Bone biology, osteoporosis and fragility fracture around the hip

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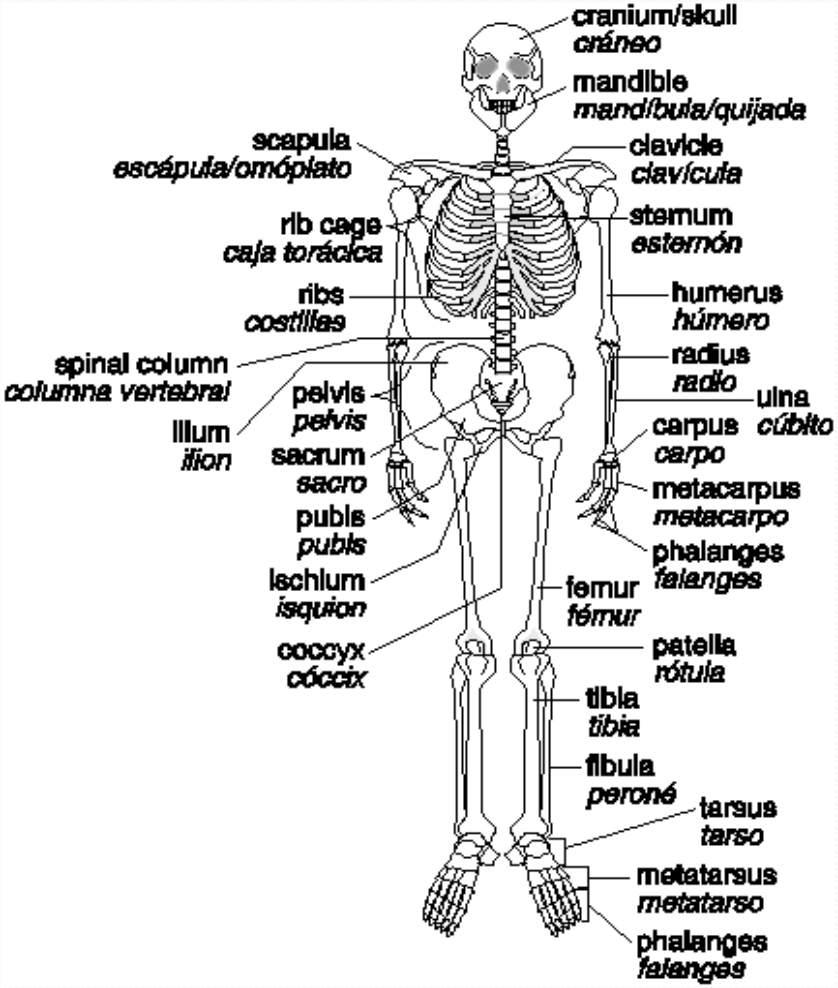
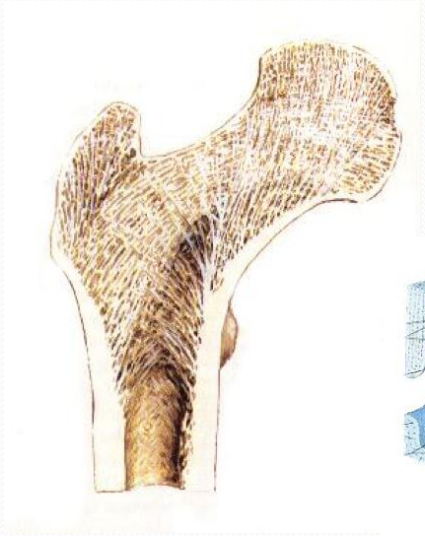
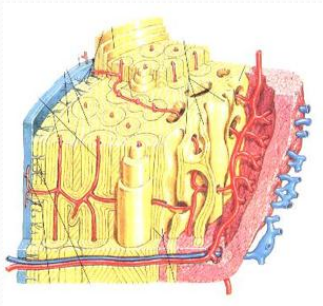
Bone: the osteology

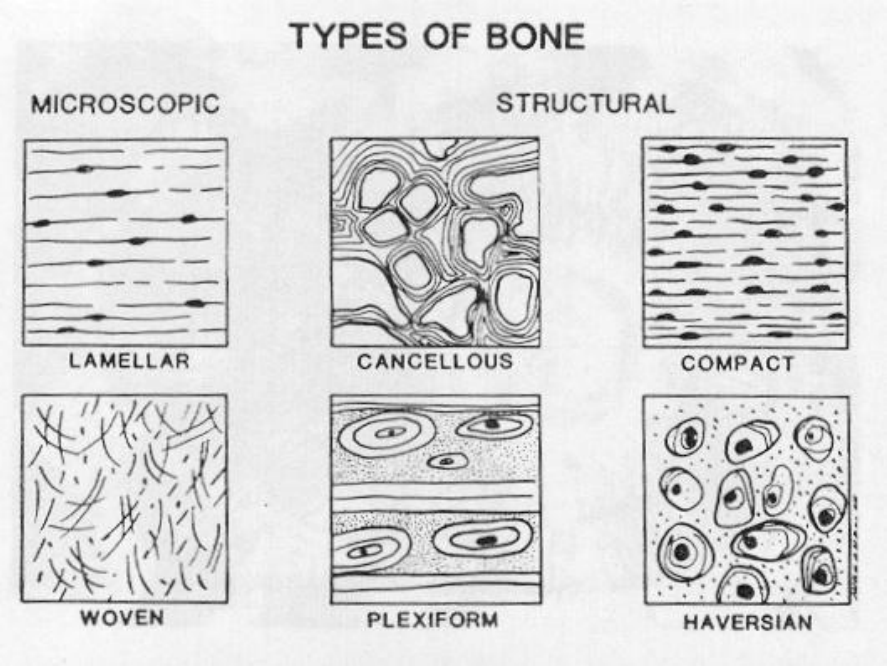






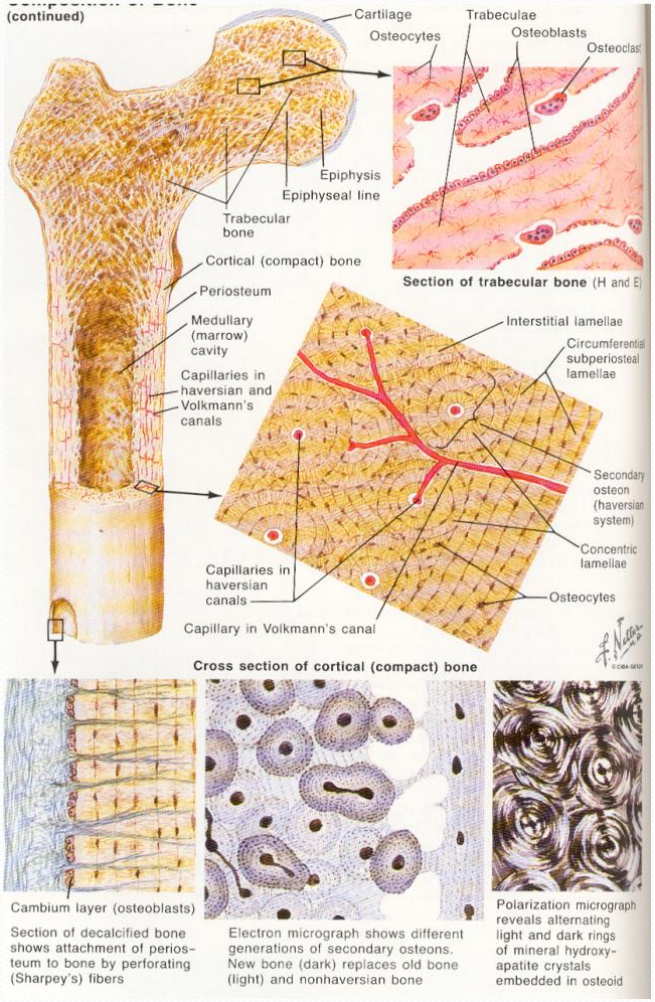
BONE: Microscopic

- **WOVEN:**
  - Immature, primitive
  - Coarse-fibered
  - No uniform collagen fiber orientation
  - More cells per unit volume & randomly arranged
  - Mineral content varies
  - Isotropic (regardless of orientation)



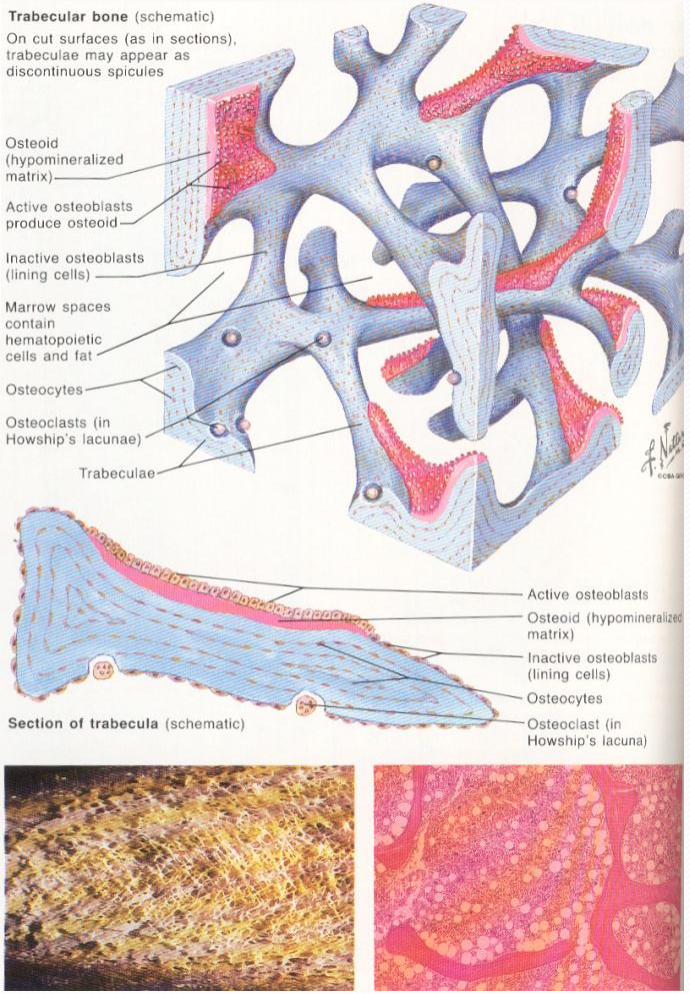
BONE: Microscopic

- **LAMELLAR:**
  - More mature
  - Remodel from woven bone
  - Highly organised, stress-oriented collagen fibers
  - Anisotropic (greatest strength parallel to longitudinal axis of collagen fibers)



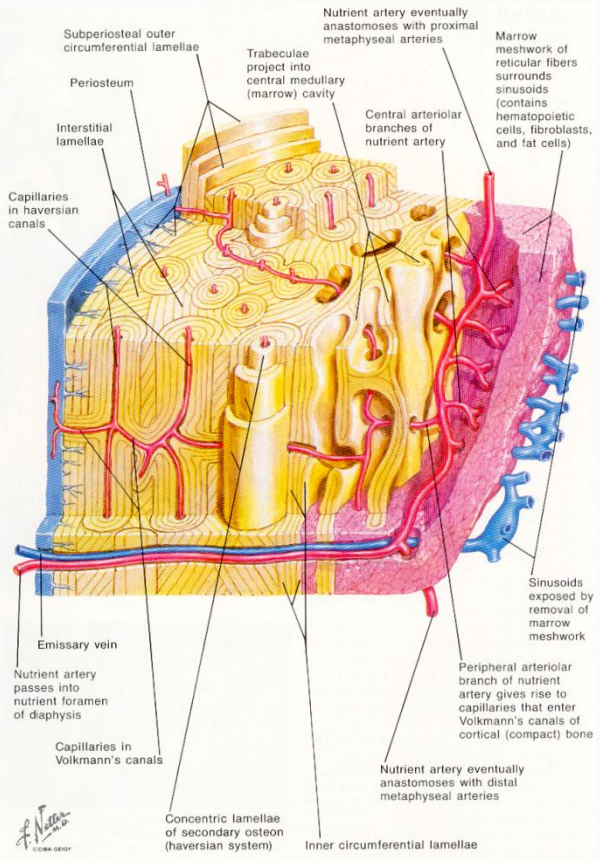
BONE: Structural

- **TRABECULAR / CANCELLOUS / SPONGY (20%):**
  - Metaphysis, epiphysis, cuboid bones
  - Complex stress & strain, compression predominate
  - More porosity & less density (typically 50% - 90%)



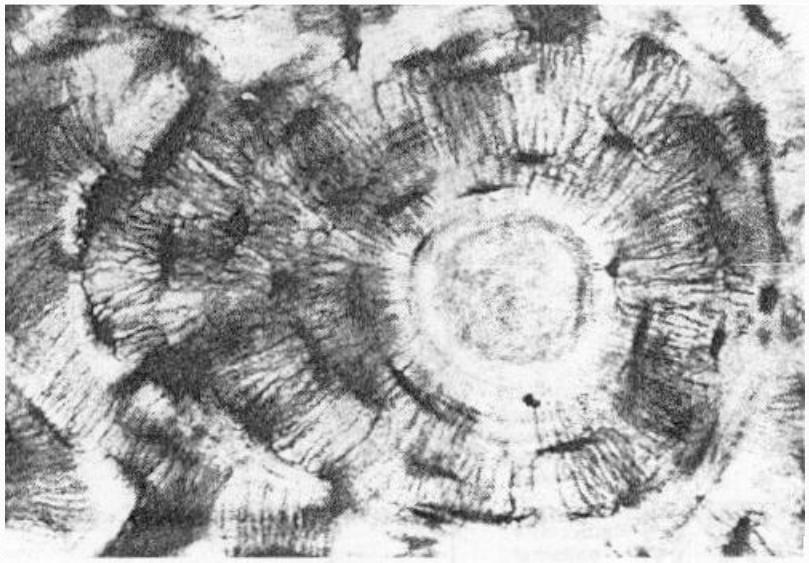
BONE: Structural / Cortical

- **CORTICAL BONE (80%):**
  - Diaphysis, envelope of cuboid bone
  - Porosity < 30% (typically 10%)

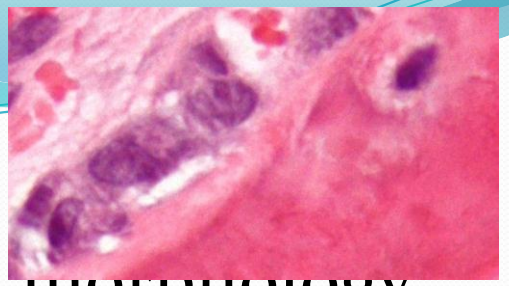


BONE: Structural / Cortical

- **Haversian bone:**
  - Vascular channels / circumferential lamellar bone
  - **"Osteon"** = major structural unit
  - Haversian canal / Volkmann's canal / Concentric vs Interstitial lamellae



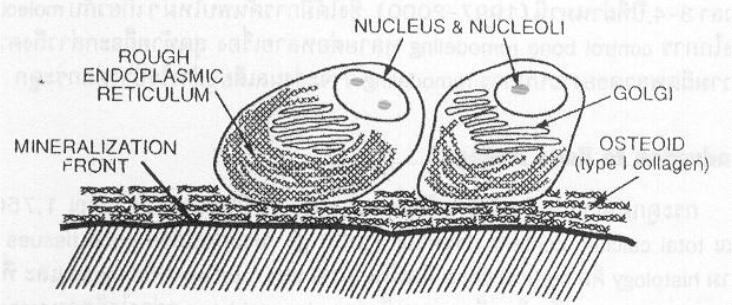
ACTIVE OSTEOBLASTS



- Intense basophilic stain
- Polarized, large eccentric nucleus away from bone surface
- Cytoplasm:
  - Abundant RER --> protein synthesis
  - Golgi apparatus --> protein secretion

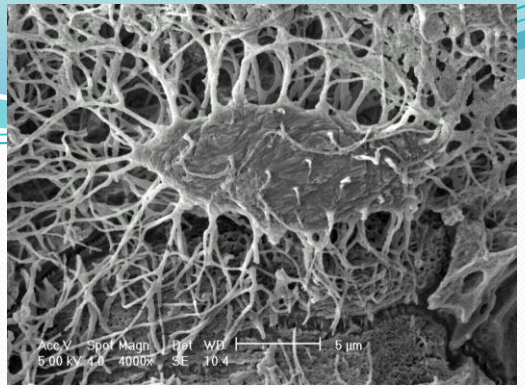
- Tall, plump morphology
- Elongated & flat (inactive)
- Cell surface receptors: PTH. PGs
- Cytosolic receptors: Calcitriol, glucocorticoids
- Estrogen receptor

ACTIVE OSTEOBLASTS



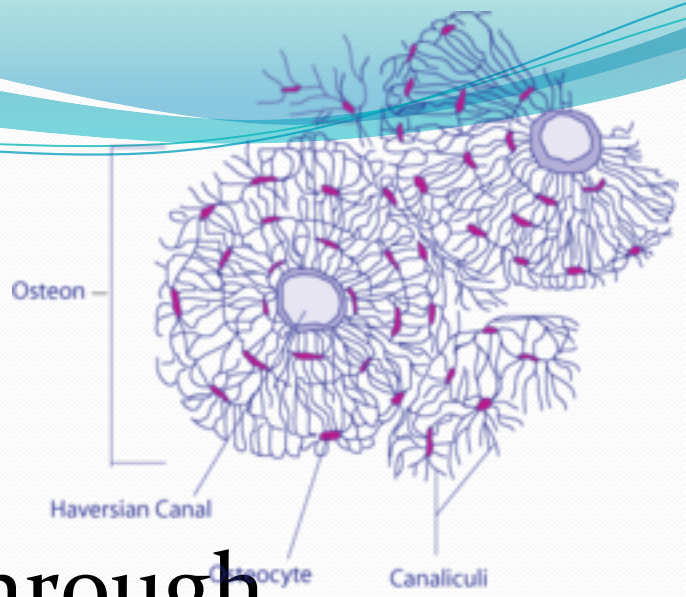
- Osteoid / bone matrix synthesis
- Make type-I Collagen
- Produce noncollagenous proteins: osteocalcin, bone sialoprotein, osteonectin, osteopontin, proteoglycan, etc.
- Produce regulatory factors: cytokines, growth factors, PGs

OSTEOCYTES



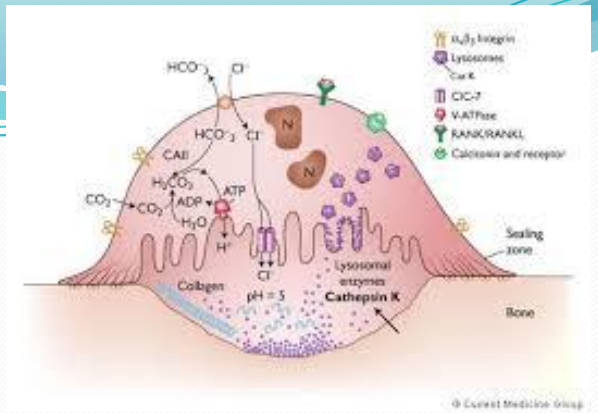
- Surrounded by mineralized bone matrix
- The most numerous of bone cells
- Uniformly concentrically oriented around Haversian canal & between lamellae
- Decreased organelle content
- Greater nucleus-to-cytoplasm ratio

OSTEOCYTES



- Extensive cell processes through canaliculi
- "Communication" via gap junctions
- Communicate stress & strain signals
- Cellular regulation of calcium exchange & bone metabolism

OSTEOCLASTS



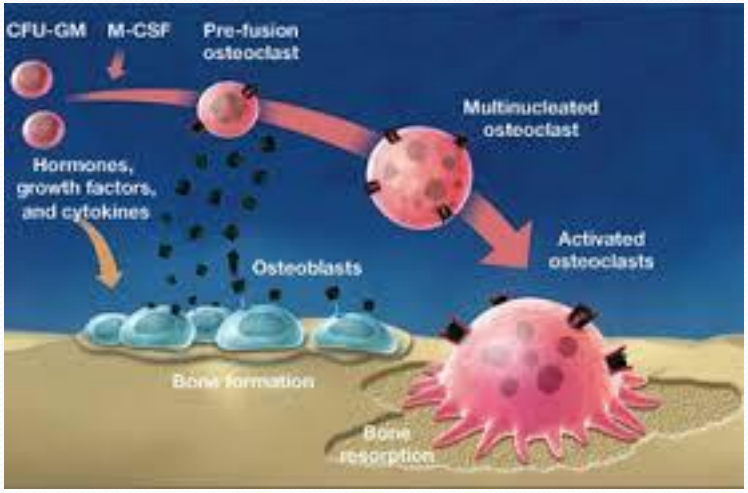
- Major resorptive cells of bone
- Large, multiple nuclei
- Hematopoietic precursors
- Formed from fusion of monocytes
- Produce tartrate-resistant acid phosphatase (differ from macrophages & FB giant cells)

OSTEOCLASTS

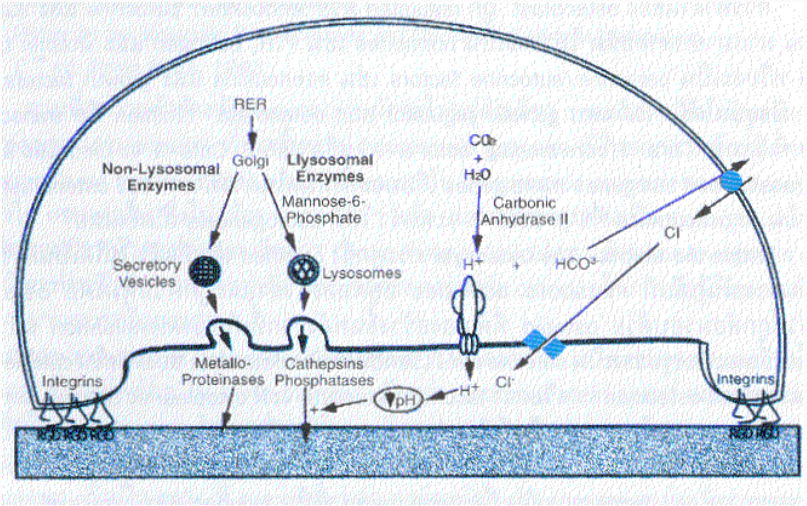
- Do not have PTH, Calcitriol, PGE receptors
- Activated by exposure to bone matrix after osteoid layer disruption "PTH-osteoblast-mediated-effect"
- Mast cells --> heparin
- Monocytes, Lymphocytes --> cytokines

OSTEOCLASTS

- Lie in Howships lacunae (bone resorption pits)



- Ruffled (brush) border: extensive infoldings of cell membrane adjacent to resorptive surface.



OSTEOCLASTIC RESORPTION

- "Integrin" bind to bone surface -->
- Subosteoclastic space -->
- Carbonic anhydrase / hydrogen ion / lower pH 4-->
- Soluble apatite / Ca removal -->
- Acidic proteolytic matrix digestion

BONE MATRIX

- **INORGANIC - MINERAL:**
  - 60% - 70%
  - Natural crystalline Ca-Hydroxyapatite:
    $Ca_{10}(PO_4)_6(OH)_2$
  - Abundant impurities --> altered physical properties
  - Water 5% - 8%

- **ORGANIC 30%:**
  - Type-I Collagen 90%
  - Noncollagenous 5% - 8%
  - [illegible] 5%

Hydroxyapatite:

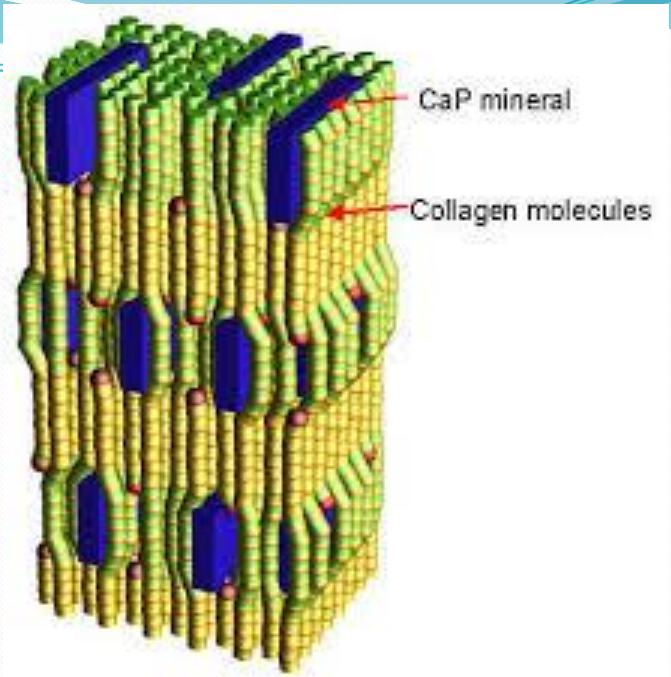
$$Ca_{10}(PO_4)_6(OH)_2$$

Mg^{+2}, Sr^{+2}, Na^{+}, K^{+} substitute for Ca

CO_3^{-2}, HPO_4^{-2} substitute for PO_4

CO_3^{-}, F^{-} substitute for OH

COLLAGEN



- Extremely low solubility
- Major structural component of bone matrix
- 3 polypeptide chains (@1000 a.a.)
- Triple helix: 2 alpha one, 1 alpha two
- Stabilized by bone specific collagen "cross-links" --> sensitive marker of bone resorption

- "Hole zones" between molecular ends --> initial mineralization
- "Pores" between sides of parallel molecules

NONCOLLAGENOUS PROTEINS

- **OSTEOCALCIN:**
  - Gamma-carboxyglutamic acid-containing protein (bone Gla protein)
  - 10% - 20% of non-collagen
  - 3 glutamic acid residues: vitamin K dependent carboxylation, inhibited by warfarin
  - Synthesis by osteoblasts, odontoblasts
  - Synthesis enhanced by Calcitriol
  - Synthesis inhibited by PTH, corticosteroids
  - Attracts osteoclasts
  - Regulate bone mineral crystal maturation

NONCOLLAGENOUS PROTEINS

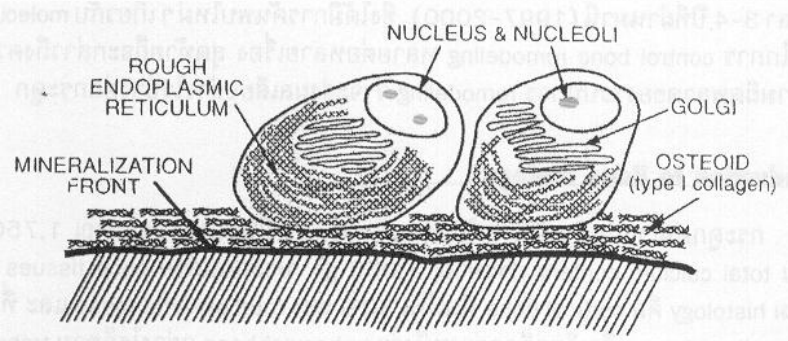
- **OSTEONECTIN:**
  - Secreted by osteoblasts & platelets
  - Bind denatured collagen & hydroxyapatite
  - Regulate Ca concentration
  - Potentiate $CaPO_4$ nucleation or stabilization
- **PHOSPHORYLATED SIALOPROTEINS:**
  - Localized in the "Hole zone"
  - Attract calcium
  - Responsible for initial mineralization & nucleation

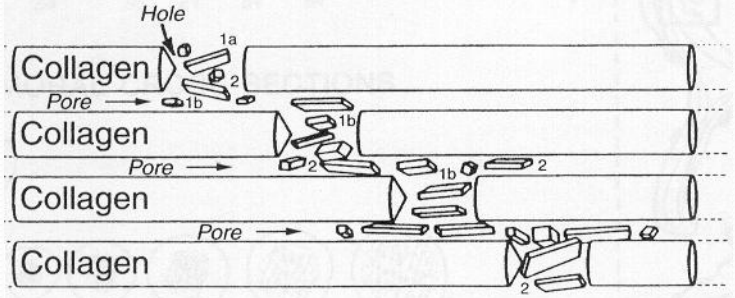
NONCOLLAGENOUS PROTEINS

- **INTEGRINS:**
  - Cell membrane proteins
  - Osteoblasts, Osteoclasts, Fibroblasts
  - Anchoring cells (cytoskeletal) to extracellular matrix
- **GROWTH FACTORS & CYTOKINES:**
  - TGF-beta, Insulin-like GF, Interleukins (IL-1, IL6), BMP 1-7
  - Bind to bone mineral & matrix
  - Released during osteoclastic bone resorption
  - Coupling factors in bone remodeling
  - Regulate Ca flux & mineralization

BONE MINERALIZATION

- **OSTEOBLASTS:**
  - Regulate Ca concentration in the matrix
  - Secrete macromolecules determining site and rate of initial calcification
- 2 Phases: Initiation & Growth





BONE MINERALIZATION

1. **Initiation of osteoid mineralization**
   - Primary nucleation
   - Require more energy
   - Several matrix proteins dependent
   - Hydroxyapatite: $Ca_{10}(PO_4)_6(OH)_2$
   - Discontinuous process starting in the "Hole zones"

2. **Crystal growth**
   - Secondary nucleation
   - More crystal deposit by agglomeration (fusion) of new crystals
   - Occur in either "Holes' or "Pores"
   - Fully mineralized mature bone = 70% mineral

BONE GROWTH

- Before skeletal maturity

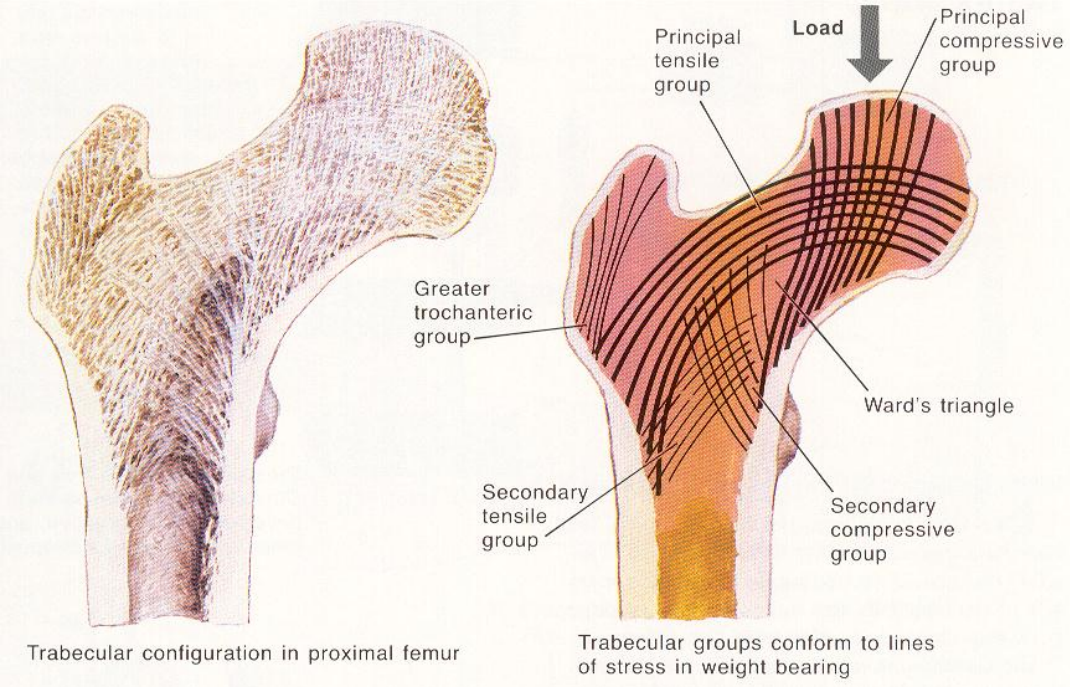
1. Endochondral ossification: length
2. Intramembranous / Subperiosteal ossification: width

BONE REMODELING

- **All ages:**
  - "Surface phenomenon" : periosteal, endosteal, Haversian canal, trabecular surfaces
  - "Coupled" resorption = formation --> no net change in bone mass
  - 5 - 10 times higher in trabecular > cortical bone
  - High in children (age < 2 yr ~ 50%/yr), Low in elderly (2% - 5%/yr)

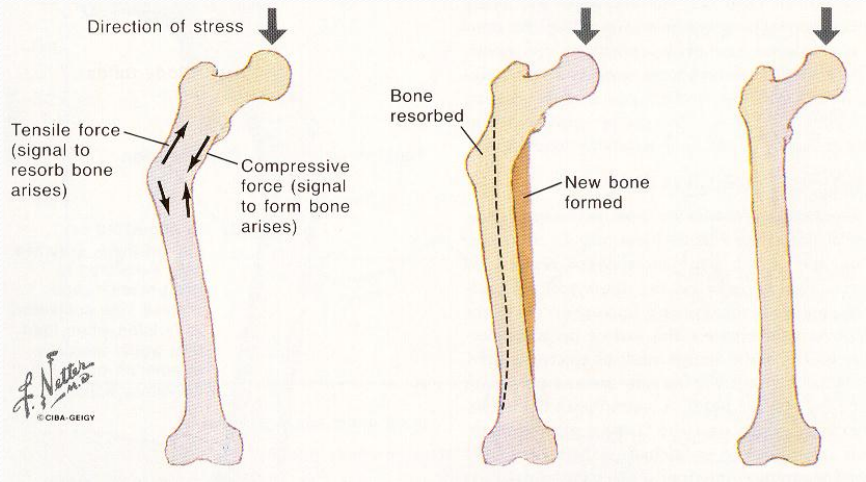
BONE REMODELING

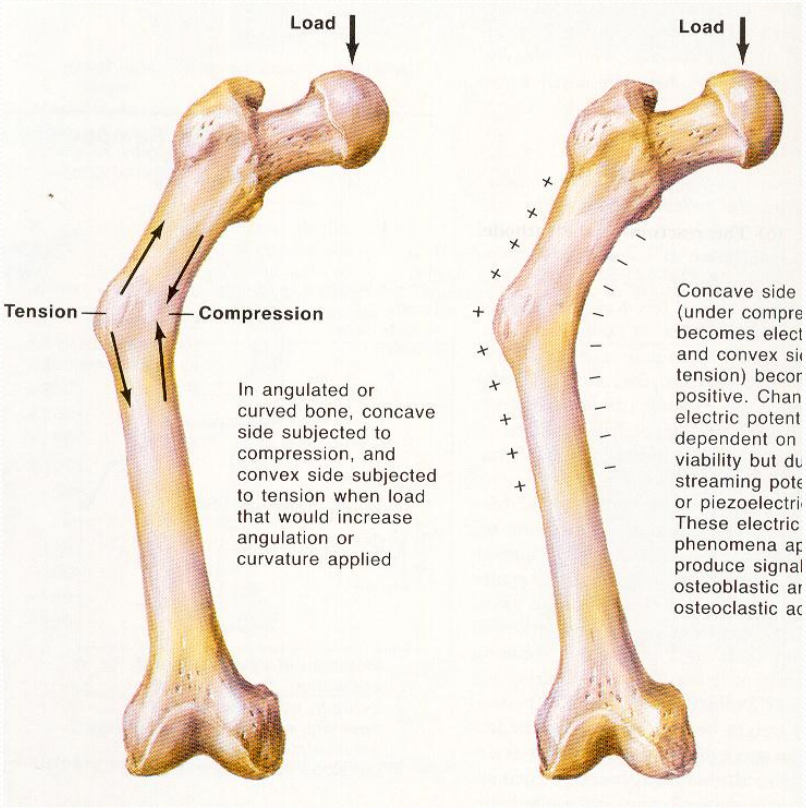
- Adapt material properties to mechanical demands **"Wolff's law"**



BONE REMODELING

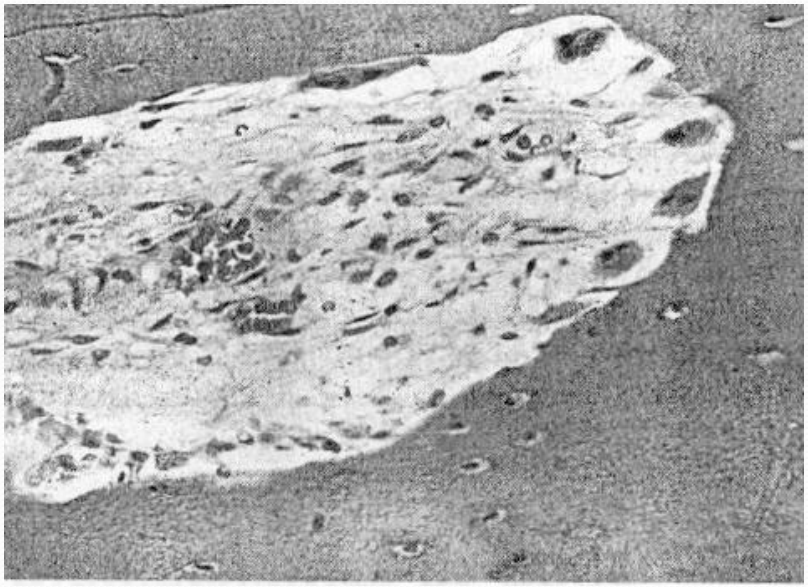
- Adapt material properties to mechanical demands





BONE REMODELING

- **"Cutting Cone"**
  - Osteoclast front --> resorb bone
  - Capillary loop
  - Osteoblasts --> form osteoid & bone



BONE BLOOD FLOW

- **3 separate but interconnectin G system**

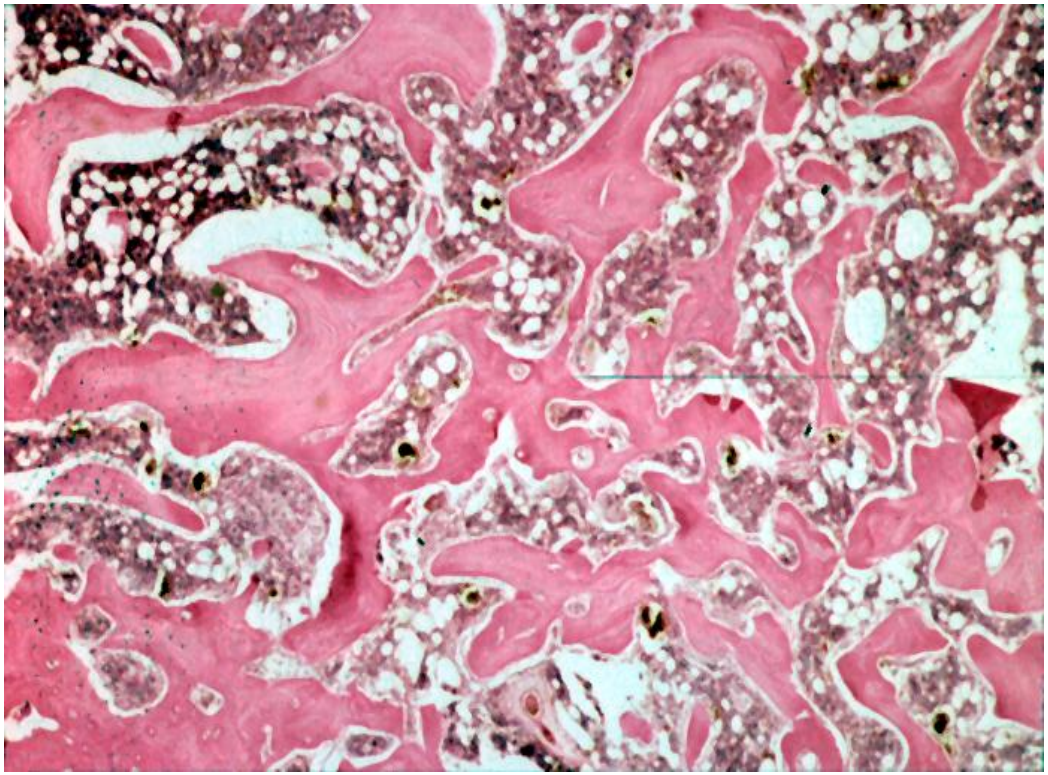
1. **Nutrient artery:**
   - Major systemic artery
   - Enters diaphysis through nutrient foramen
   - Ascending & descending medullary arteries & arterioles

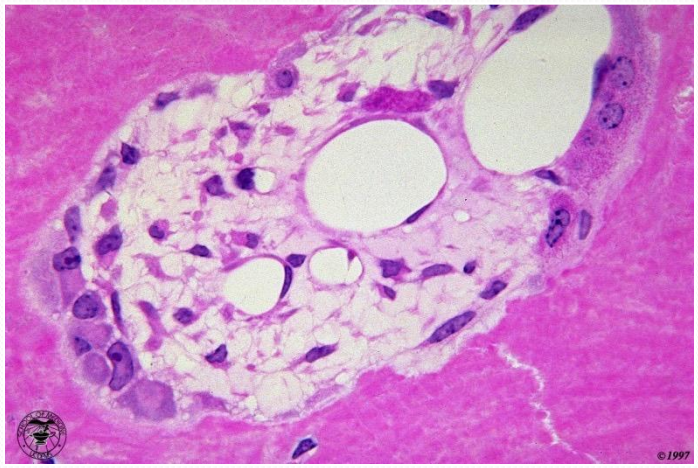
2. Metaphyseal complex:
   - Periarticular plexus / geniculate arteries
   - Supply metaphyseal regions
   - Anatomose with medullary arteries & epiphyseal arteries

3. **Periosteal capillary supply:**
   - Muscular attachment
   - Outer 15% - 20% of cortex

Bone Regeneration

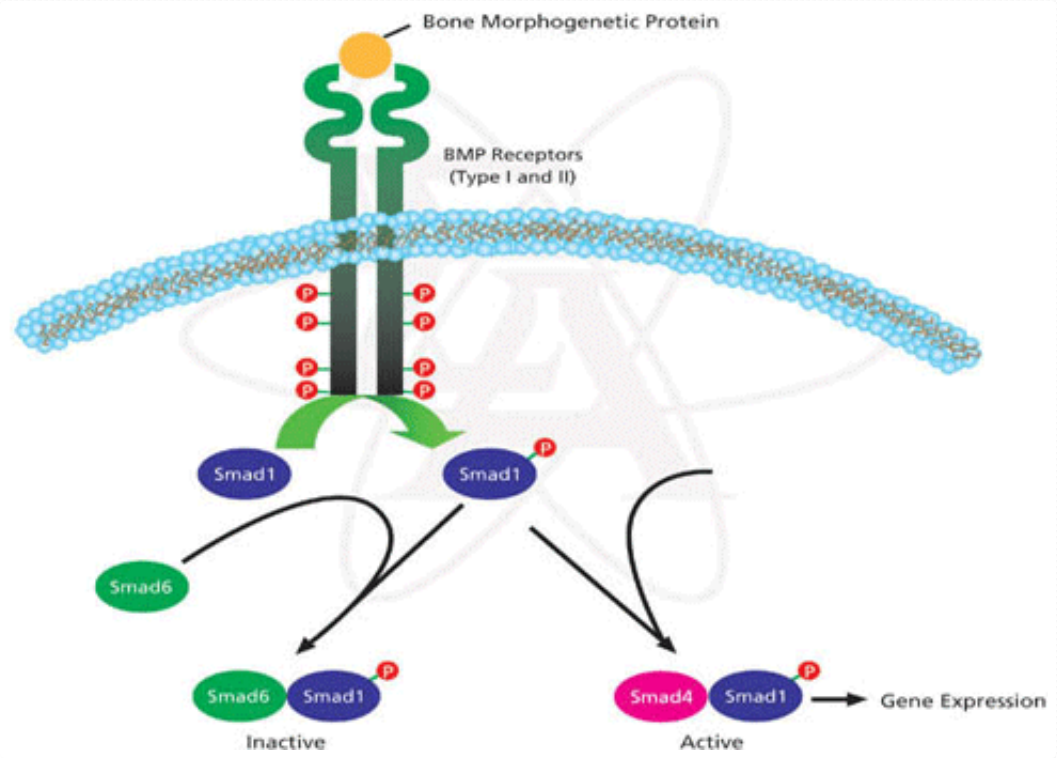
- Requires three critical elements:
  - Osteogenic cells that have the capacity to synthesize new bone (osteoblasts)





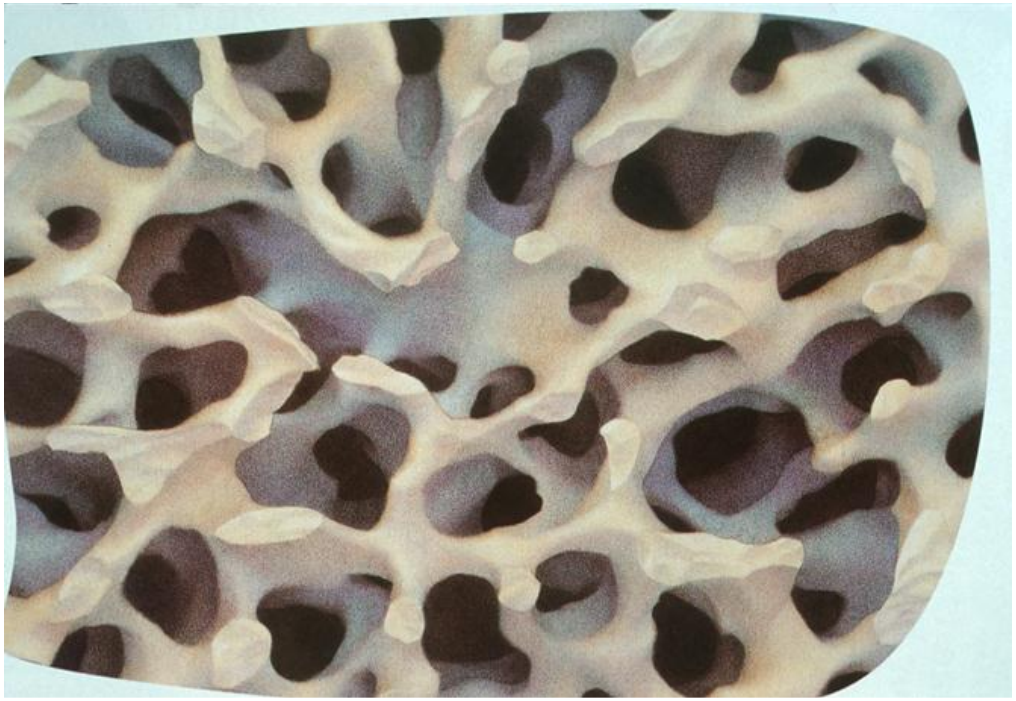
Bone Regeneration

- Requires three critical elements:
  - Osteoblasts
  - Osteoinductive factors that promote osteoblasti differentiation and activation

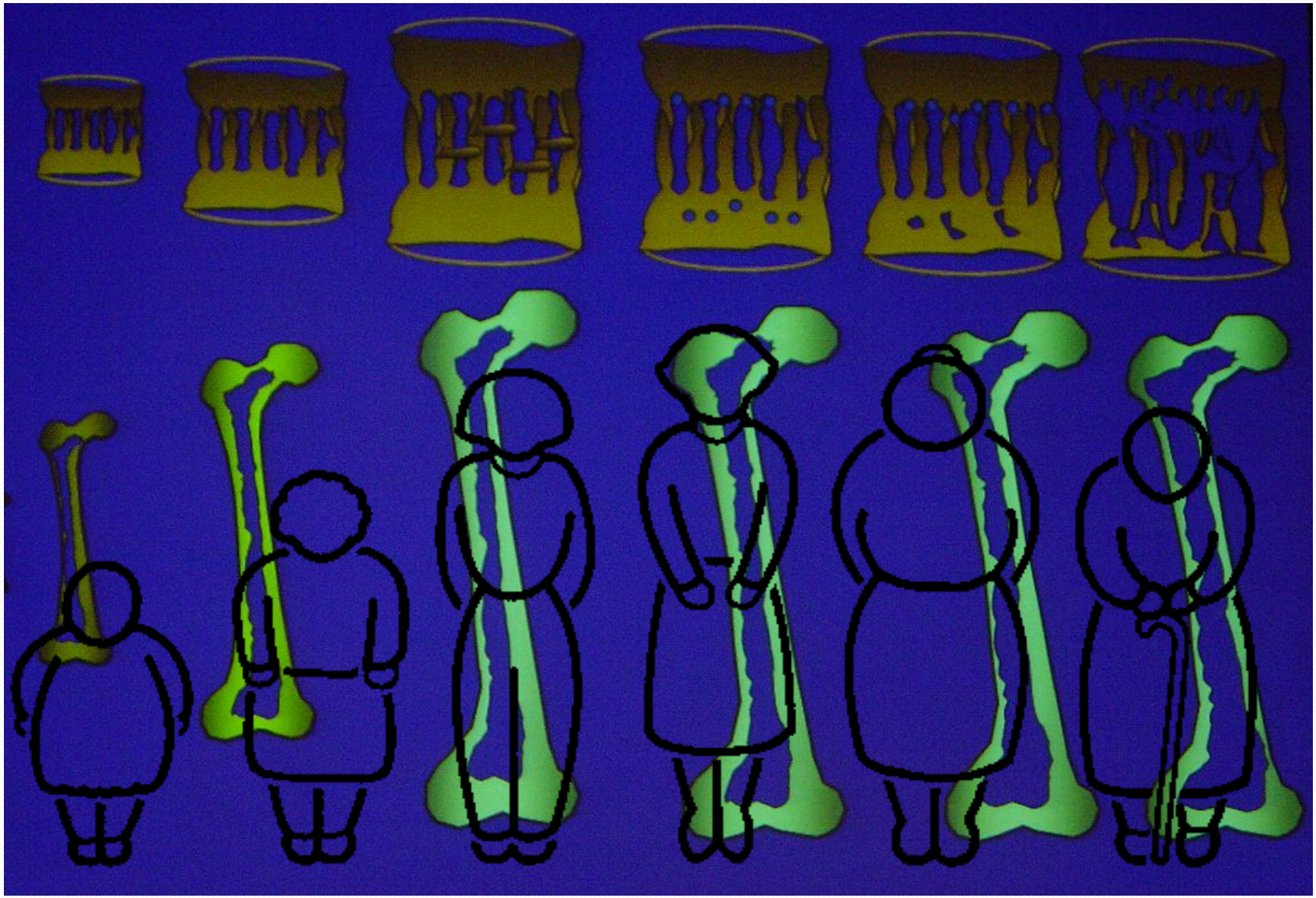


Bone Regeneration

- Requires three critical elements:
  - Osteoblasts
  - Osteoinductive factors
  - Osteoconductive scaffold that facilitates neovascularization and supports the in-growth of bone



Bone Change by Age

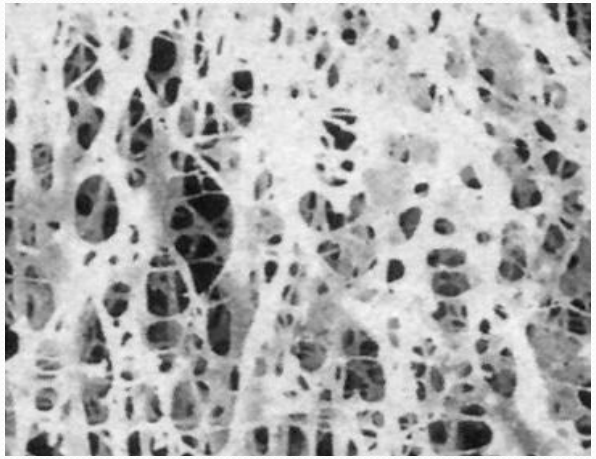


Metabolic Bone Disorder

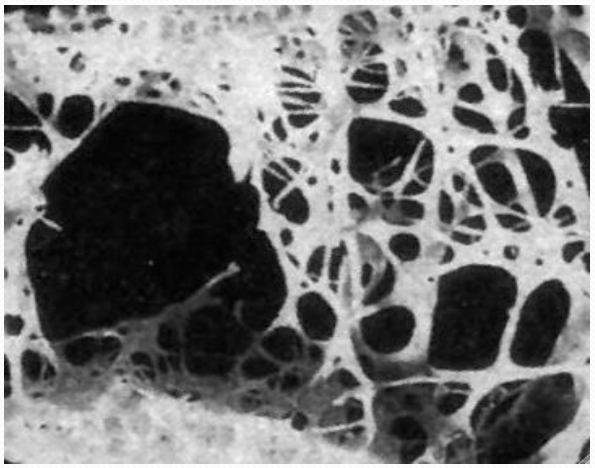
- Disease
  - Hypercalcaemia
  - Hyperparathyroid bone disease
  - Hypocalcaemia
  - Osteomalacia
  - Pagets Disease
- Disorder
  - Osteoporosis

Osteoporosis

- "A systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture."
  Consensus Development Conference on Osteoporosis, 1993



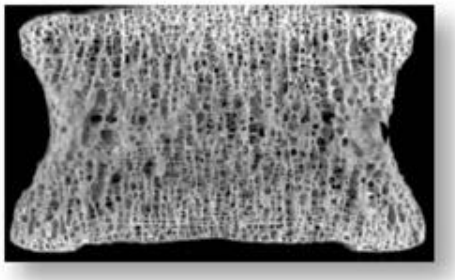
Normal Bone



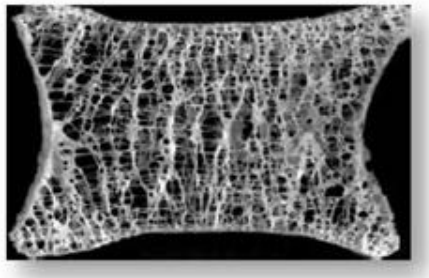
Osteoporosis

Peck WA, et al. *Am J Med.* 1993;94:646. Graphics courtesy of the International Osteoporosis Foundation.

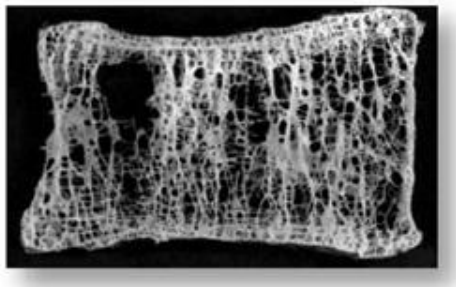
Osteoporosis and fracture



Normal bone

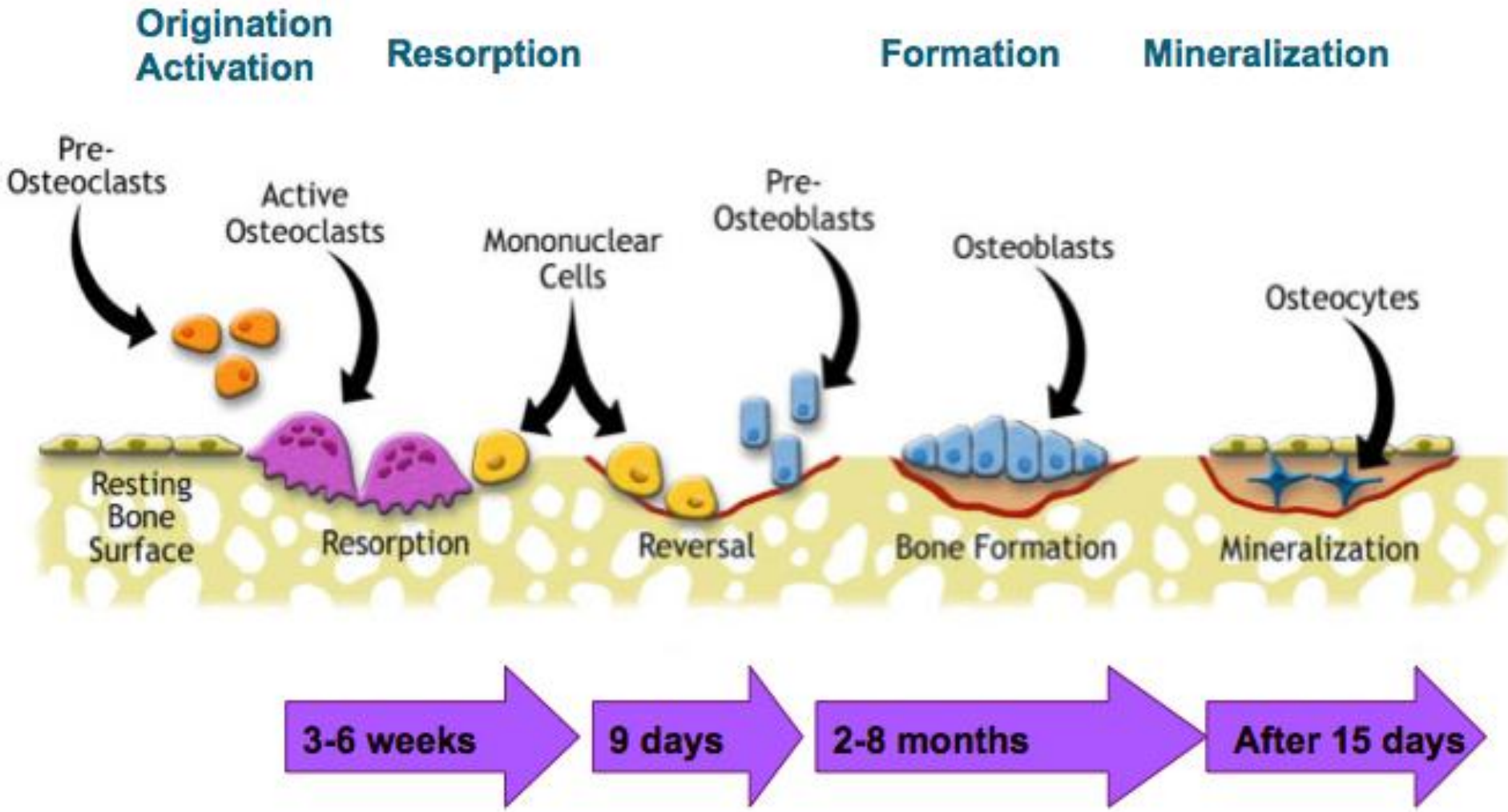


Moderate osteoporosis



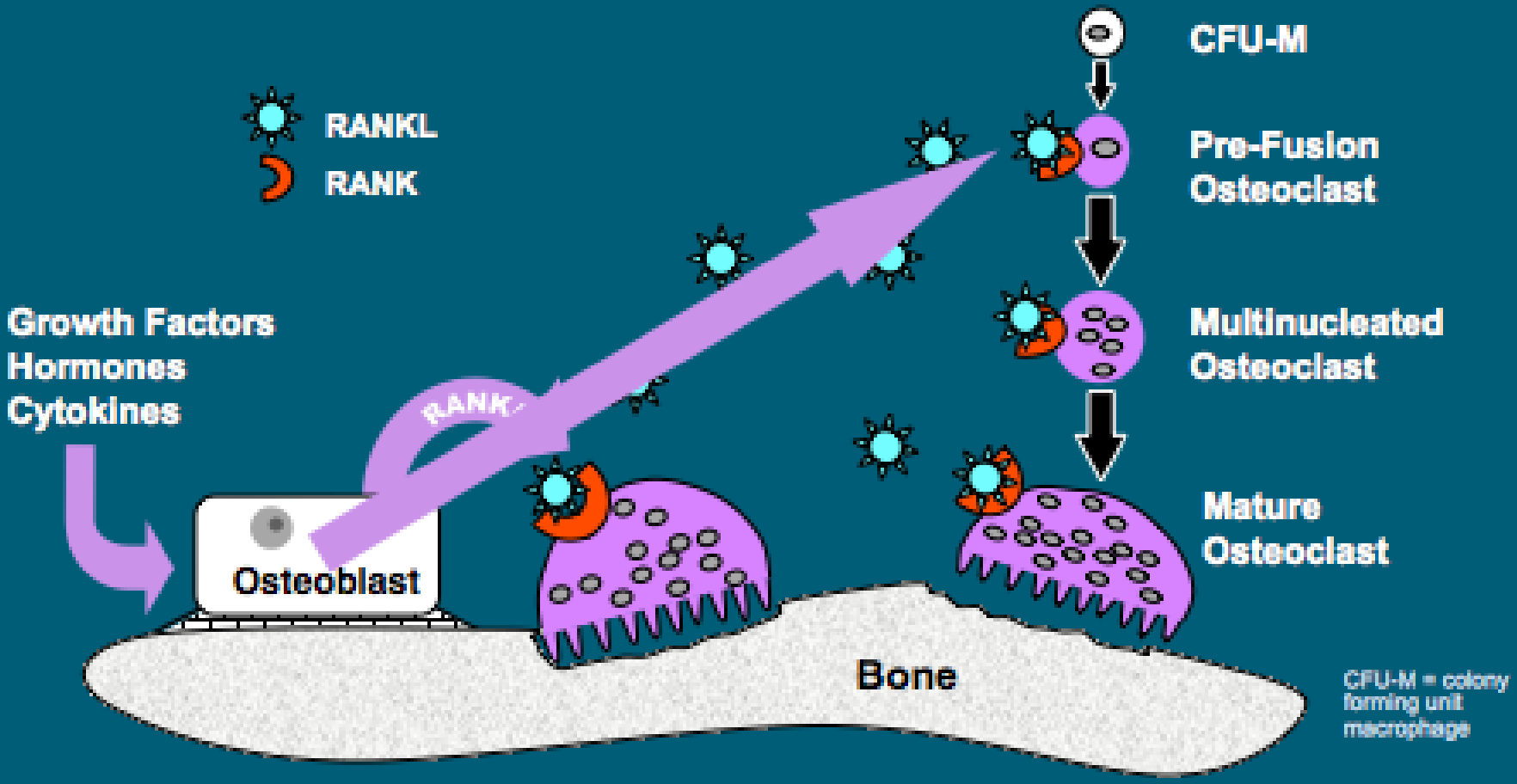
Severe osteoporosis

Bone Remodeling Cycle



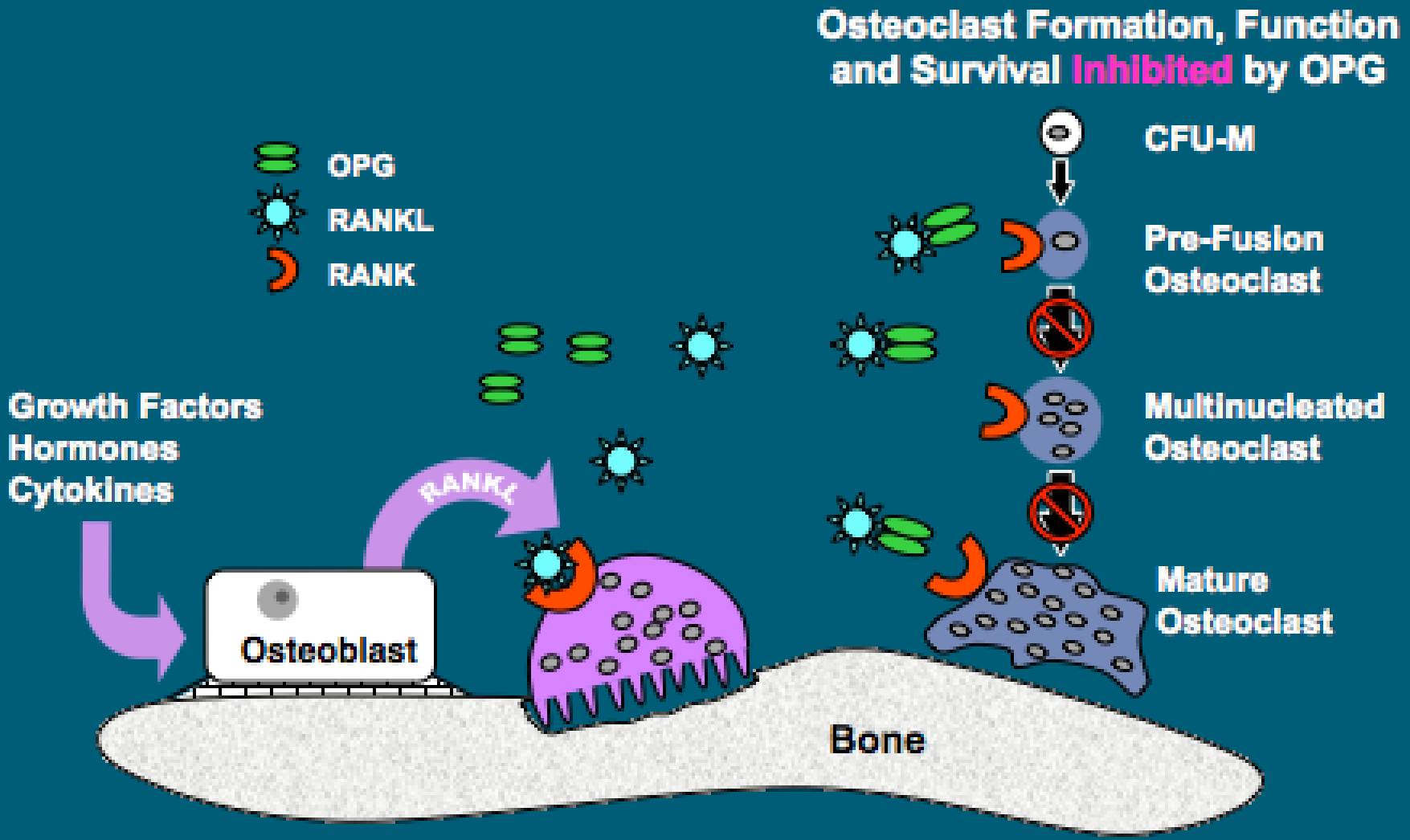
RANKL Stimulates Osteoclast-mediated Bone Resorption

RANK Ligand Is Essential for Osteoclast Formation, Function, and Survival



Adapted from Boyle WJ et al. *Nature*. 2003;423:337-42.

Osteoprotegerin controls actions of RANKL on osteoclast function



Adapted from Boyle WJ et al. *Nature*. 2003;423:337-42.

Osteoporosis endpoint

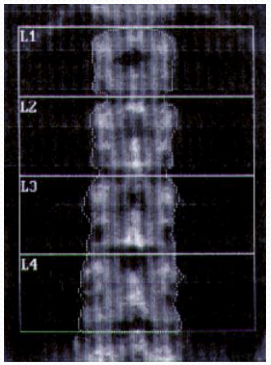
hip fracture

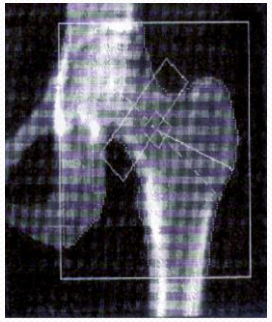
wrist fracture

spines fracture

Measurement of Osteoporosis

Dual energy X-ray absorptiometry (DXA)

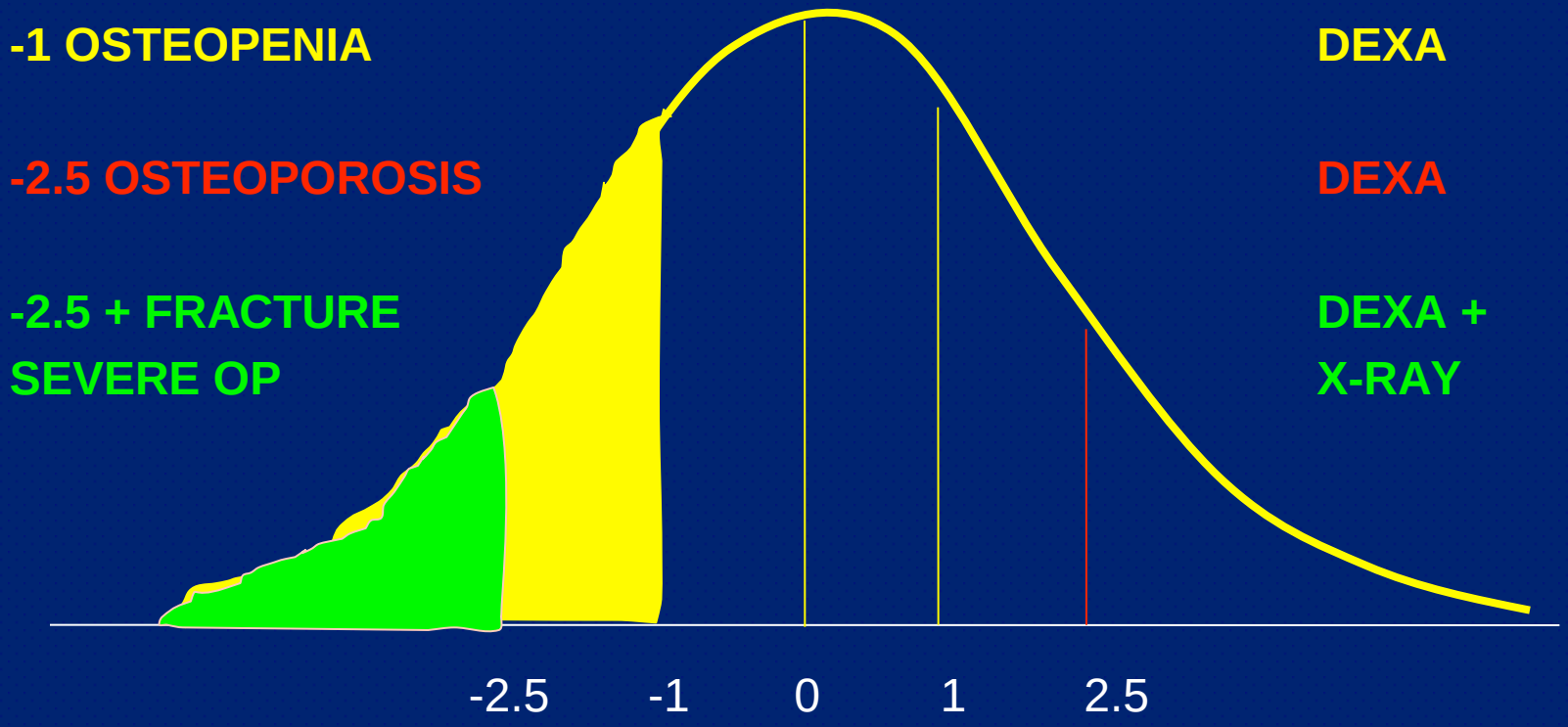




Quantitative computed tomography (QCT)

Ultrasound Scan (heel, wrist)

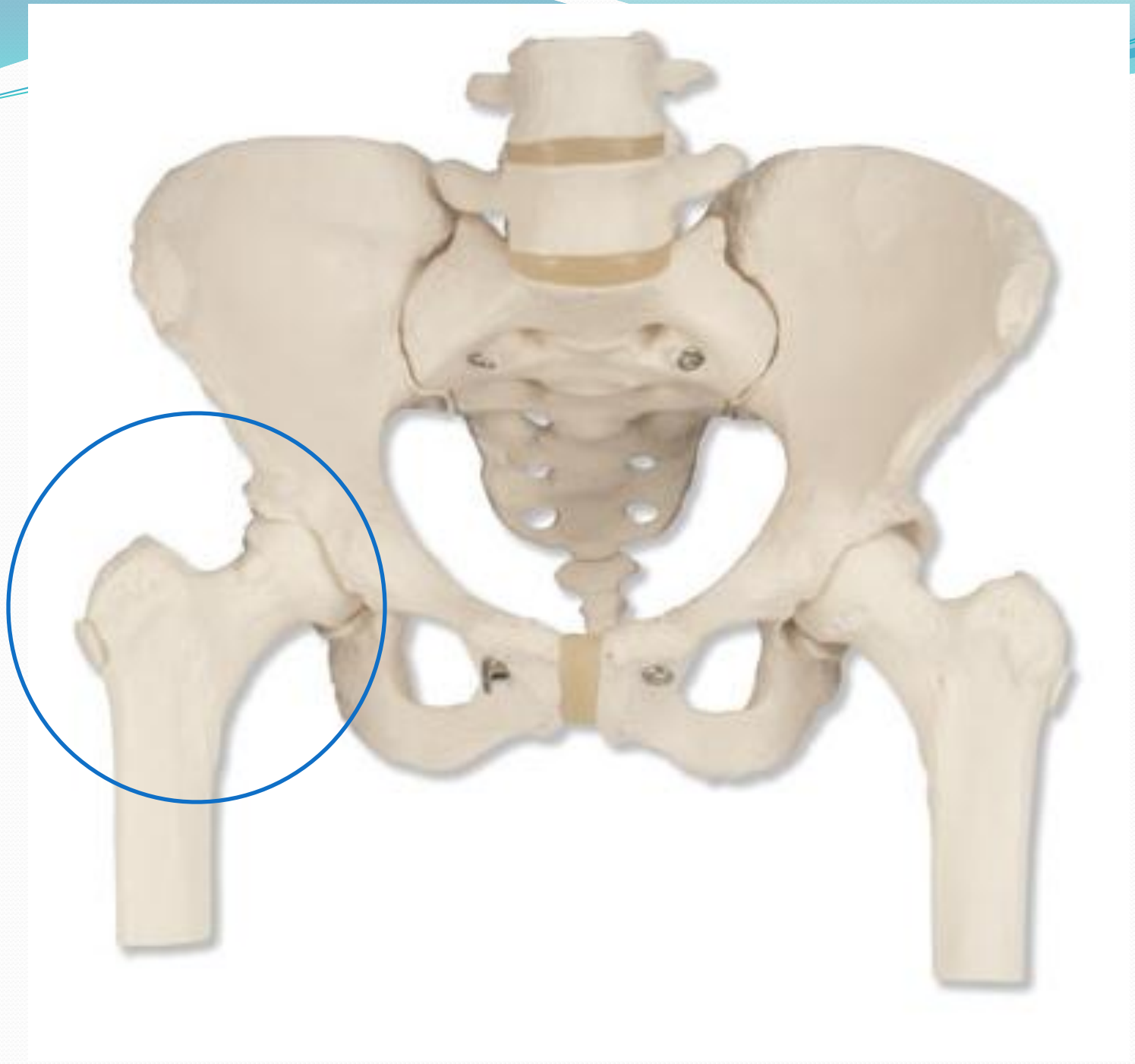
OSTEOPOROSIS(OP) DX: T-score

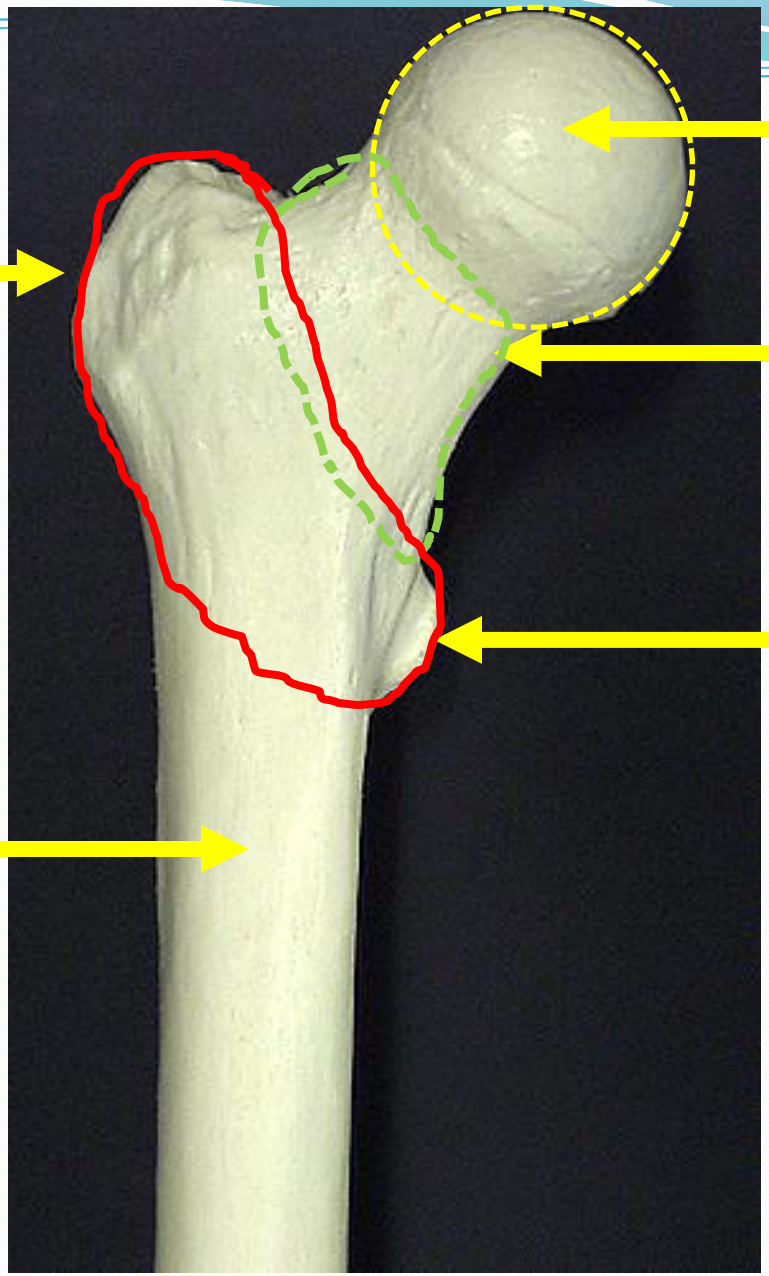


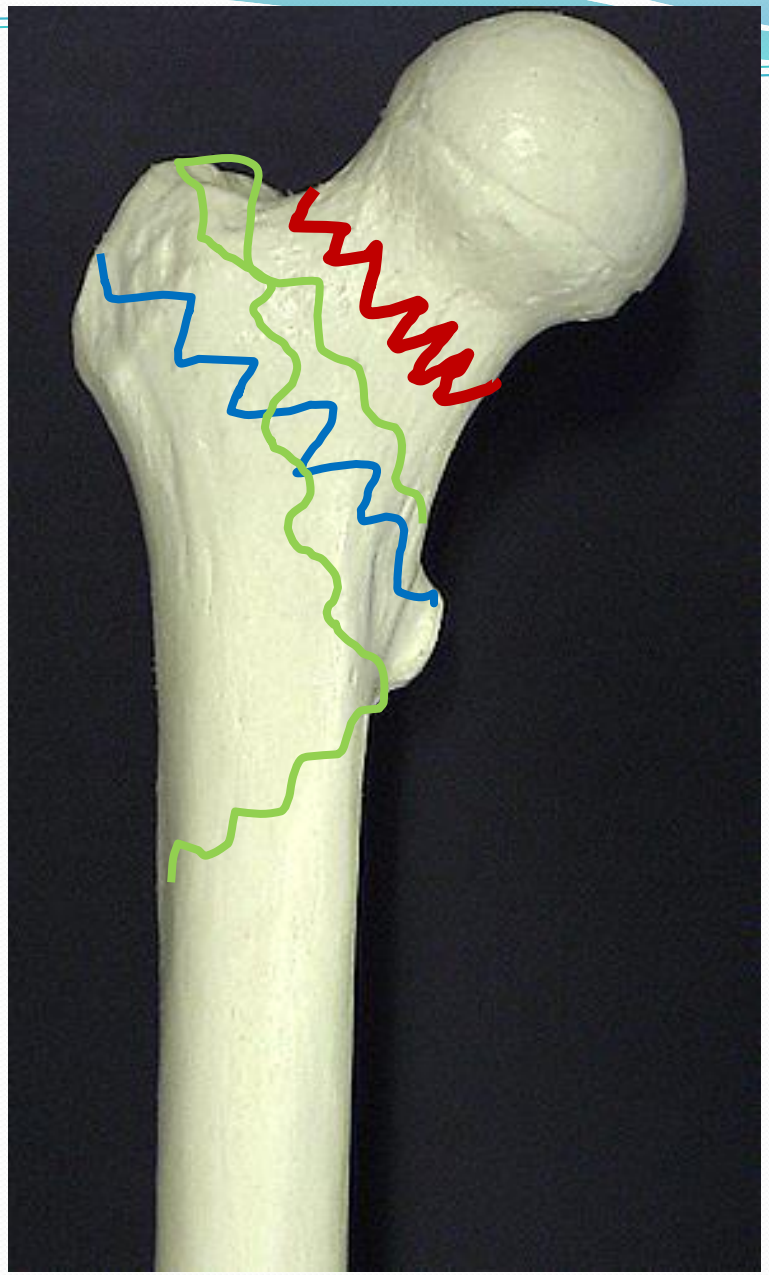
Dual energy X-ray absorptiometry (DXA)

Hip fracture

- Fracture around proximal femur




Head
Greater Trochanter
Neck
Lesser Trochanter
Subtrochanteric Region/Femoral Shaft



Objectives

- Anatomy of Hip Fractures
- Common Mechanisms of Injury
- Common Patterns of Hip Fractures
- Common Techniques for Surgical Management of Hip Fractures
- Special Situations
- Summary

Mechanism of injury

- Trivial trauma in elderly
- High energy trauma in the young

Physical examination

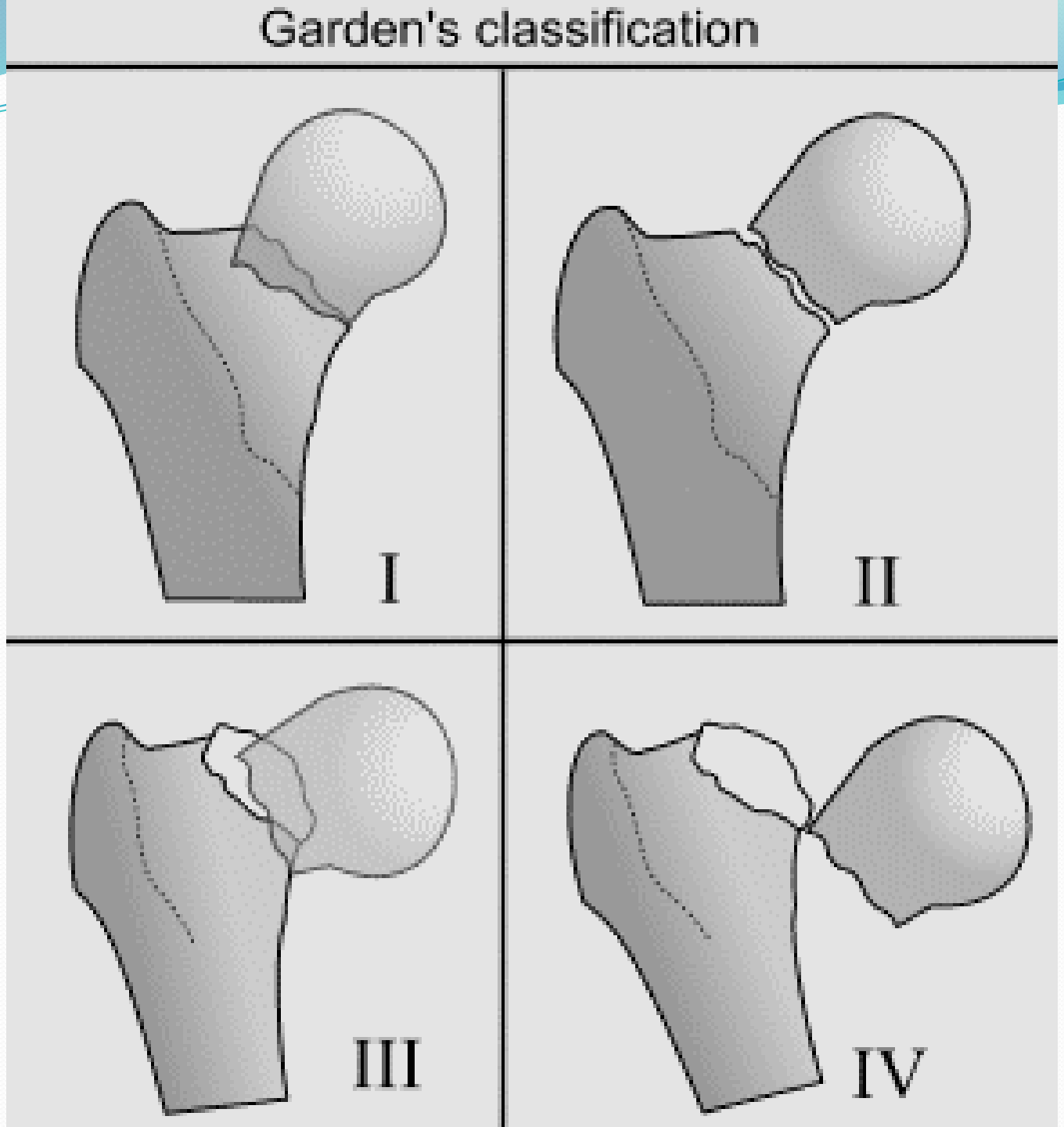
- Shortening
- Not swelling, less or no ecchymosis (intracapsular fracture)
- External rotation
- Severe pain with hip motion
- Rolling test
- Anvil test

Investigation

- Plain X-ray

- Both hips AP, Lateral cross table view

- Frog leg view is not recommend


Garden's classification
I
II
III
IV

Treatment

- Initial treatment

- Skin traction

- General perioperative care, avoid pressure sore, UTI, pneumonia, etc.

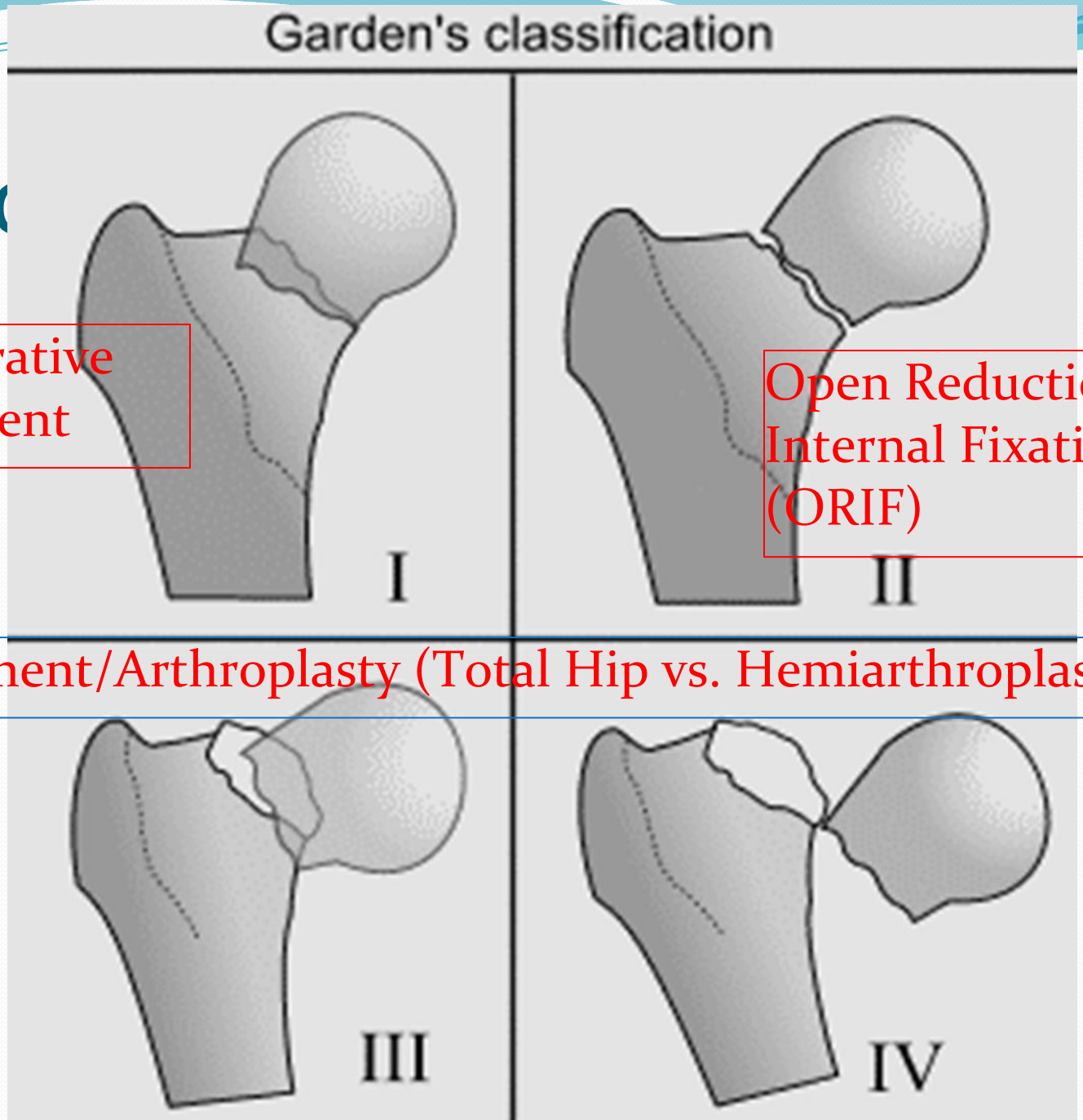
Definitive treatment for femoral neck fracture

- Operative treatment except

- Severe medical comorbidities

- Painless and paralyzed patient

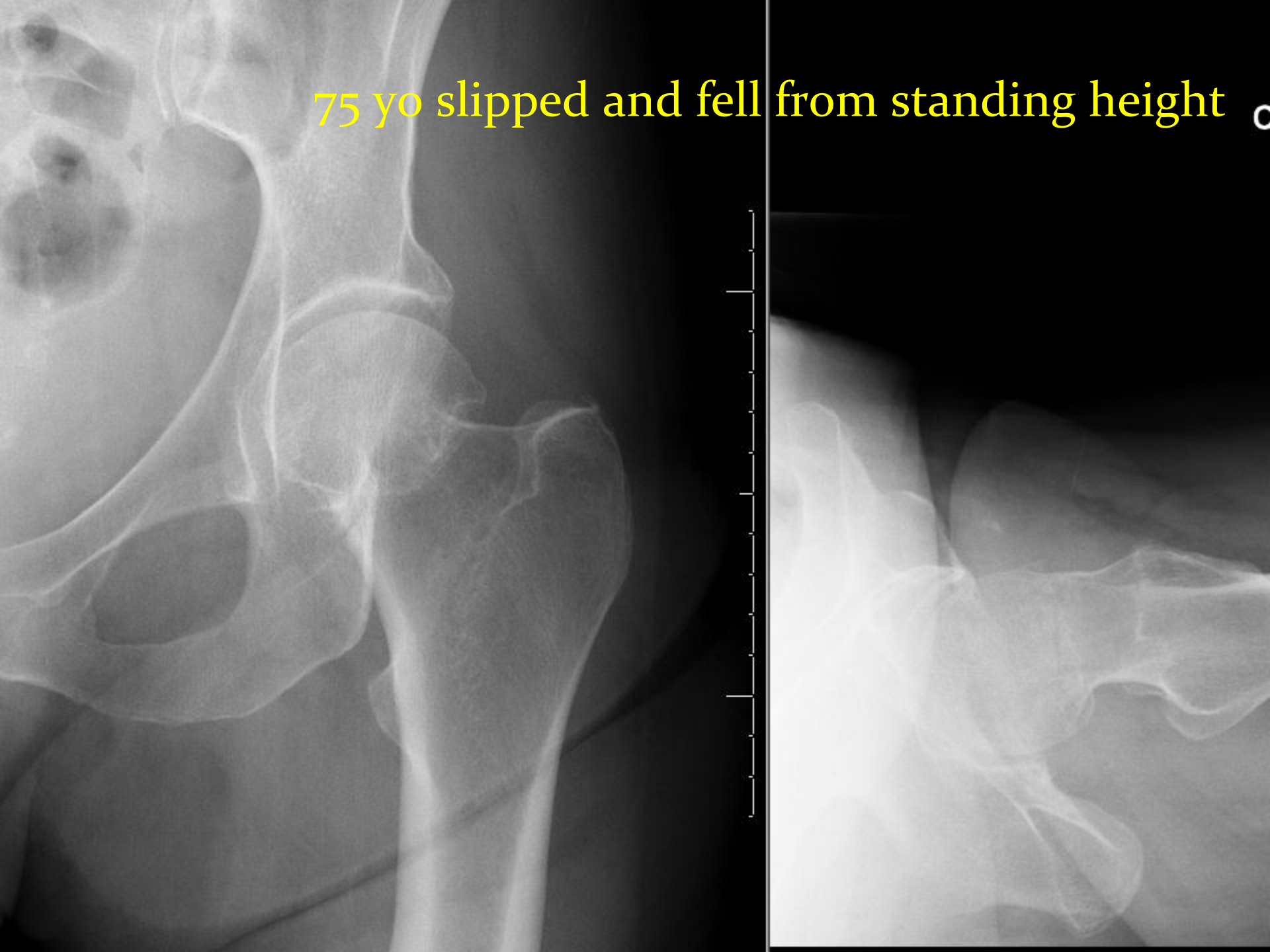
Femo



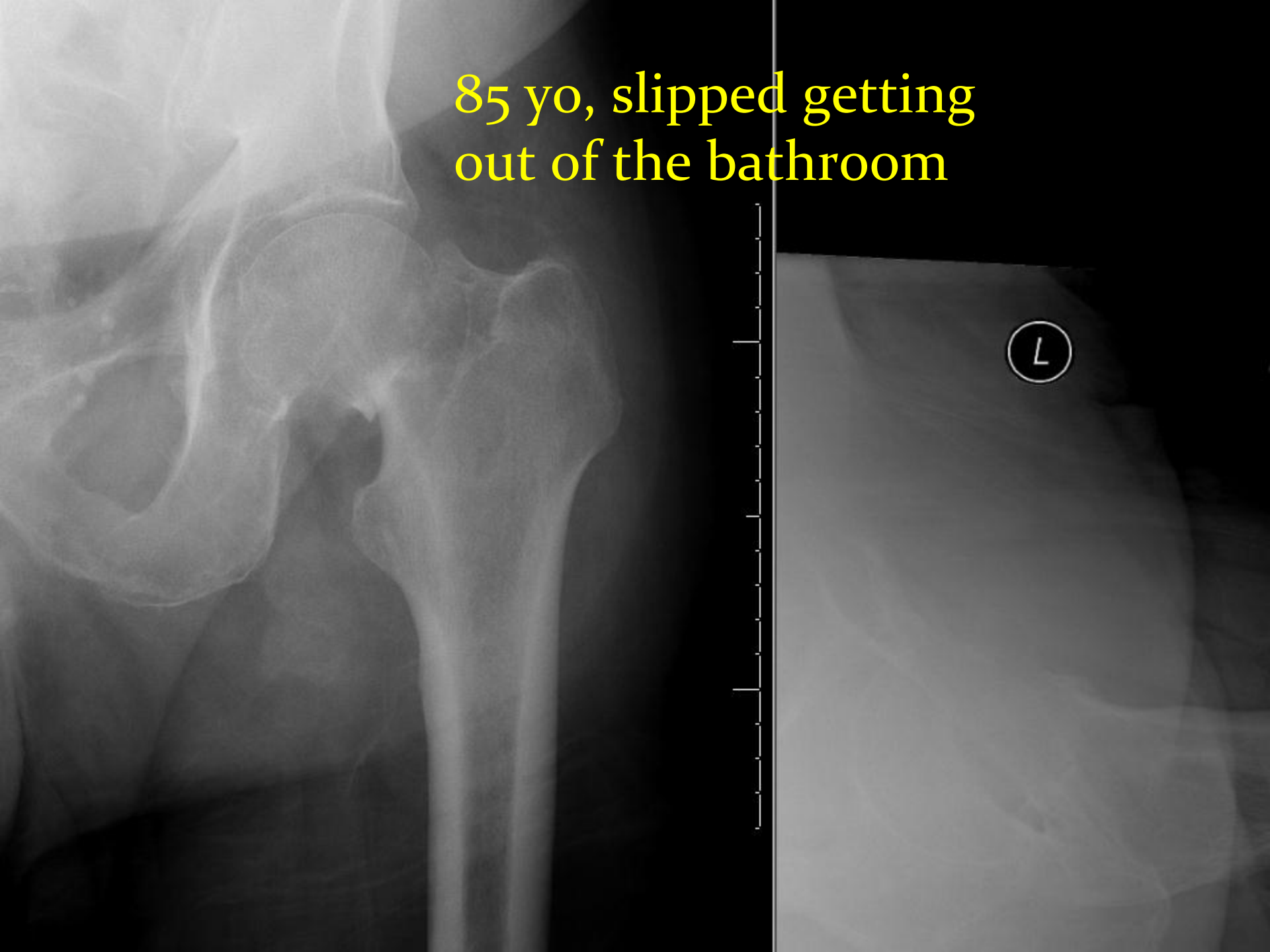
Non-Operative Management

Open Reduction and Internal Fixation (ORIF)

Replacement/Arthroplasty (Total Hip vs. Hemiarthroplasty)


75 yo slipped and fell from standing height


L
PORTABLE
CROSS
POR


85 yo, slipped getting
out of the bathroom
L


65 yo, healthy active, fell off a truck
L

Intertrochanteric Hip Fracture

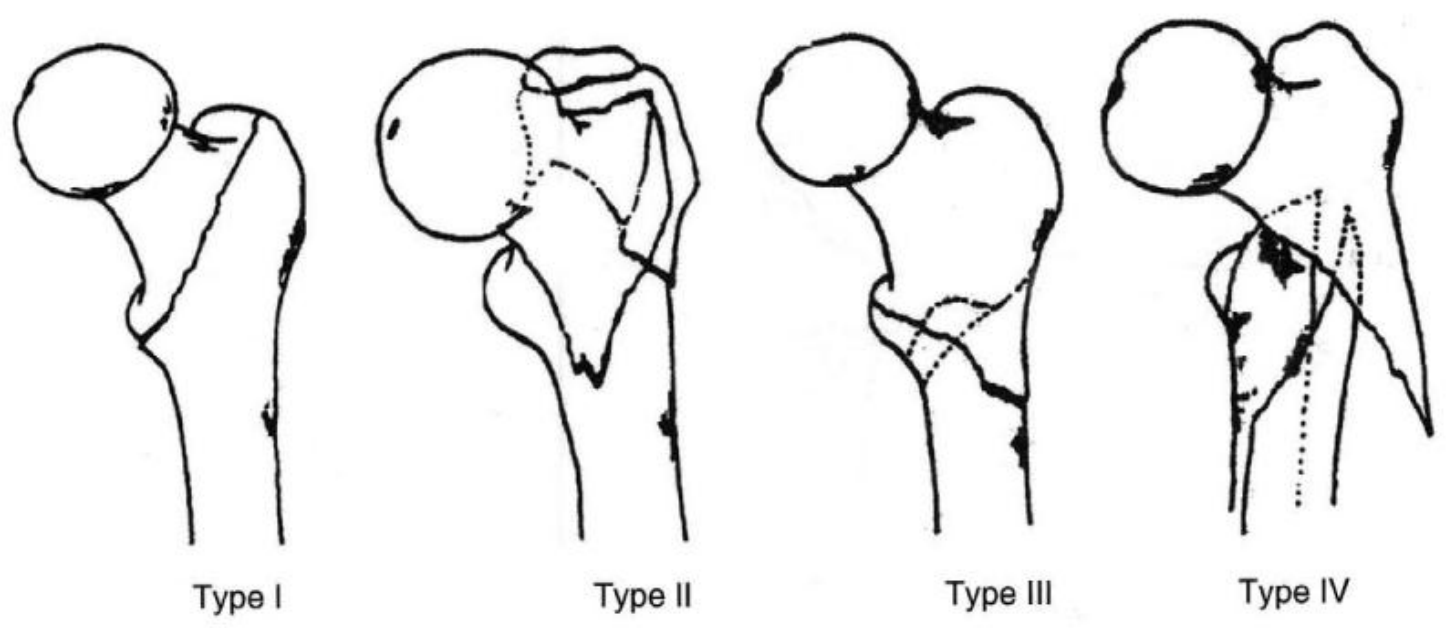
- Extracapsular fracture of the proximal femur between greater and lesser trochanters

Physical examination

- Swelling, ecchymisis
- Shortening
- Neutral or external rotation position

Classification

- Boyd and Griffin classification

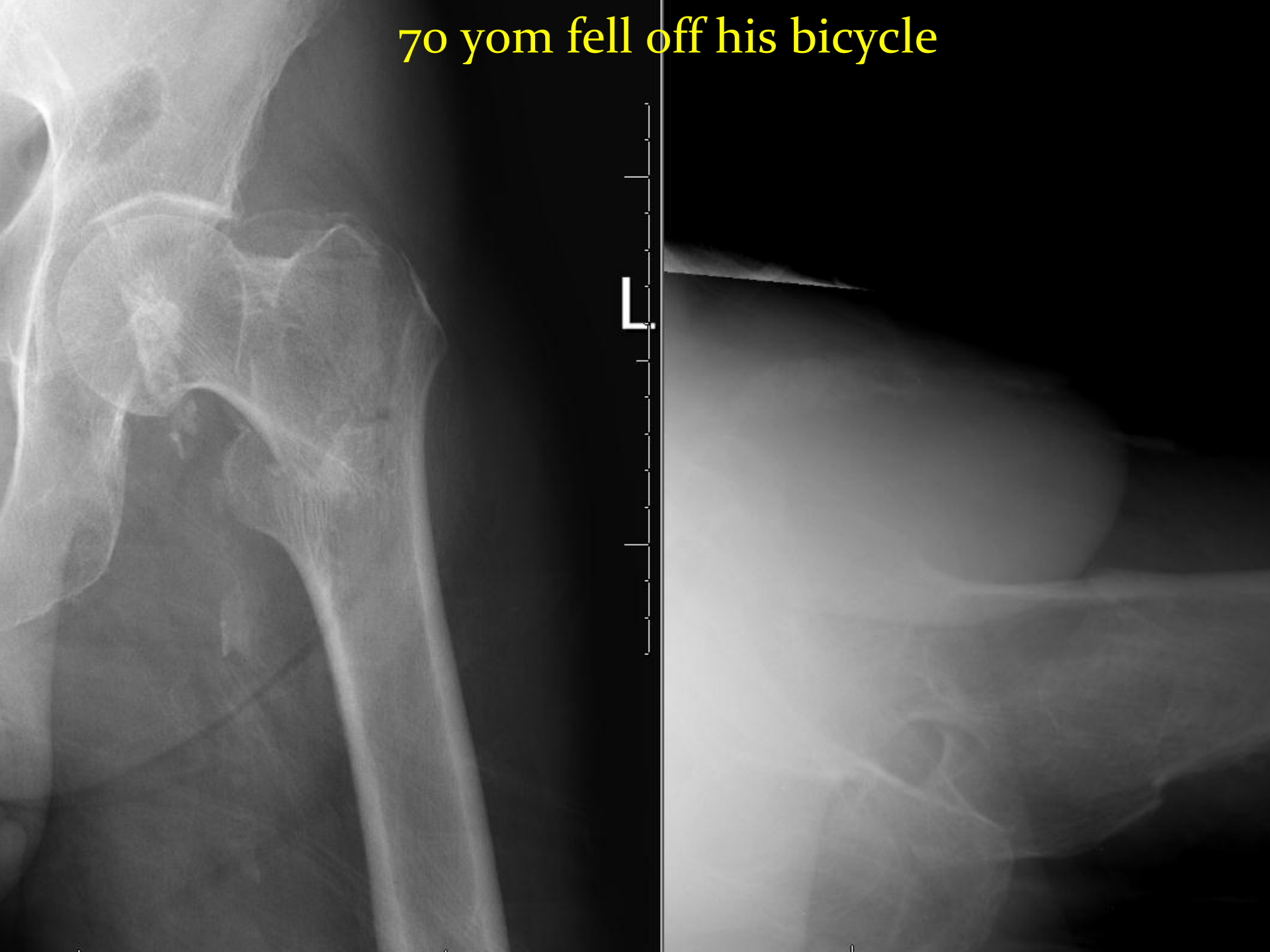


Treatment

- Initial treatment
  - Skin traction

- Definite treatment

- Internal fixation with Dynamic hip screw or Cephalomedullary nail or proximal femoral locking plate


70 yom fell off his bicycle
L

95 yof lives alone fell doing chores

Complications

- From prolong immobilization

- VTE, pressure sore, UTI and pulmonary complications

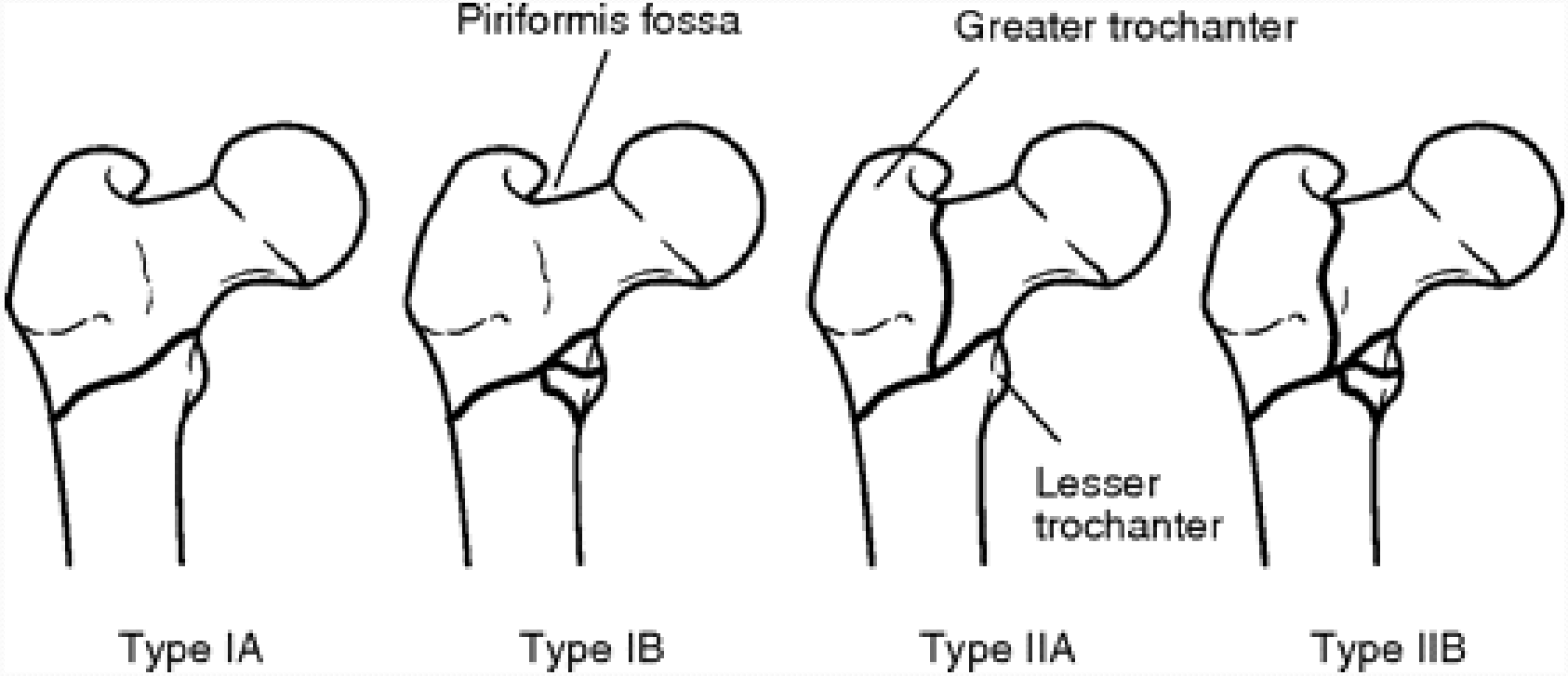
- From fracture

- Non-union, AVN

Subtrochanteric fracture

- Subtrochanteric typically defined as area from lesser trochanter to 5 cm distal

Russel Taylor Classification



Treatment

- Initial treatment
  - Skin traction or skeletal traction

- Definite treatment
  - Fixation with Cephalomedullary nail or proximal femoral locking plate

Complications of hip fracture

- From prolong immobilization

- VTE, pressure sore, UTI and pulmonary complications

- From fracture

- Non-union, AVN

Hip Fractures

Summary

- Common
- Fall prevention should be directed at minimizing delerium, using common sense
- Most common patterns recognized are femoral neck and intertrochanteric fractures
- Treatment depends on patient related factors and fracture pattern
  - Fix with screws, plates and screws or IMN
  - Replace part of the hip or the whole hip

Thank you