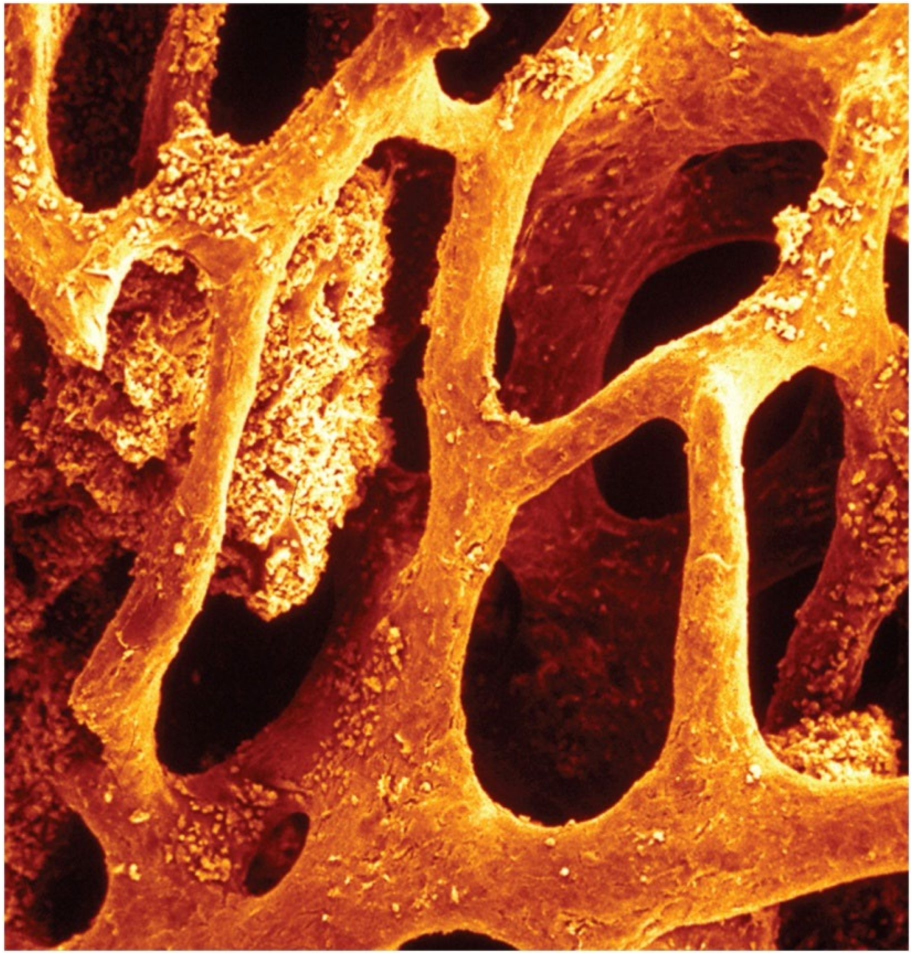
Chapter 7.1

Bone Tissue



Functions of the Skeleton

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

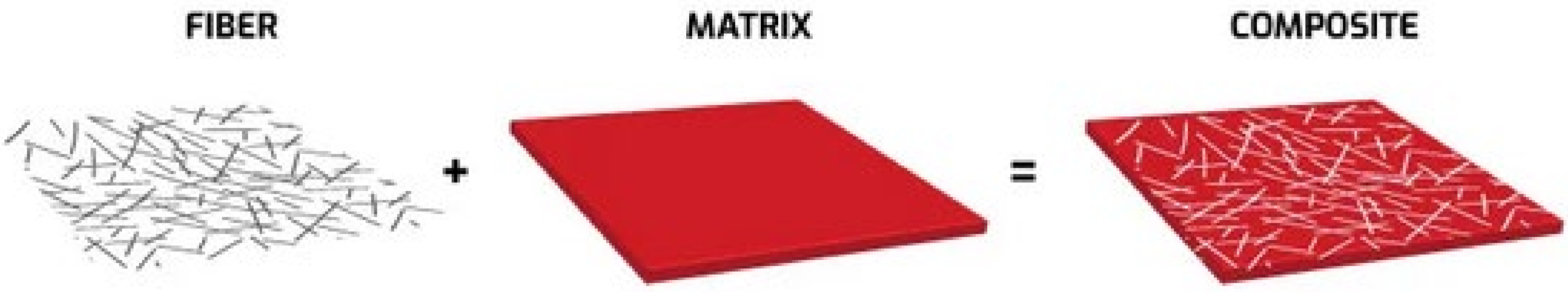
blood formation – red bone marrow is the chief producer of blood cells

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 these fibers by exocytosis.

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

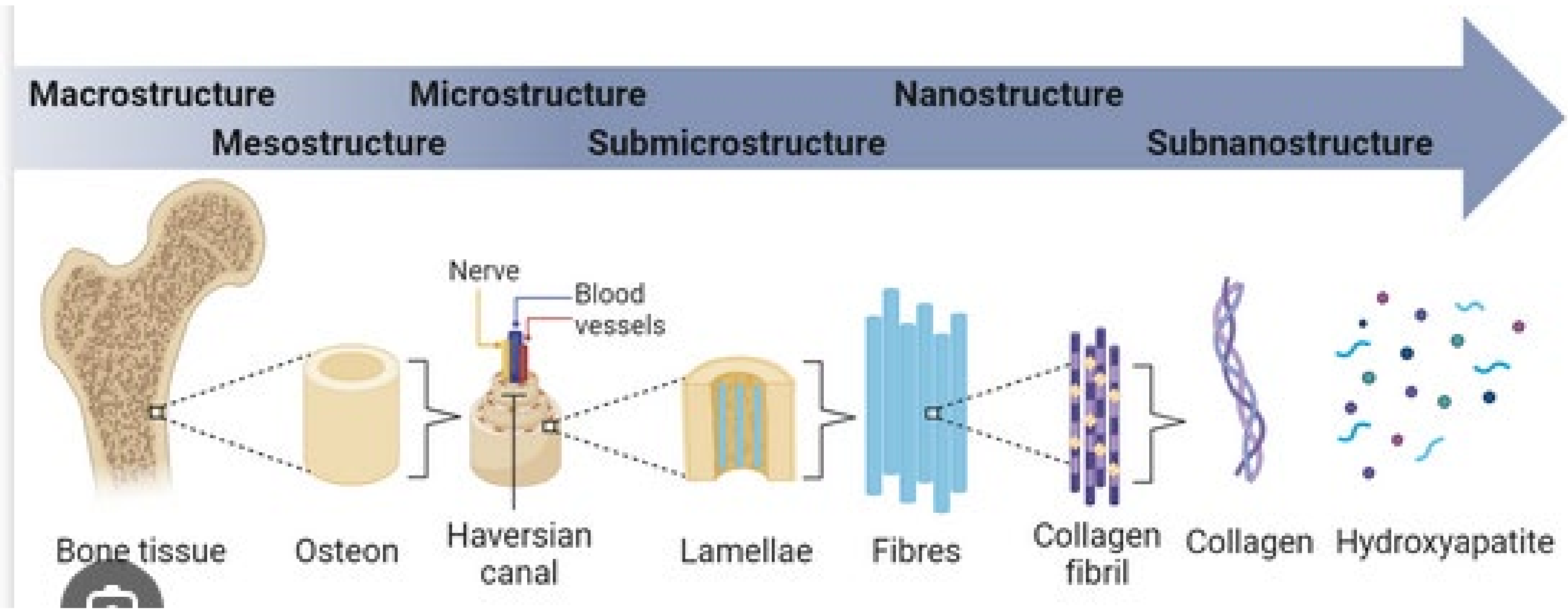


Bone Is Osseous Tissue

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

Consist of…..

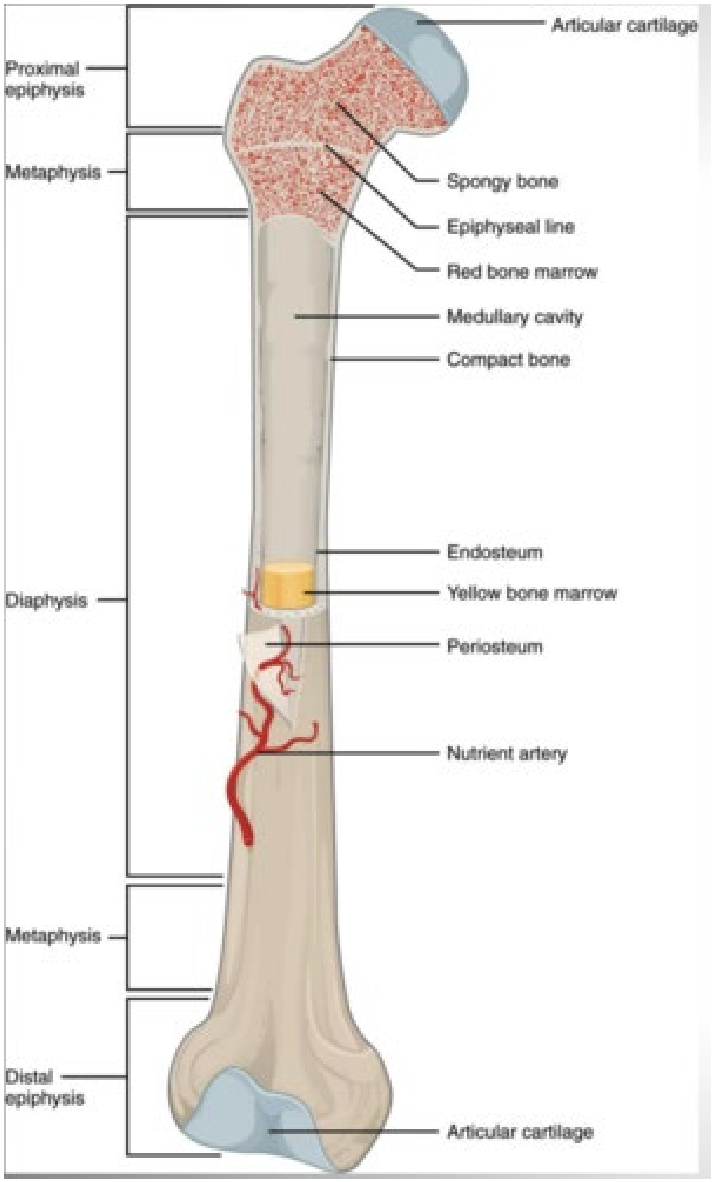
- –bone (cells and matrix)
- –compact and spongy bone
- –bone marrow (red & yellow)
- –cartilage
- –adipose tissue
- –nervous tissue
- –fibrous connective tissue membanes
- –blood vessels

Structure of a Long Bone

(lab learning objective)

The articular cartilage is hyaline.

Endosteum // connective tissue membrane lining marrow cavity /// between membrane and bone there are osteogenic cells (osteoblast and osteoclast)



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

–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

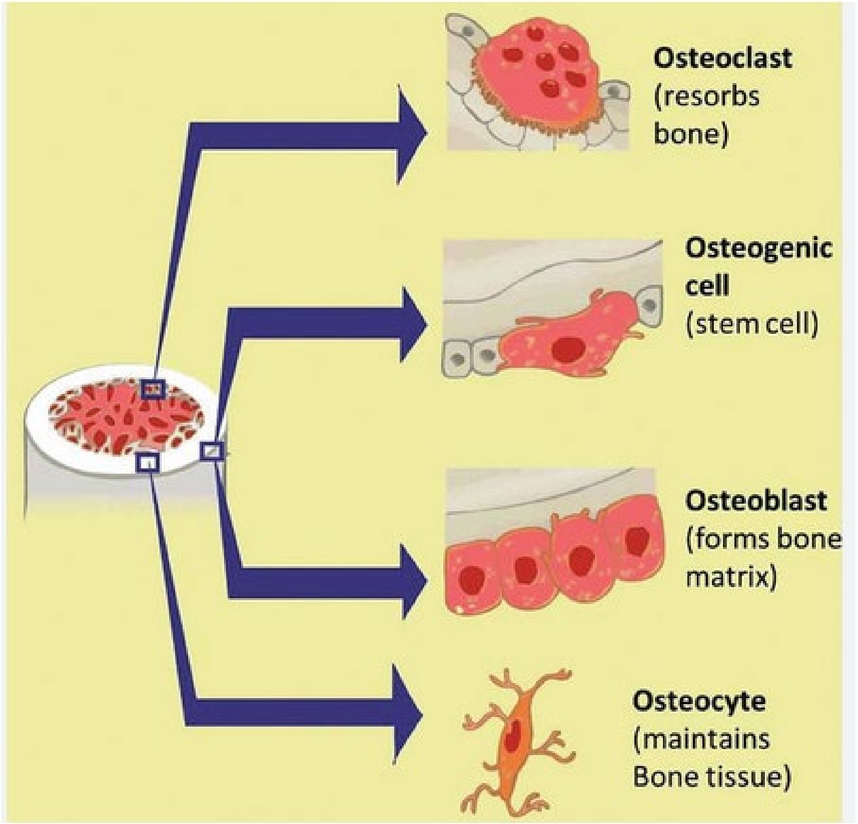
not present on articular surfaces (hyalin cartilage)

Bone Cells

Osteogenic vs Osteoblasts vs Osteoclast vs Osteocytes

One of the key characteristics of osteoblasts, osteocytes, and osteoclasts is that **they do not undergo mitosis**.

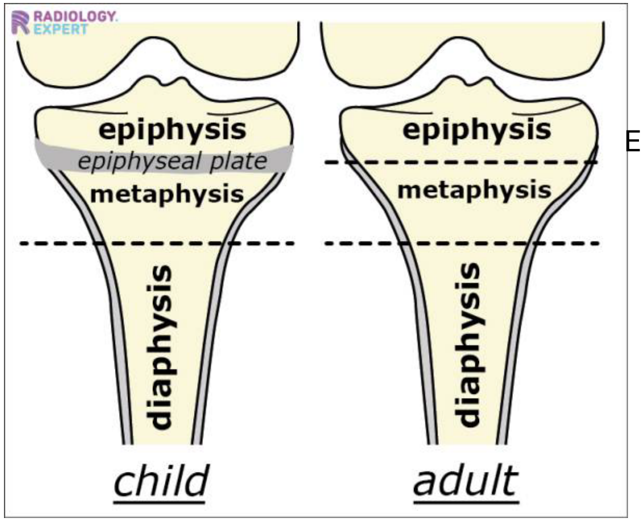
Only the osteogenic stem cells may undergo mitosis



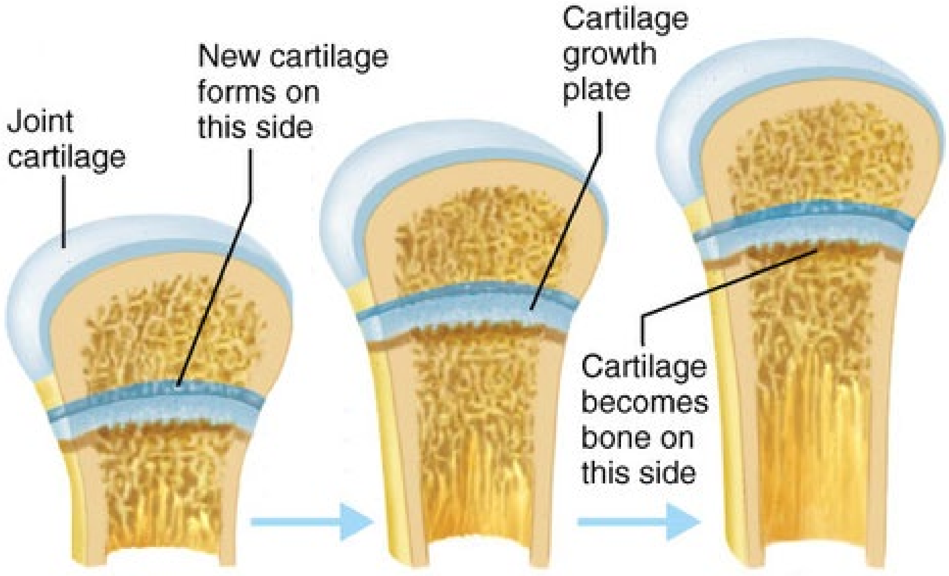
About Bone Growth

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

Epiphyseal line // epiphyseal plate is ossified // this occurs about age 20 // in adults, a bony scar marks where growth plate used to be

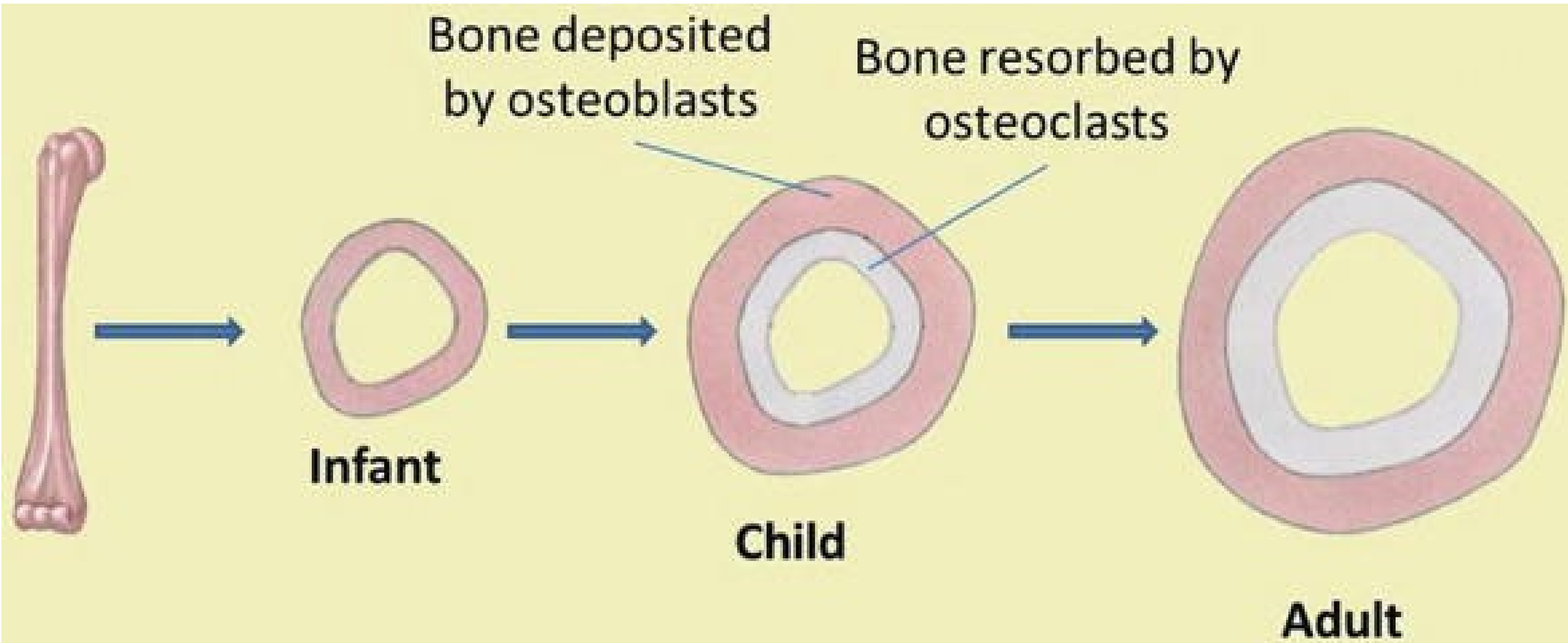


Epiphyseal line



Adults bone growth: interstitial ossification – increases length (stop at 20yr) /// appositional ossification – increases diameter (continues throughout life)

Appositional Ossification



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

<u>Osteoblast become osteocyte after surrounded by matrix</u>

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 “steam” into the canaliculi to connect osteocytes with the central canal (blood vessels)

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

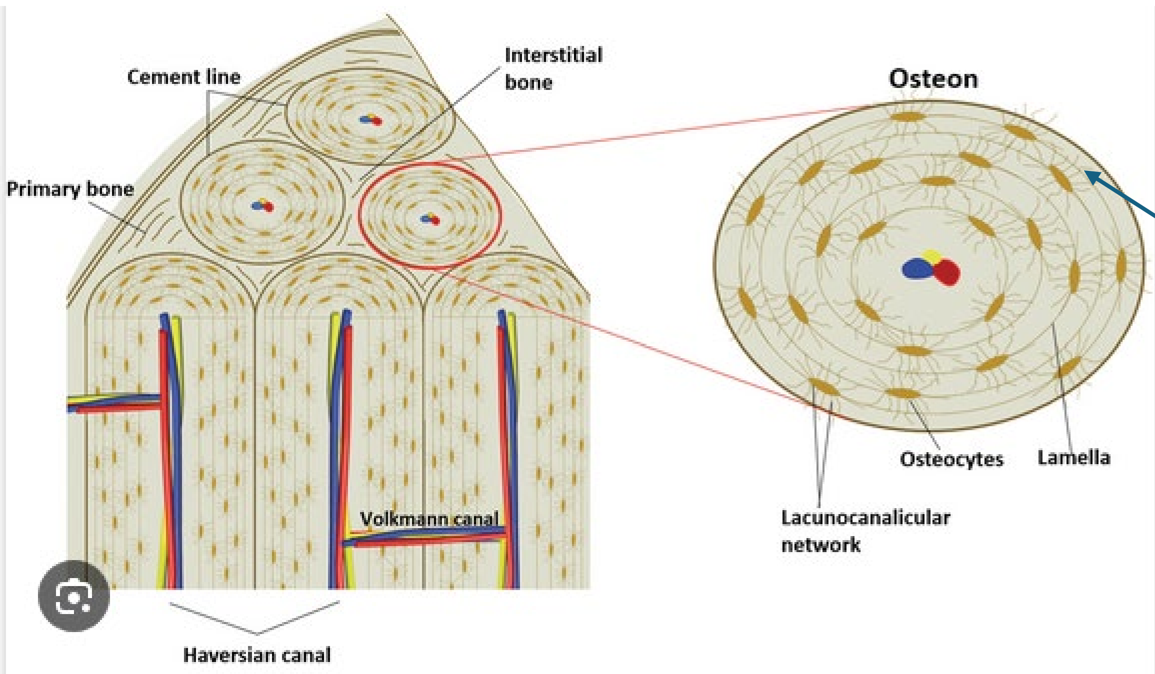
when stressed, produce biochemical signals that regulate bone remodeling

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

The Osteon

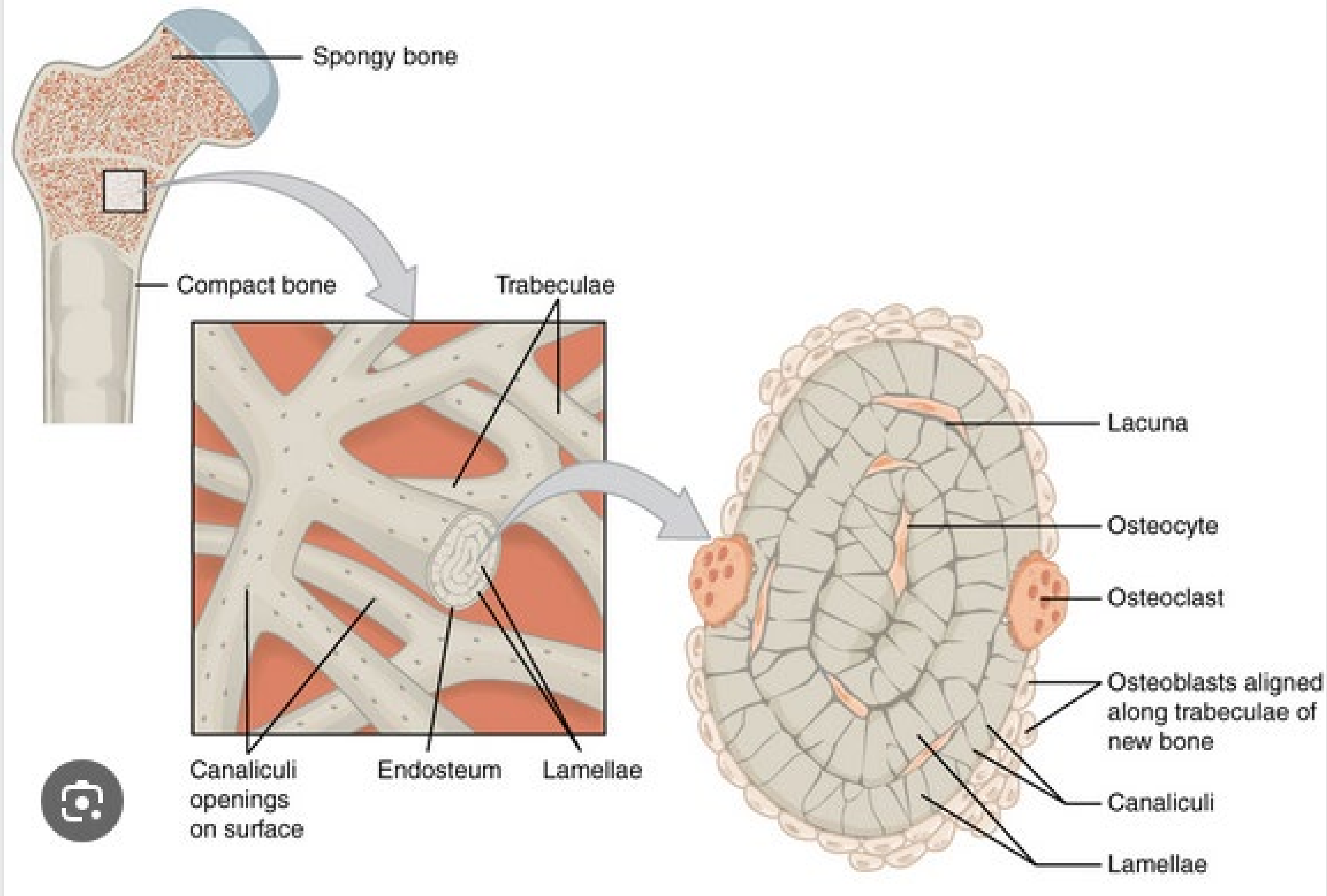
The functional unit of compact and cancellous bone is the osteon

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

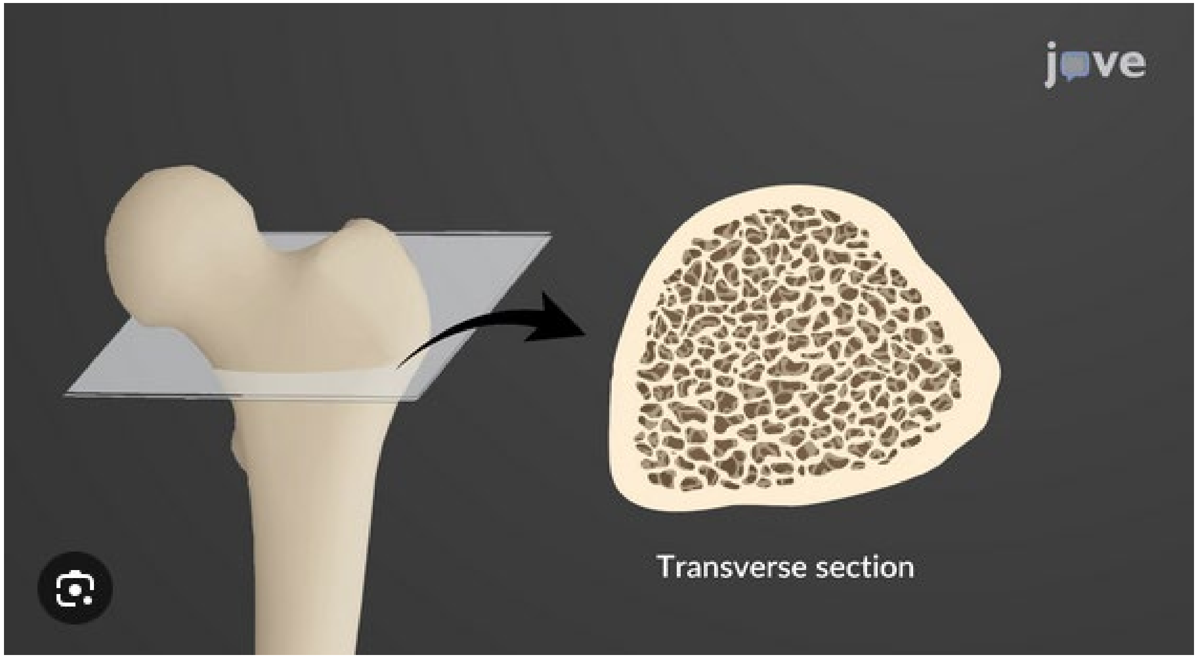


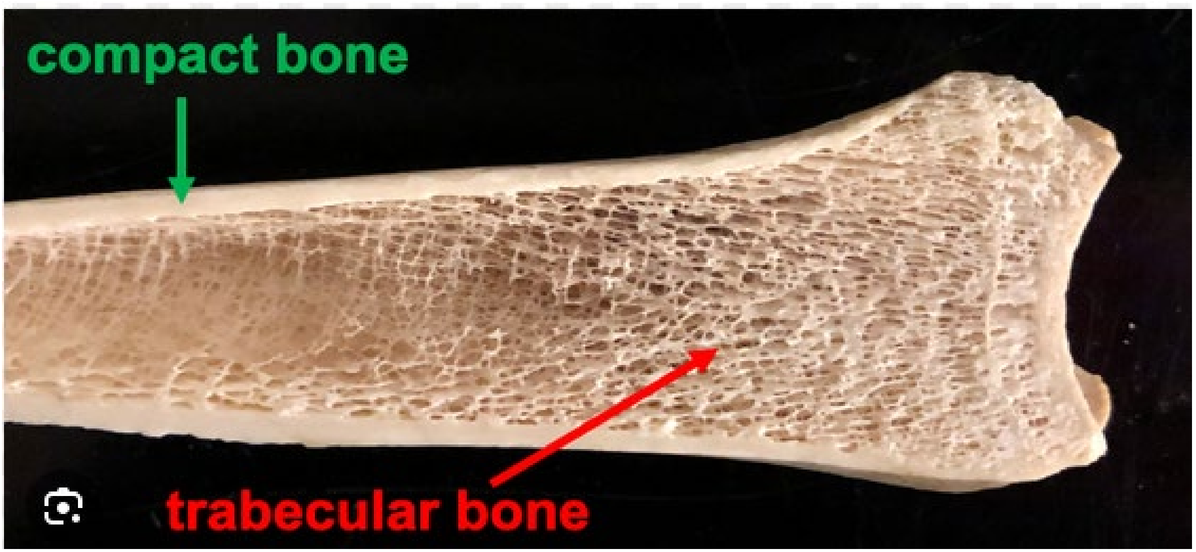
Osteon in compact bone

Canaliculi – "little canals" between central canal and osteocytes for diffusion of nutrient and waste products

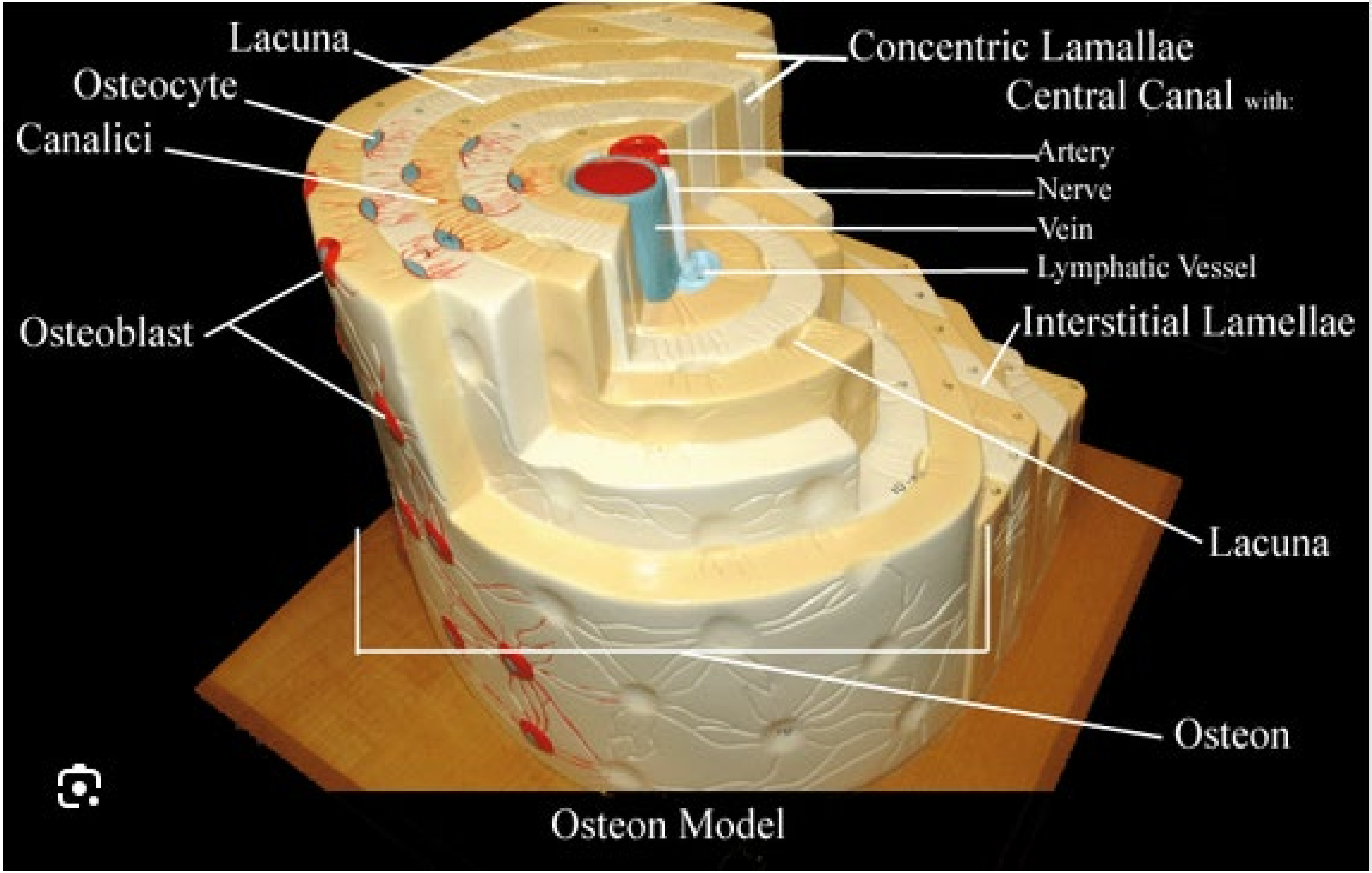


Osteon in spongy bone





Trabecular bone = spongy bone


Lacuna
Concentric Lamallae
Osteocyte
Central Canal with:
Canalici
Artery
Nerve
Vein
Lymphatic Vessel
Osteoblast
Interstitial Lamellae
Lacuna
Osteon
Osteon Model

Spongy Bone (Cancellous Bone)

sponge-like appearance // but as hard as compact bone

spongy bone consists of:

–slivers of bone called **spicules**

–thin plates of bone called **trabeculae**

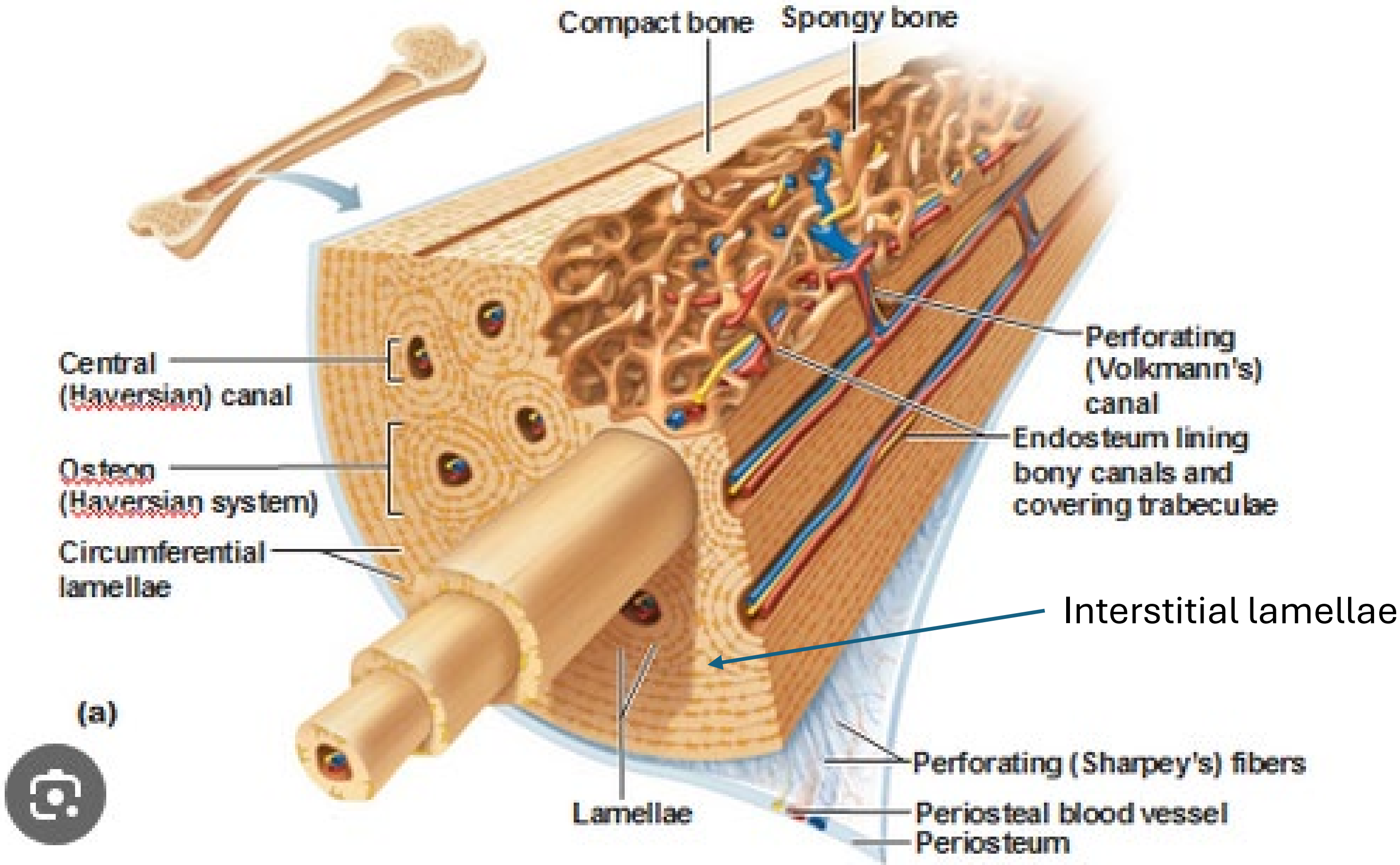
–spaces filled with **bone marrow**

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



Note: concentric lamellae surrounds central canal.

Three Types of Lamellae in Compact Bone

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

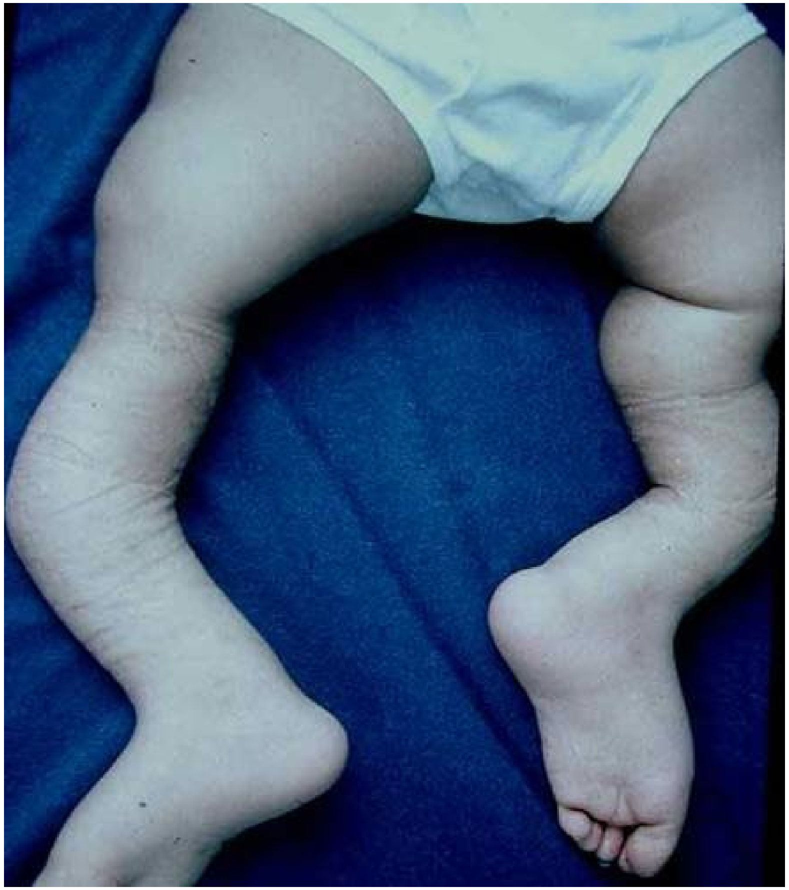
Matrix Failed

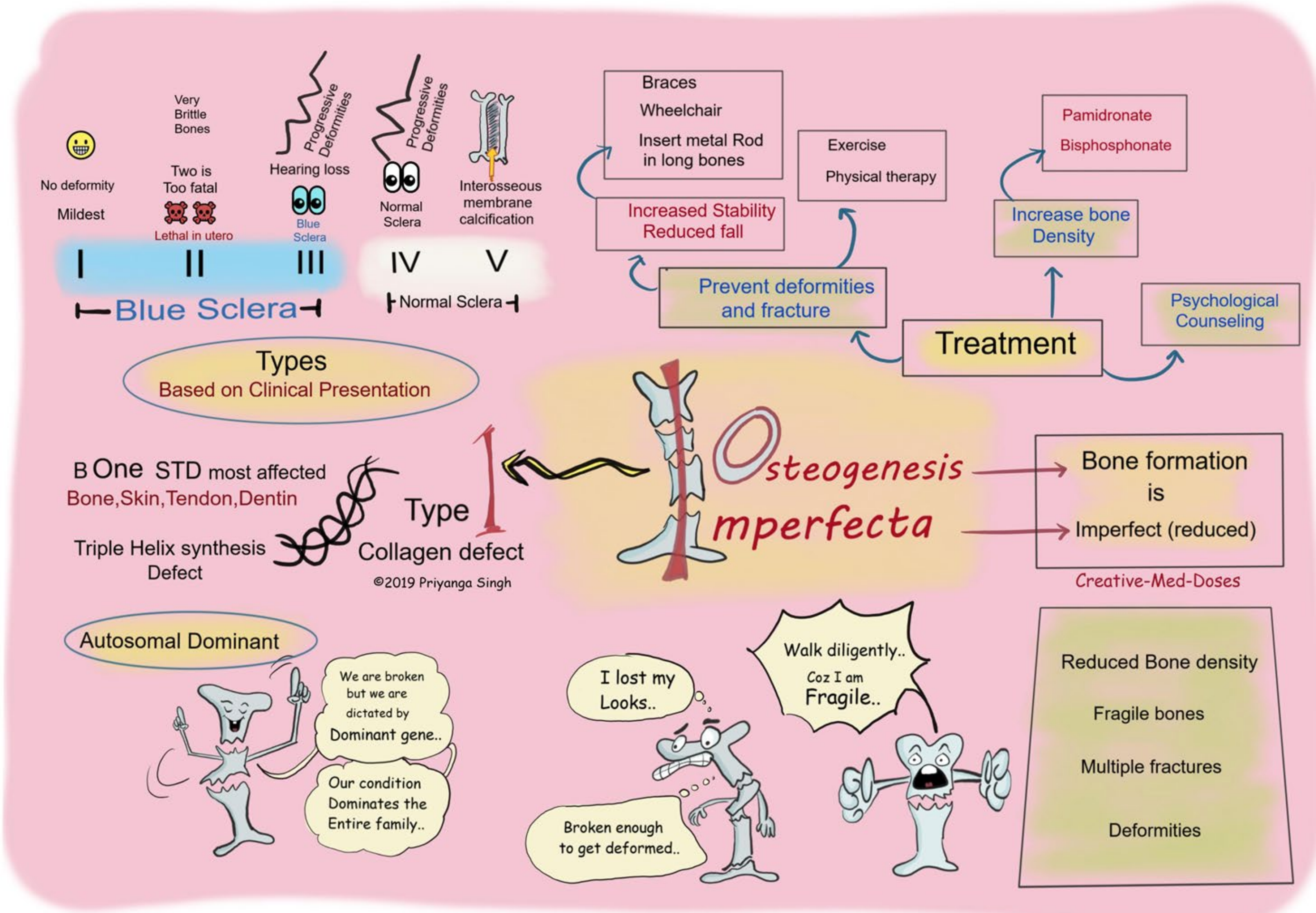
Rickets – soft bones due to deficiency of calcium salts

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

Rickets

Osteogenesis Imperfecta





Very Brittle Bones
No deformity
Mildest
Two is Too fatal
Lethal in utero
Progressive Deformities
Hearing loss
Blue Sclera
Progressive Deformities
Normal Sclera
Interosseous membrane calcification
I
II
III
IV
V
Blue Sclera
Normal Sclera
Types
Based on Clinical Presentation
B One STD most affected
Bone,Skin,Tendon,Dentin
Triple Helix synthesis Defect
Type I
Collagen defect
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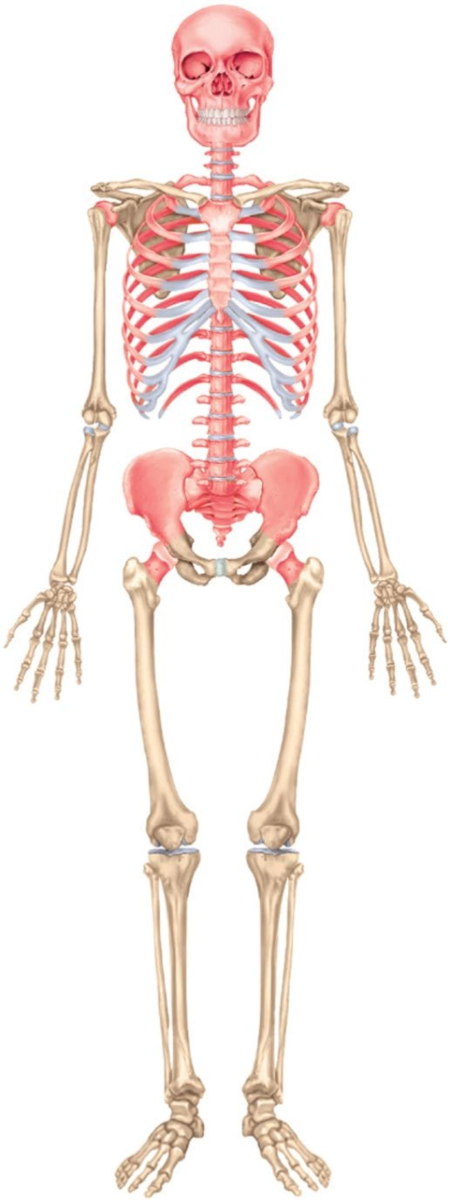
Osteogenesis Imperfecta
Bone formation is Imperfect (reduced)
Creative-Med-Doses
Braces
Wheelchair
Insert metal Rod in long bones
Increased Stability
Reduced fall
Exercise
Physical therapy
Prevent deformities and fracture
Pamidronate
Bisphosphonate
Increase bone Density
Treatment
Psychological Counseling
Autosomal Dominant
We are broken but we are dictated by Dominant gene..
Our condition Dominates the Entire family..
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

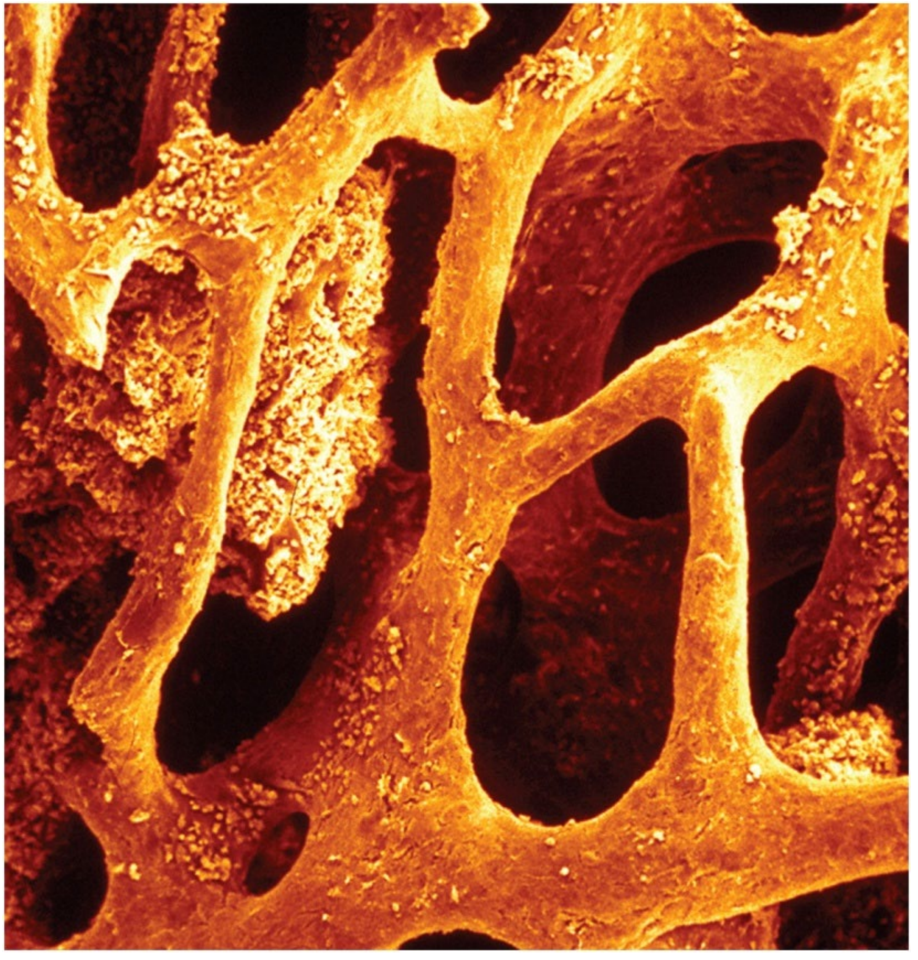
–in adults, found in **skull**, **vertebrae**, **ribs**, **sternum**, part of **pelvic girdle**, and **proximal heads of humerus and femur**

yellow marrow found in adults

–most red marrow turns into fatty yellow marrow

–no longer produces blood

Bone Development



Bone Development in Fetal Growth

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

Process in which bone develops from pre-existing hyaline cartilage model

–beginning the 6th 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

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

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

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 ephyseal plate

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

Interstitial Bone Growth

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

Interstitial Bone Growth

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

Appositional Bone Growth

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

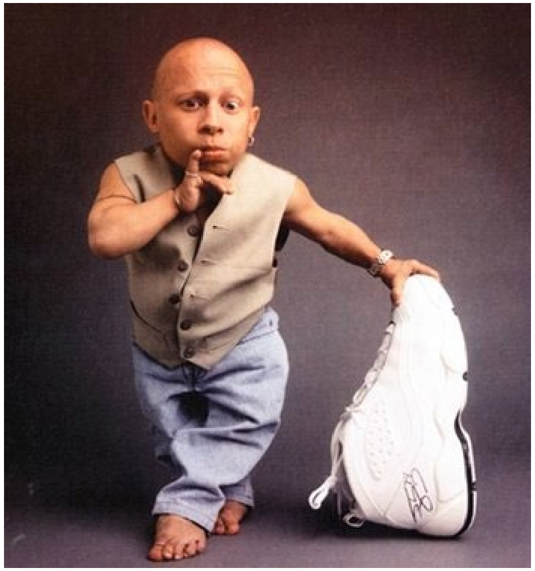
architecture of bone determined by mechanical stresses placed on it and bones adapt to withstand those stresses

remodeling is a collaborative and precise action of osteoblasts and osteoclasts

bony processes grow larger in response to mechanical stress

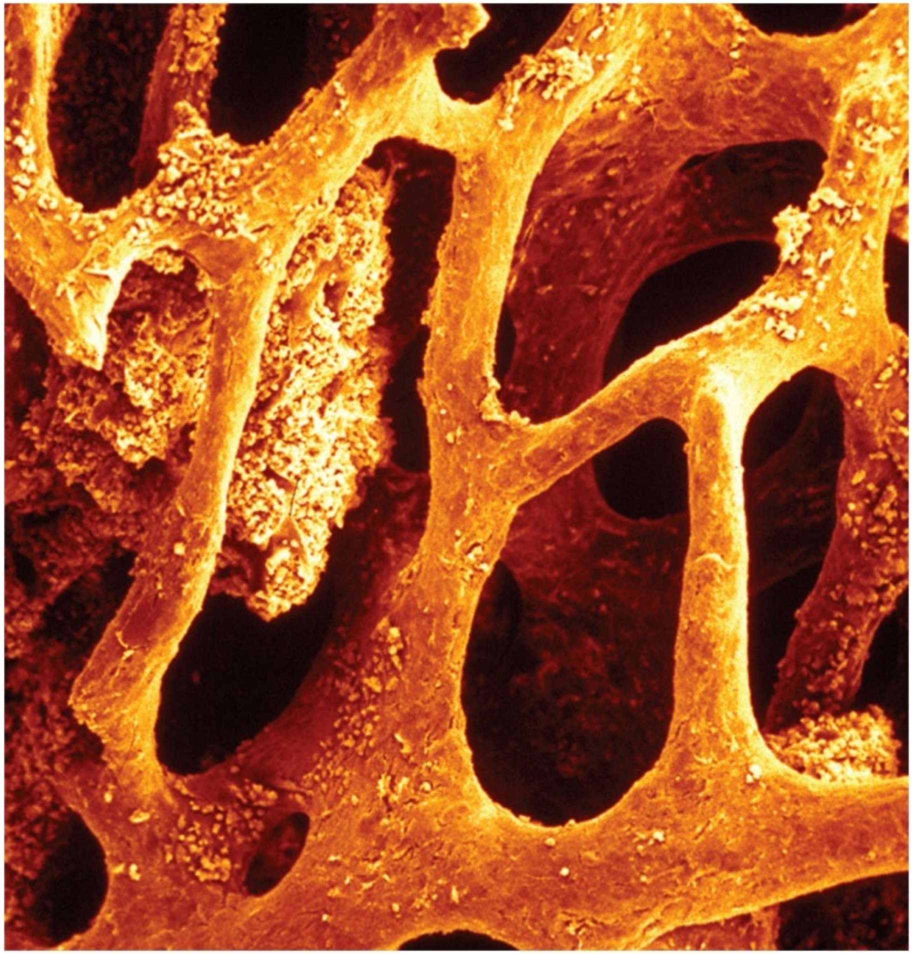
Tendons pull on periosteum and matrix to produce "stress" and osteoblasts and osteoclast respond to this physical force and remodels the bone

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

Bone Fracture & Repair



Fractures and Repair

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 deveop 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 <u>6 weeks</u> 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

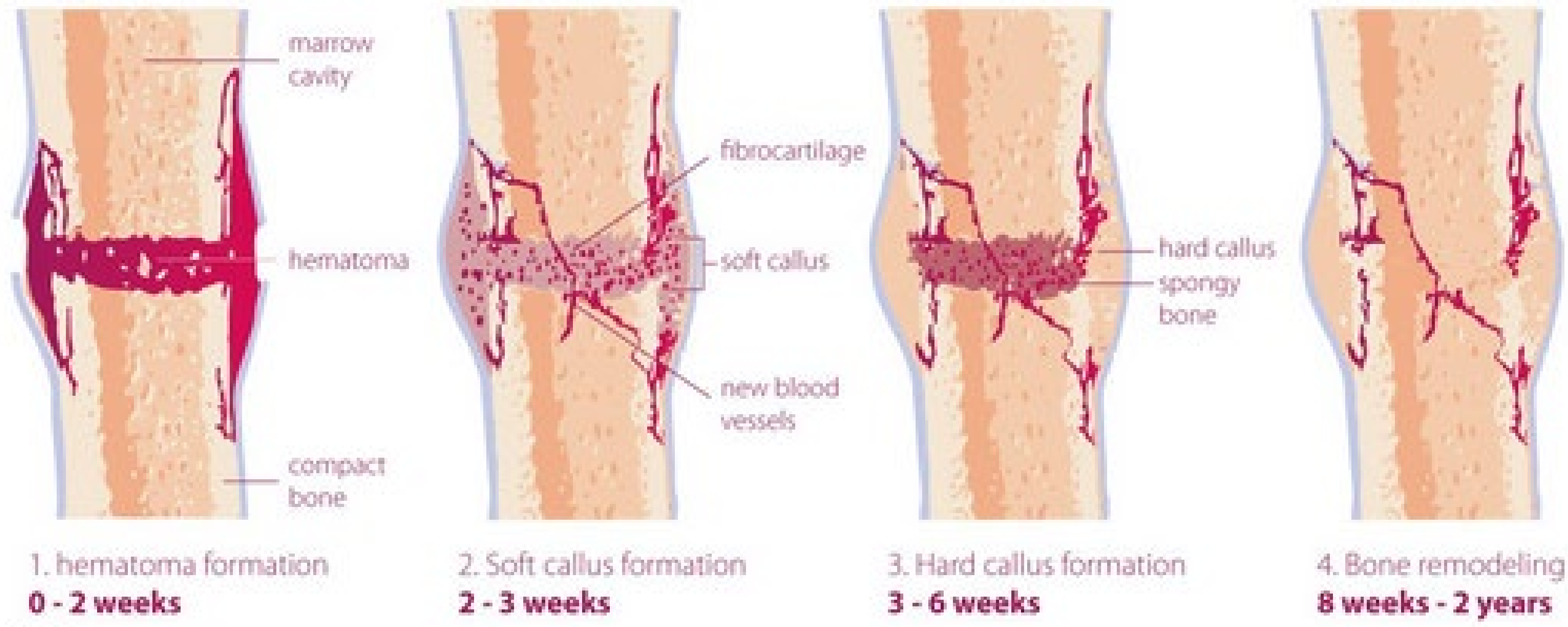
–***Note: Vitamin A, vitamin C, and vitamin D are*** *required nutritional factors for growth and repair*

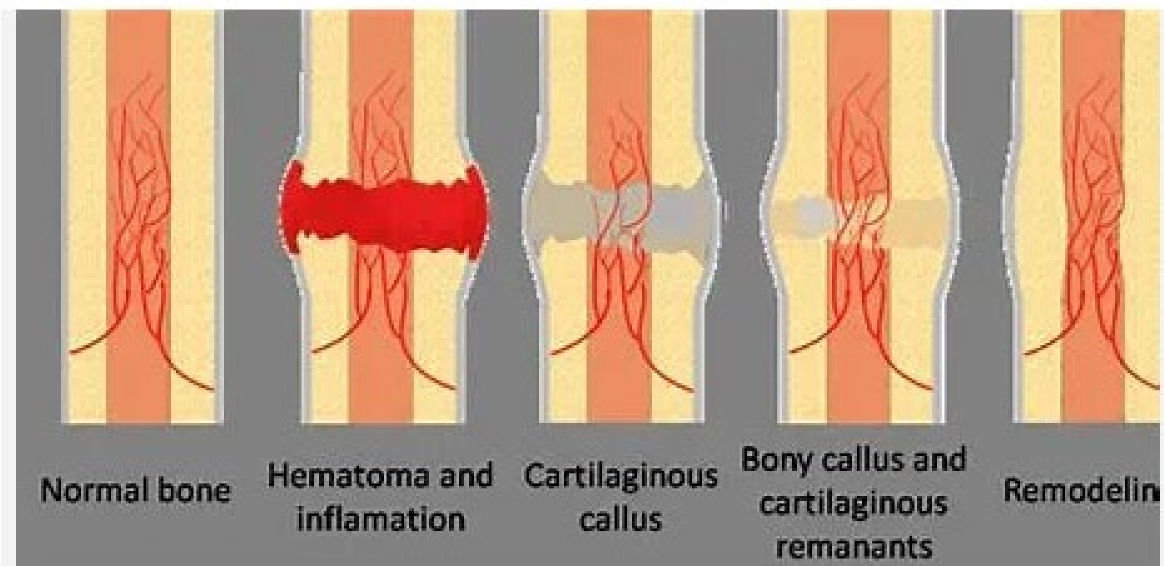
Treatment of Fractures

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


marrow cavity
hematoma
compact bone
fibrocartilage
soft callus
new blood vessels
hard callus
spongy bone
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


Normal bone
Hematoma and inflamation
Cartilaginous callus
Bony callus and cartilaginous remanants
Remodelin

Treatment of Fractures

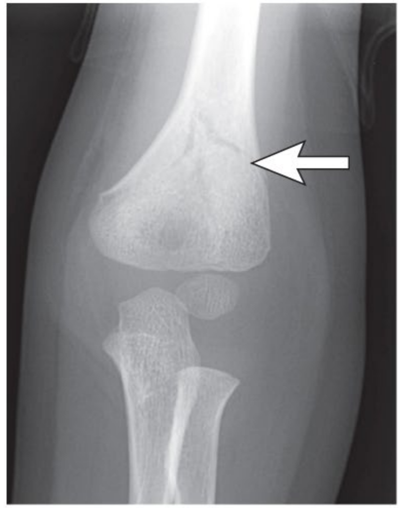
Traction used to treat fractures of the femur in children // Aligns bone fragments by overriding force of the strong thigh muscles

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

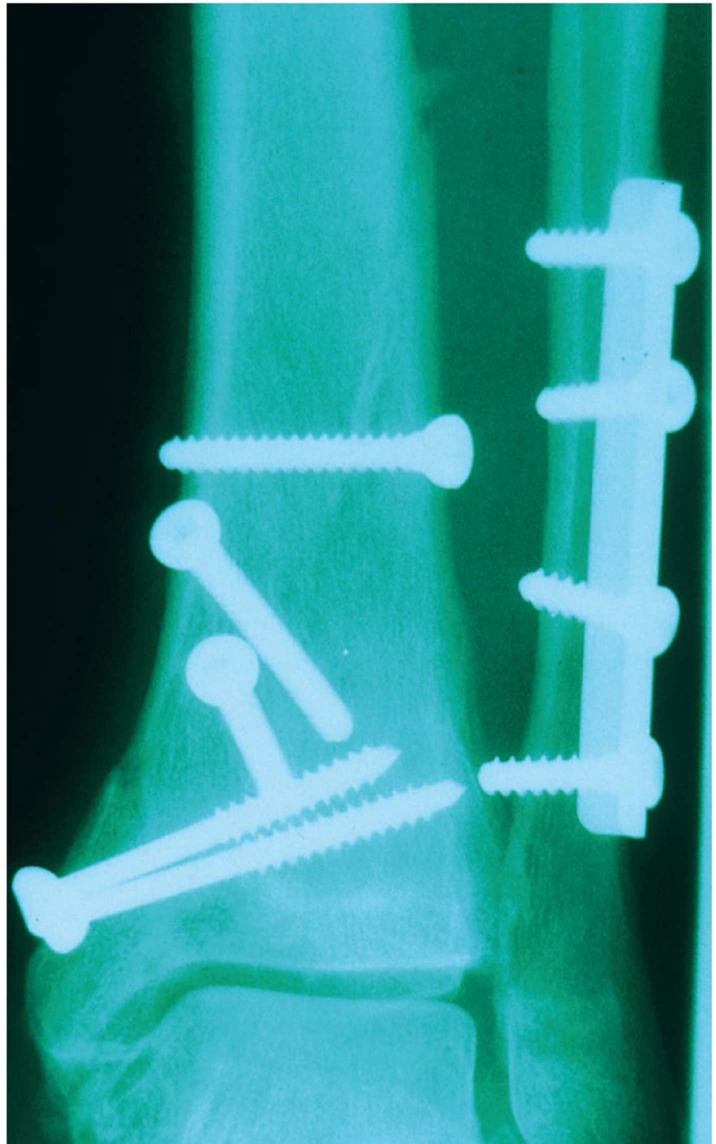


(a) Nondisplaced

(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 bone density, typically // primary cause a result of hormonal changes, or deficiency of calcium and/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:

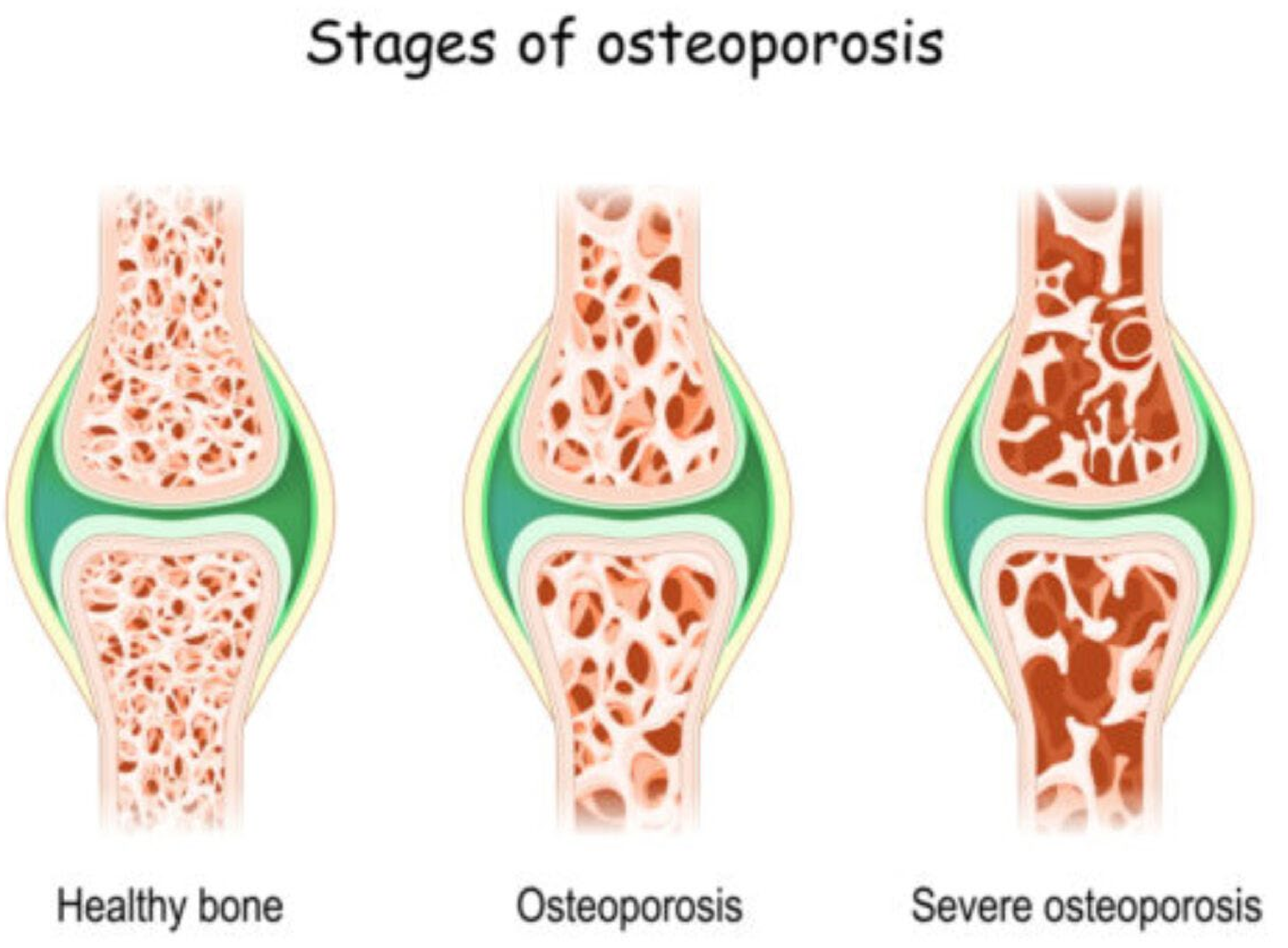
- Fragility-related fractures. These occur when even mild impact causes a fracture of the
- wrist, back, hip or other bones.

> Height loss. More than two inches in height can be lost over time.

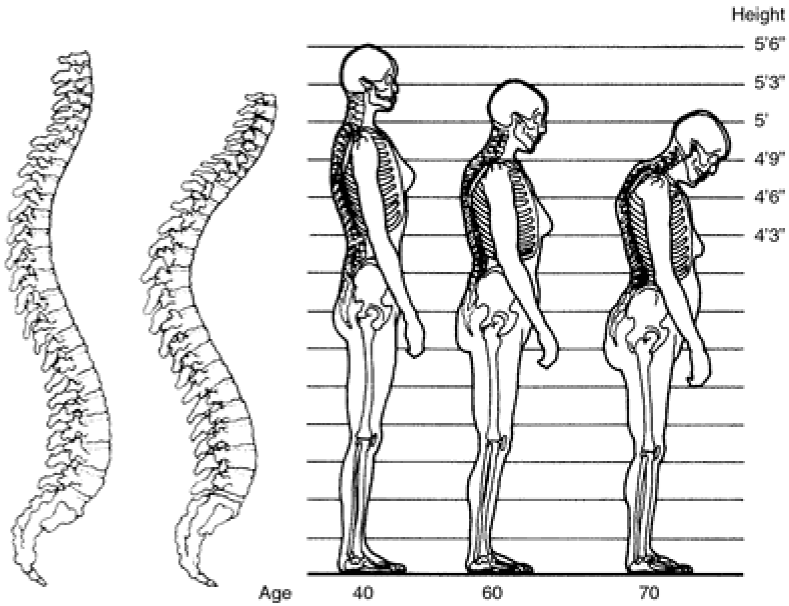
> Receding gums. …

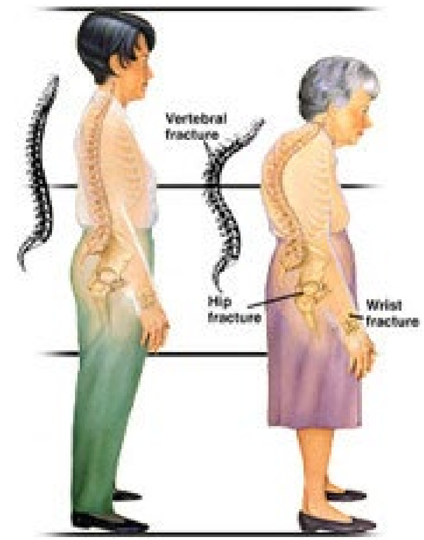
> A curved, stooped shape to the spine. …

> Lower back pain.


Stages of osteoporosis
Healthy bone
Osteoporosis
Severe osteoporosis

Osteoporosis





Osteoporosis