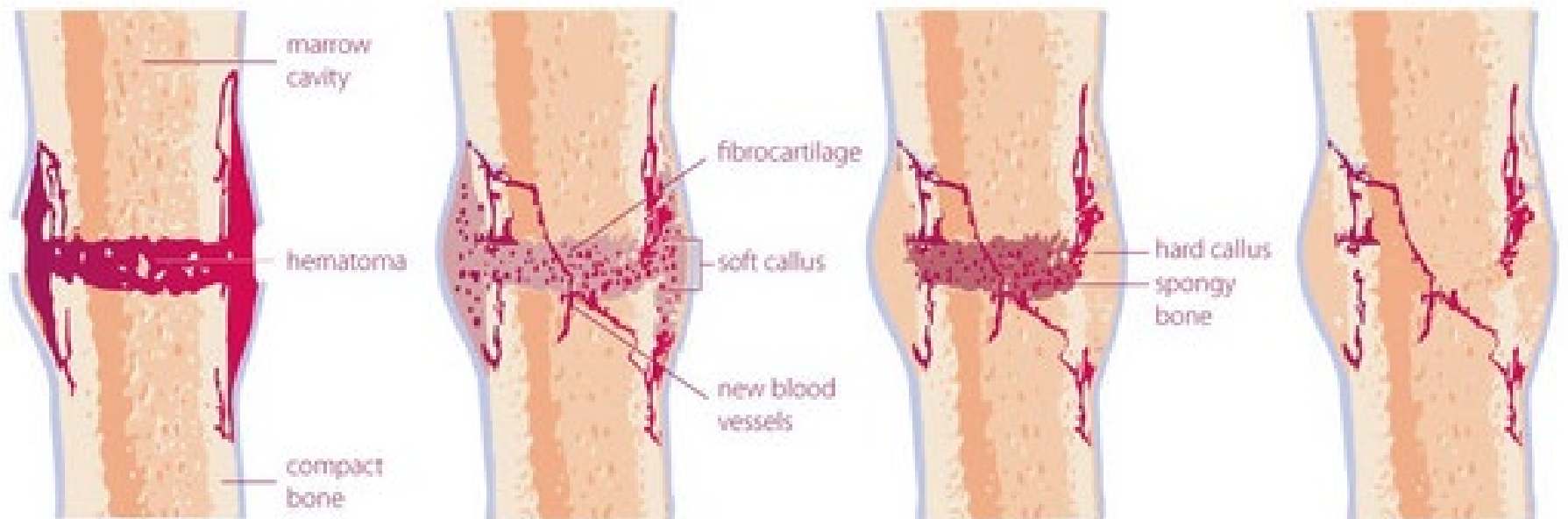
# Treatment of Fractures

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Cast – normally used to stabilize and immobilize healing bone

Electrical stimulation accelerates repair // suppresses the effects of parathyroid hormone

Orthopedics – the branch of medicine that deals with prevention and correction of injuries and disorders of the bones, joints, and muscles

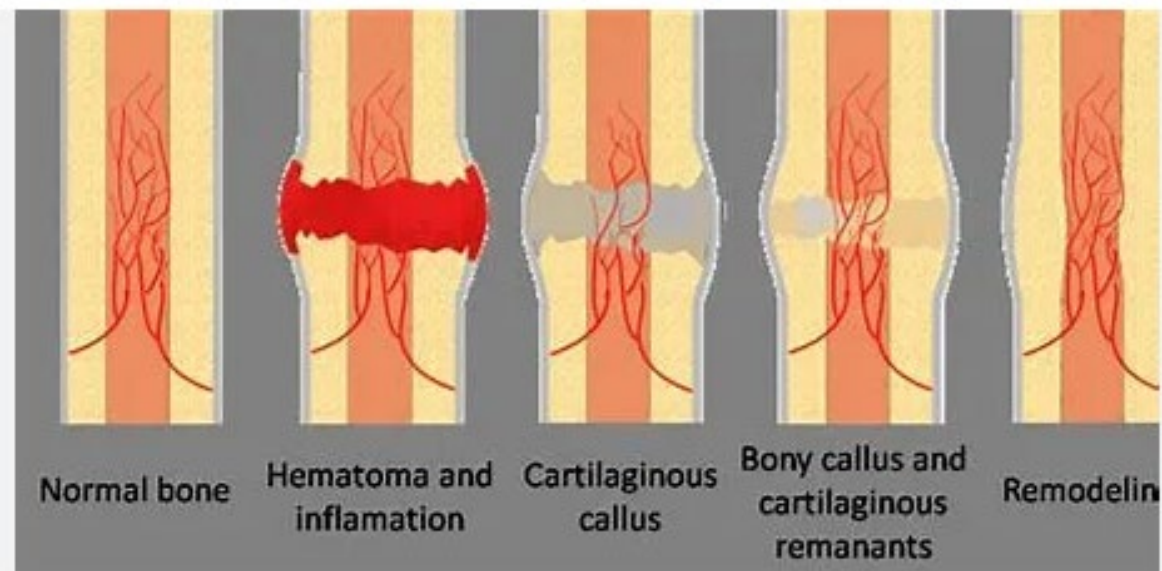


1. hematoma formation  
**0 - 2 weeks**

2. Soft callus formation  
**2 - 3 weeks**

3. Hard callus formation  
**3 - 6 weeks**

4. Bone remodeling  
**8 weeks - 2 years**



# Treatment of Fractures

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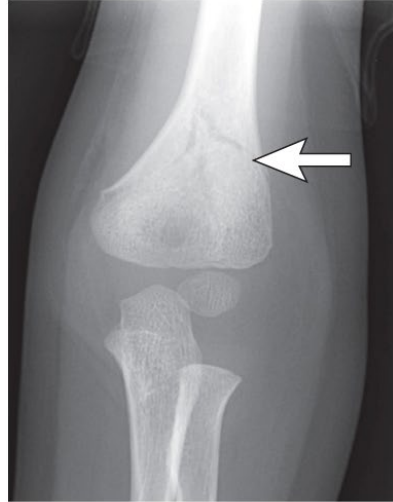
Traction used to treat fractures of the femur in children // Aligns bone fragments by overriding force of the strong thigh muscles

Risks long-term confinement to bed

Rarely used for the elderly

Hip fractures are usually pinned in elderly and early ambulation (walking) is encouraged to promote blood circulation and healing

# Types of Bone Fractures



**(a) Nondisplaced**

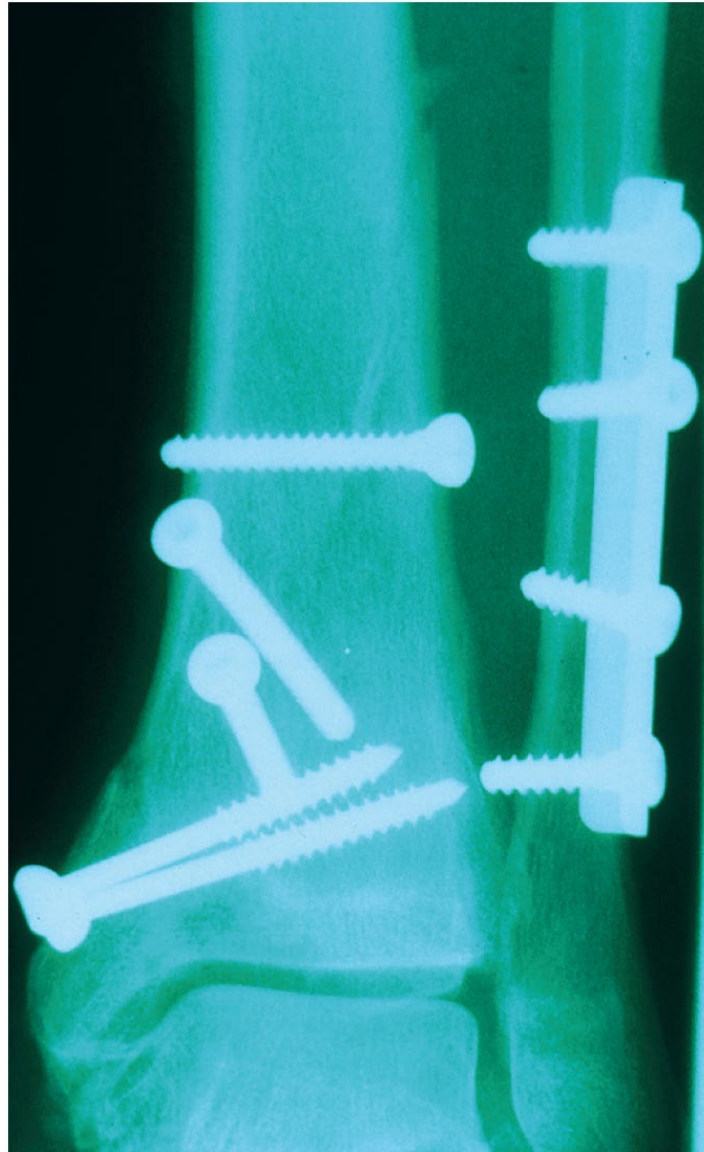


**(c) Comminuted**



**(d) Greenstick**

# X-Ray of Fractures and Their Repairs



# Osteoporosis

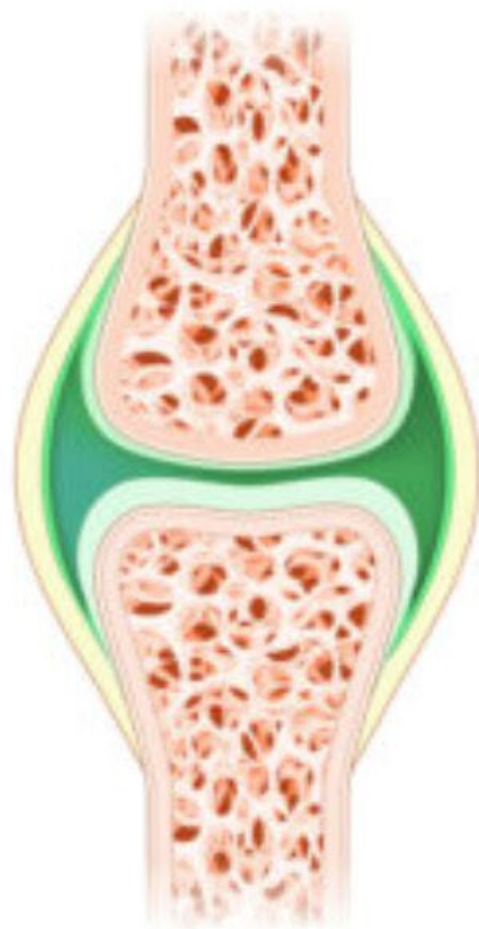
A medical condition in which the bones become brittle and fragile from loss of tissue, typically, as a result of hormonal changes, or deficiency of calcium or vitamin D.

Estrogen inhibits osteoclast. After menopause, the ovaries no longer secrete estrogen. Osteoclast become more active and erode bone mass especially the spongy bone

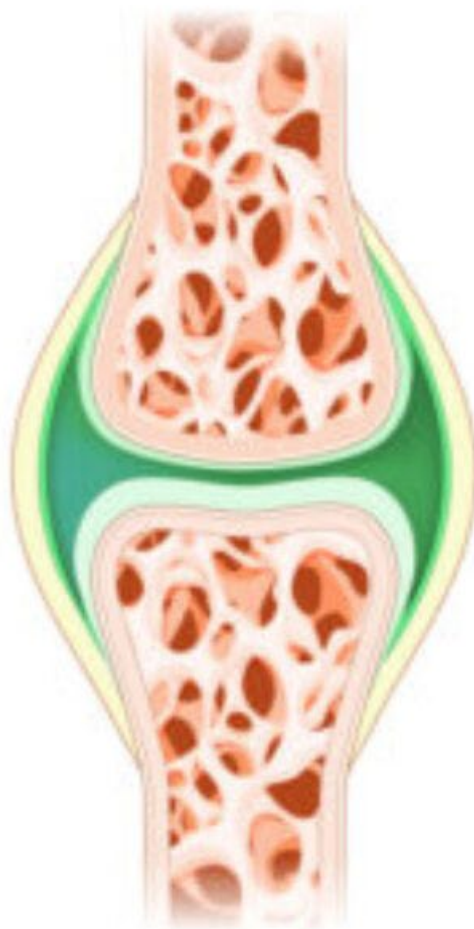
Five Symptoms:

- Fragility-related fractures. These occur when even mild impact causes a fracture of the
  - wrist, back, hip or other bones.
- > Height loss. More than two inches in height can be lost over time.
- > Receding gums. ...
- > A curved, stooped shape to the spine. ...
- > Lower back pain.

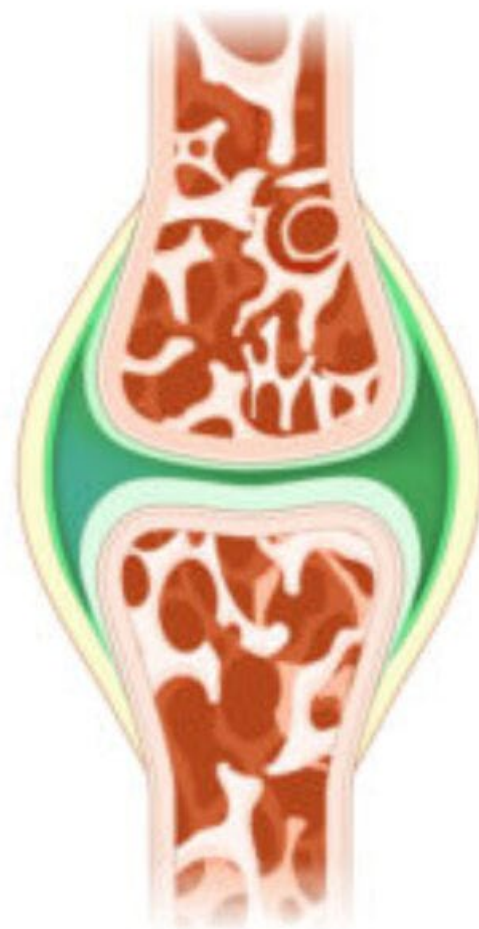
# Stages of osteoporosis



Healthy bone

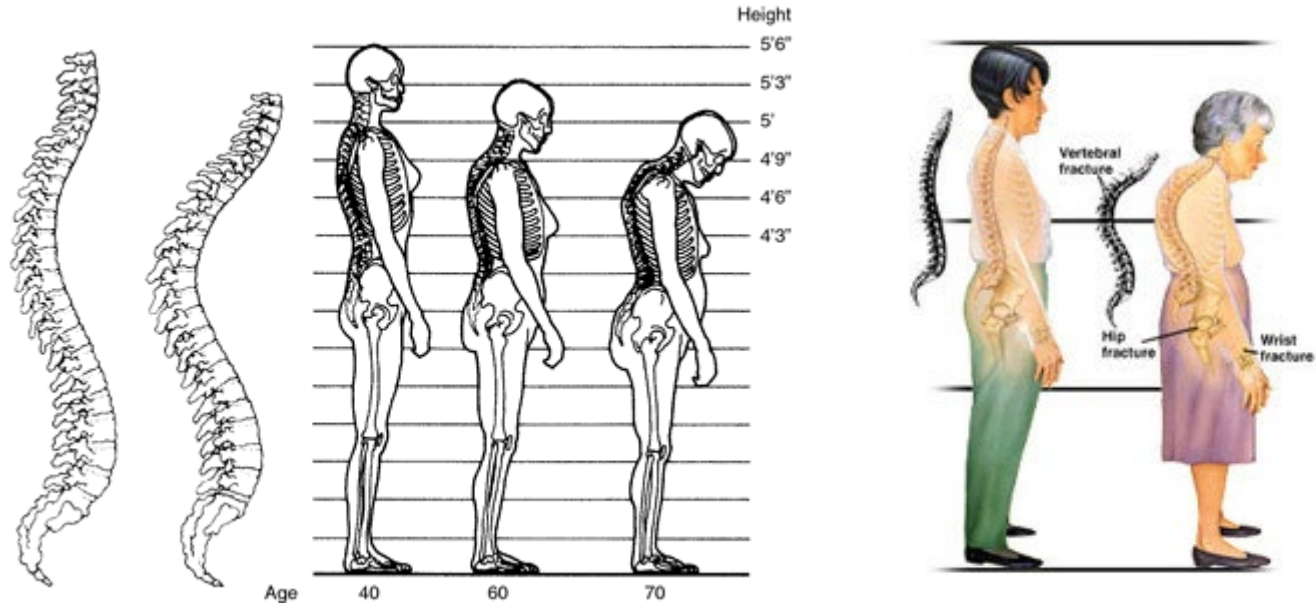


Osteoporosis



Severe osteoporosis

# Osteoporosis





# Osteoporosis

