Osteoporosis and Bone Quality and Bone Fracture and Fixation

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Studying the Bone

Biology

Biomechanics

Imaging

Bone

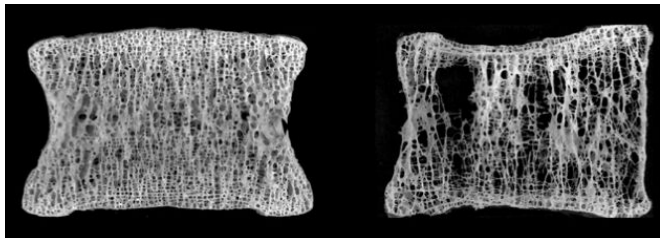
Osteoporosis
Bone Quality

Bone Fracture
and Fixation

Osteoporosis
And
Bone Quality

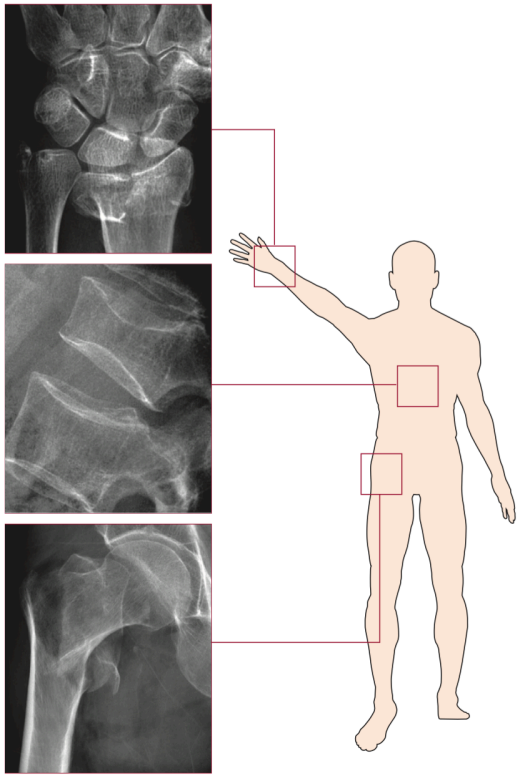
Osteoporosis

- WHO: progressive 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



- About 50% of women and 20% of man older than 50 years will have a fragility fracture
  - 20% individual with hip fracture will die in the next year
  - 20% individual with hip fracture will require permanent nursing home care

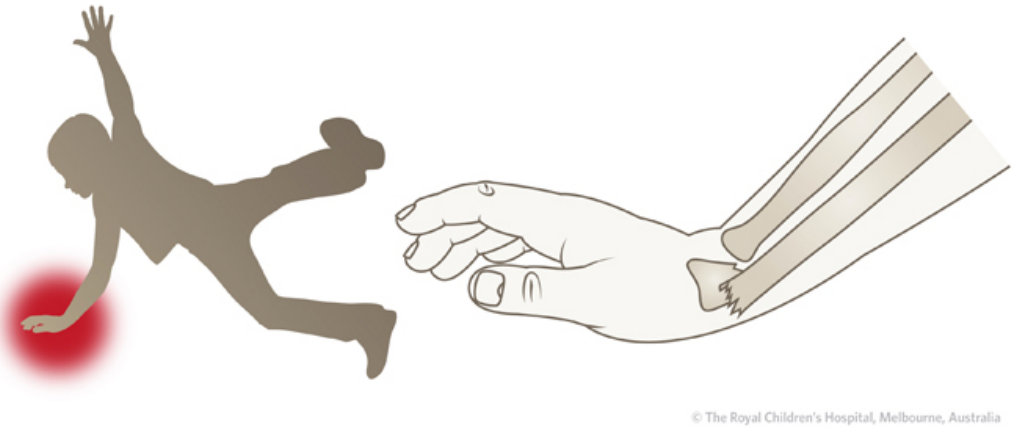
- Osteoporotic fractures happen at wrist, spine and hip

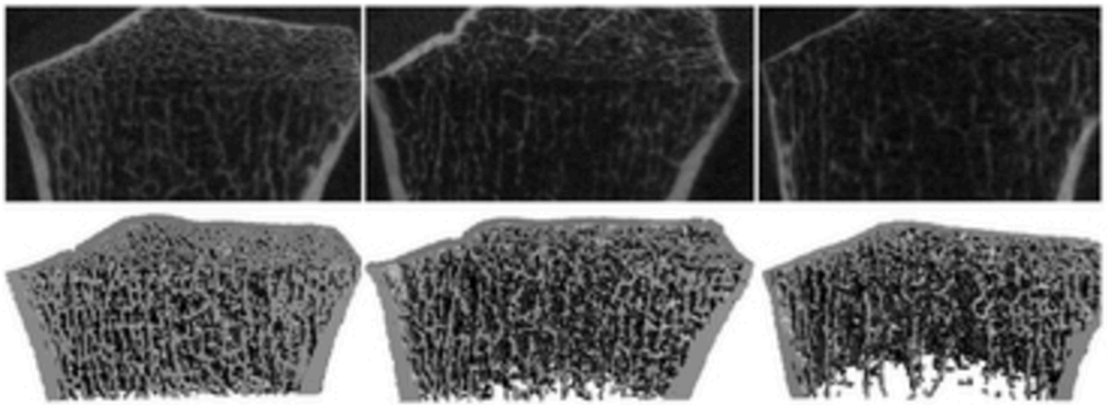


Rachner et al. 2011

2014. Bone Health and Osteoporosis: A Report of the Surgeon General

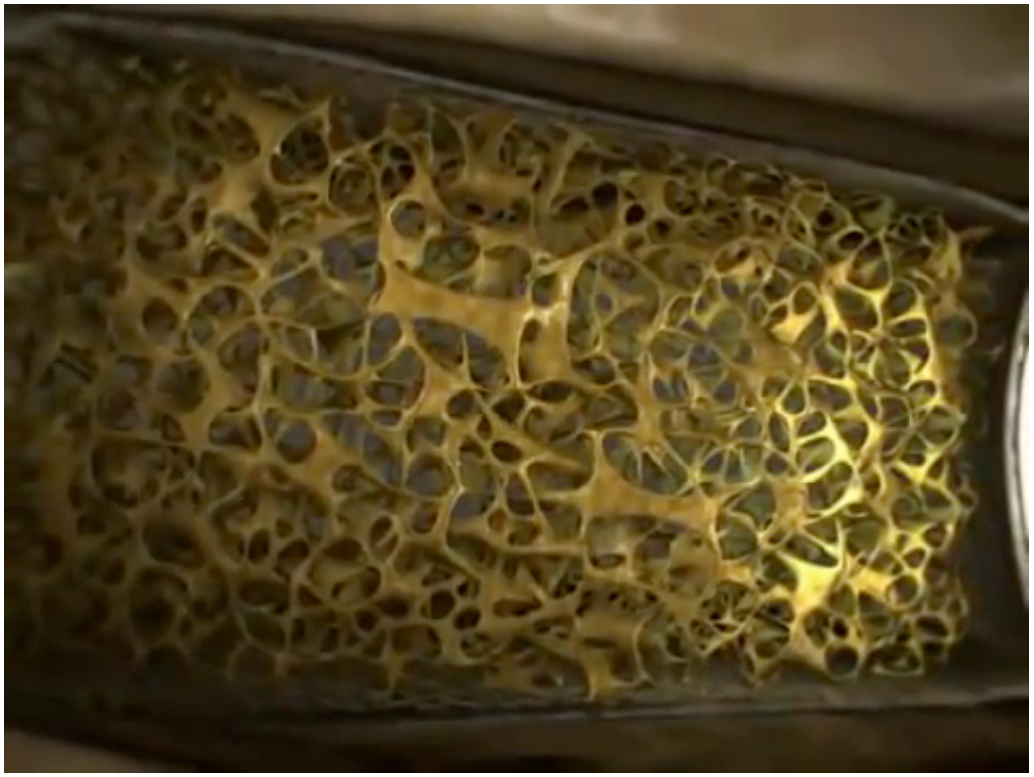
Osteoporosis At The Wrist





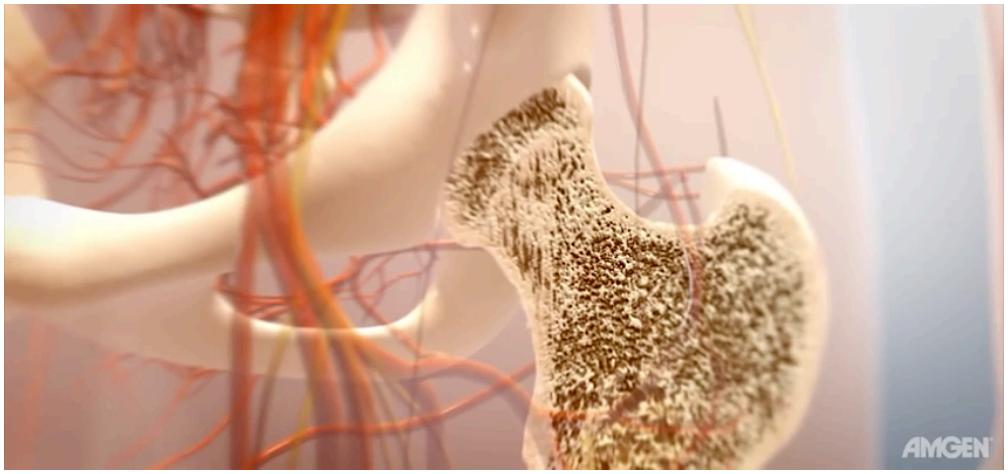
Geusen et al. 2014

Osteoporosis At The Spine

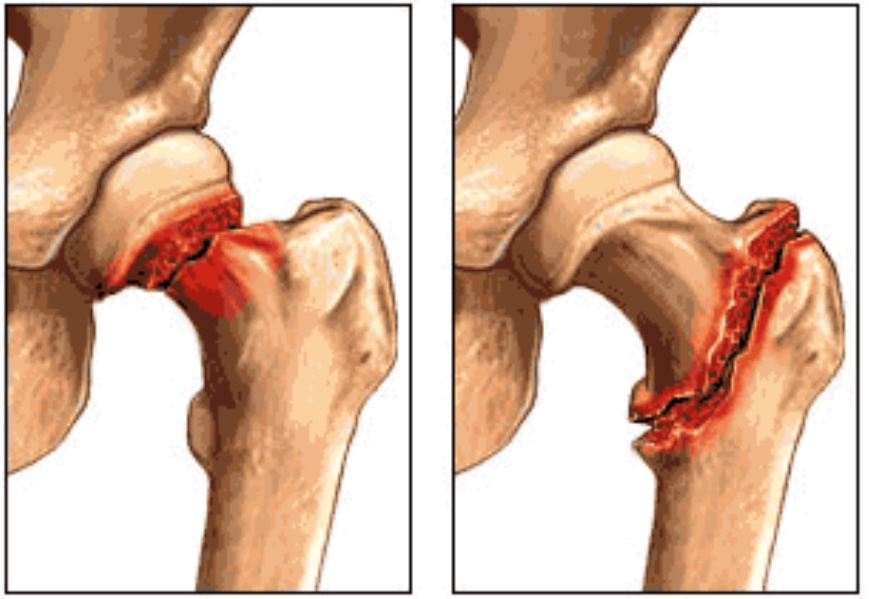


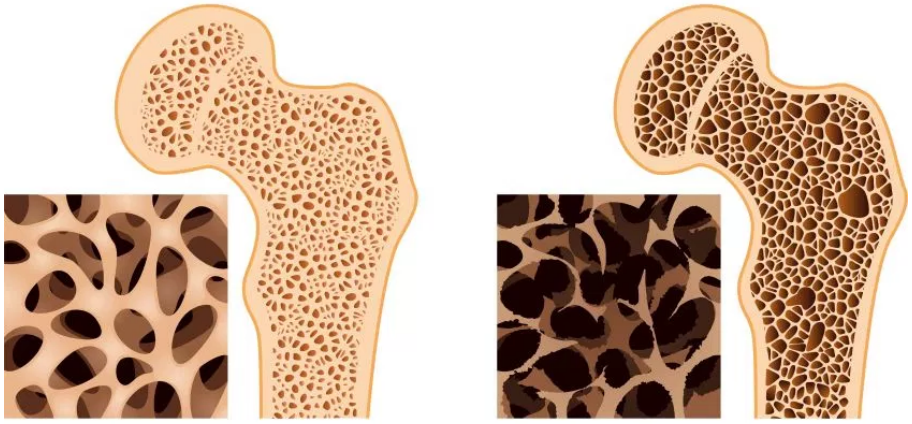
https://www.youtube.com/watch?v=Dr4_RqbWkyE

Osteoporosis At The Hip



https://www.youtube.com/watch?v=P5HwYWShBhw

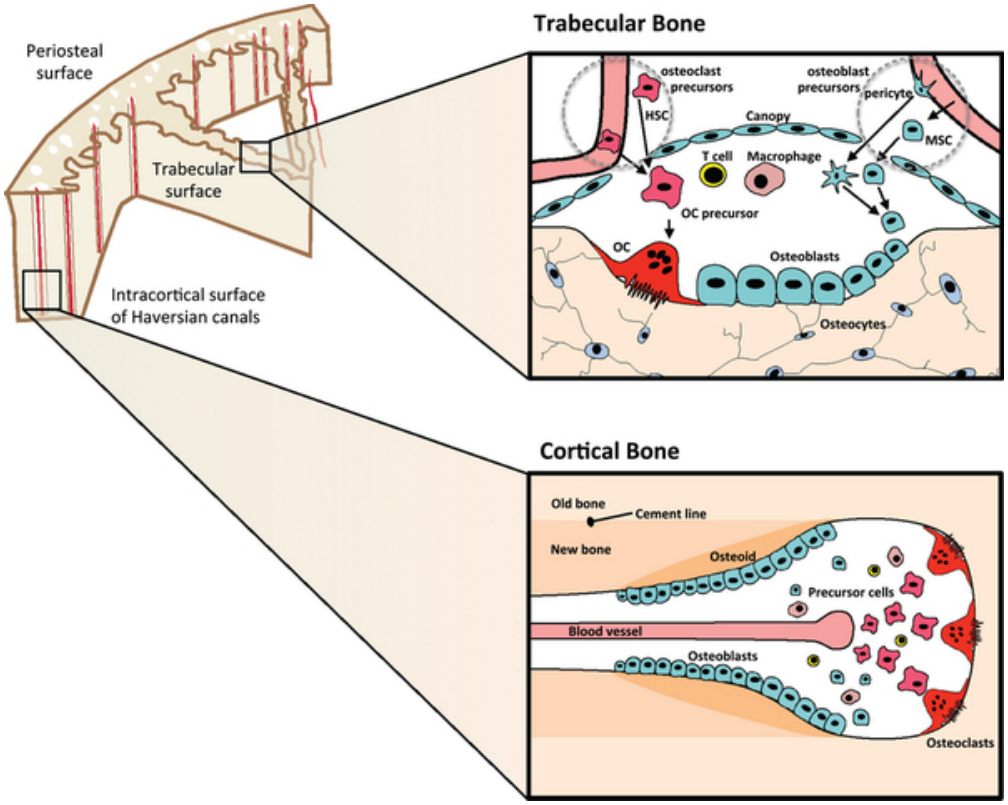




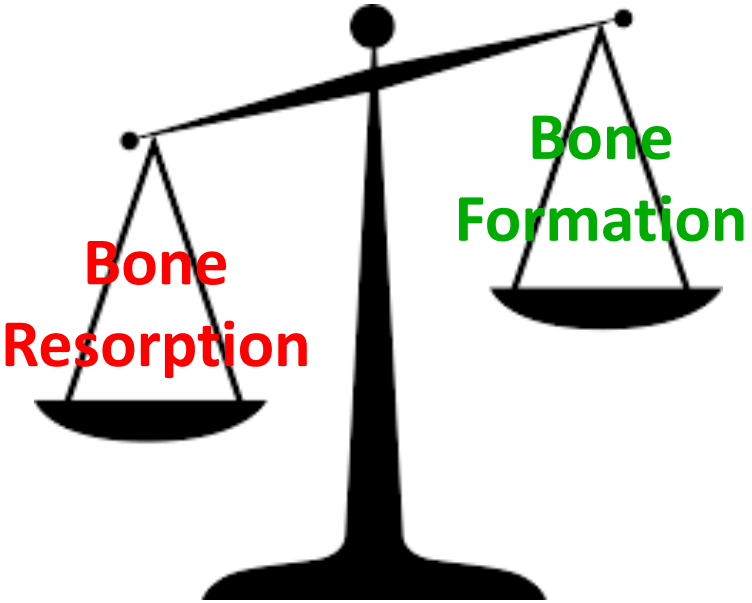
Healthy bone

Osteoporosis

Biology of Osteoporosis

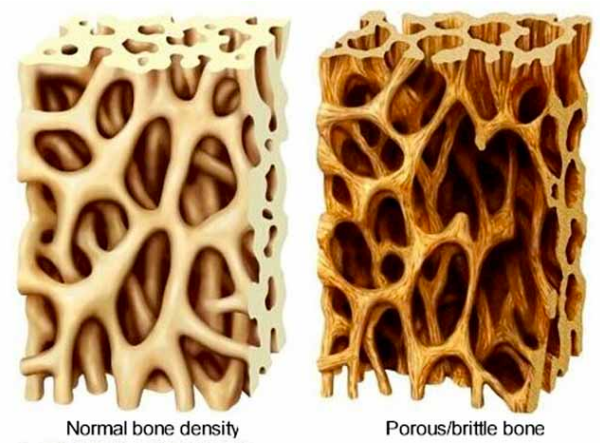


Sims and Martin. 2014

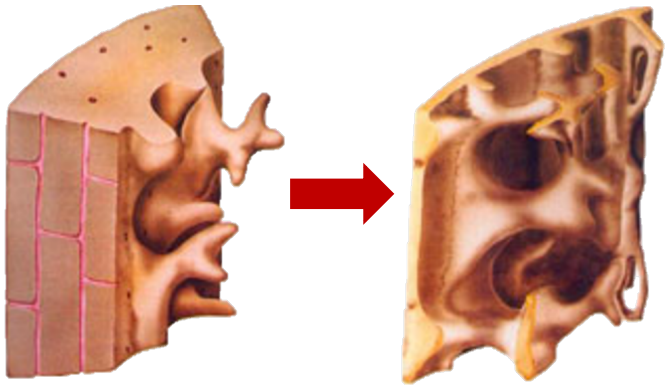


Bone Tissue Changes in Osteoporosis

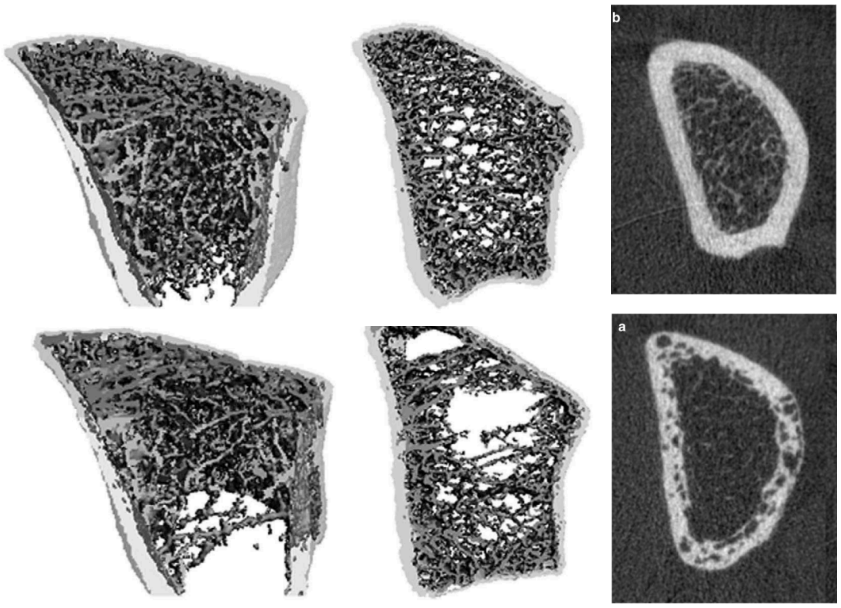
Trabecular thinning and loss of connectivity



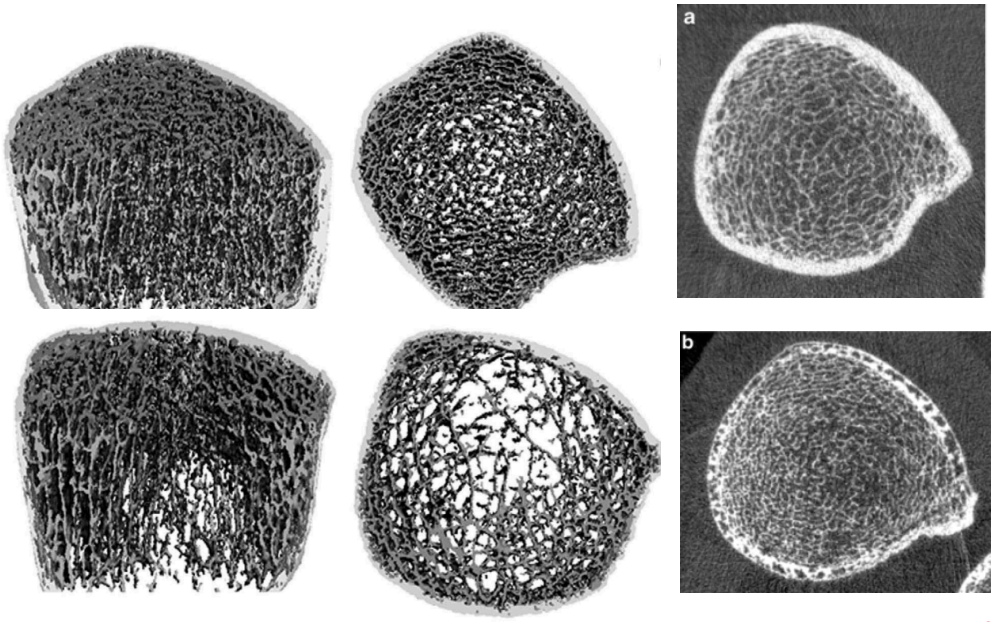
Cortical thinning and porosity "Trabecularization"



Radius



Tibia



Zhu et al. 2016

Woman Vs. Man Osteoporosis

- 50% > 45-50yrs will have osteoporotic fracture
  - 20% will die in the first year

- 20% men > 50yrs will have osteoporotic fracture
- Each year 80,000 hip fractures
  - 1/3 will die in the first year
  - 1/3 will fracture again

Veldurthy 2016; Macdonald et al. 2011

Woman Vs. Man Osteoporosis

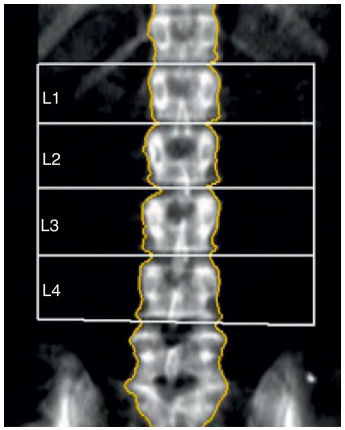
- Young age
  - Smaller bone
  - Less thick cortical bone
  - Less and thinner trabeculae
- > 45-50 years
  - Menopause: Decreased level of estrogen increase bone resorption
  - Loss of trabeculae
  - Higher cortical porosity

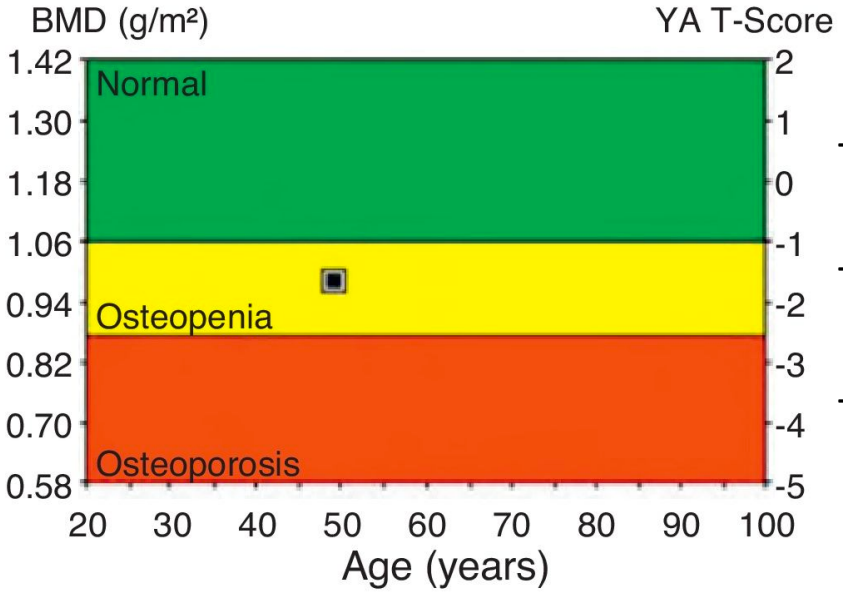
- Young age
  - Larger bone
  - Thicker cortical bone
  - More and thicker trabeculae
- > 70 years
  - Slower decrease of sexual hormones and decrease of bone formation
  - Thinning of trabeculae
  - Less cortical porosity

Macdonald et al. 2011

Diagnosis Of Osteoporosis

- DXA





T-score > -1 Normal → Normal

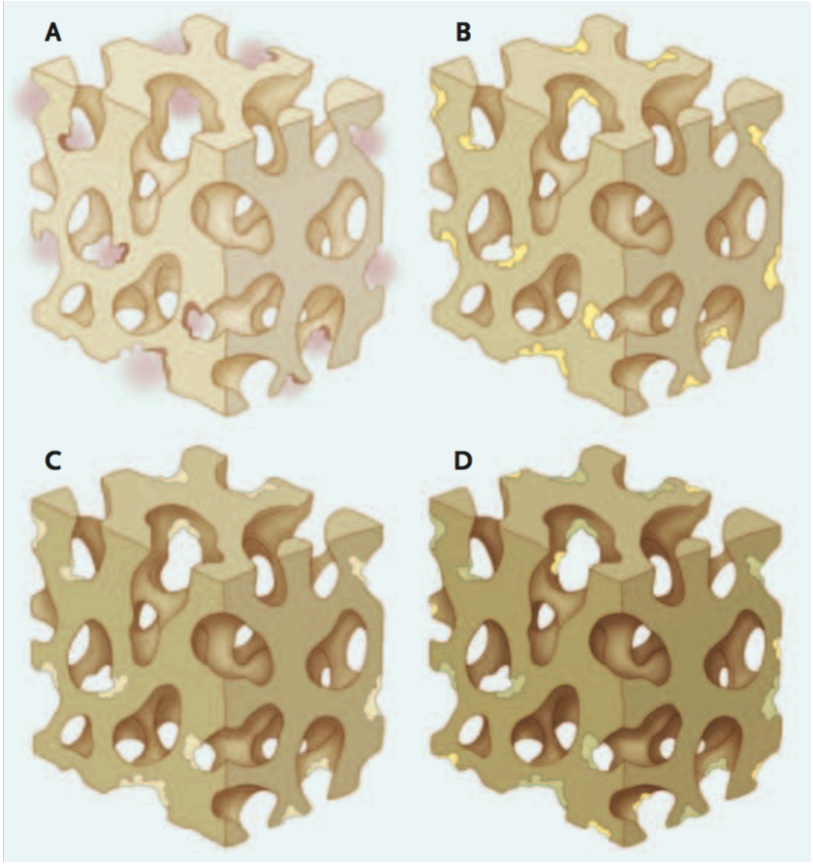
T-score < - 1 and > -2.5 → Osteopenia

T-score < -2.5 → Osteoporosis

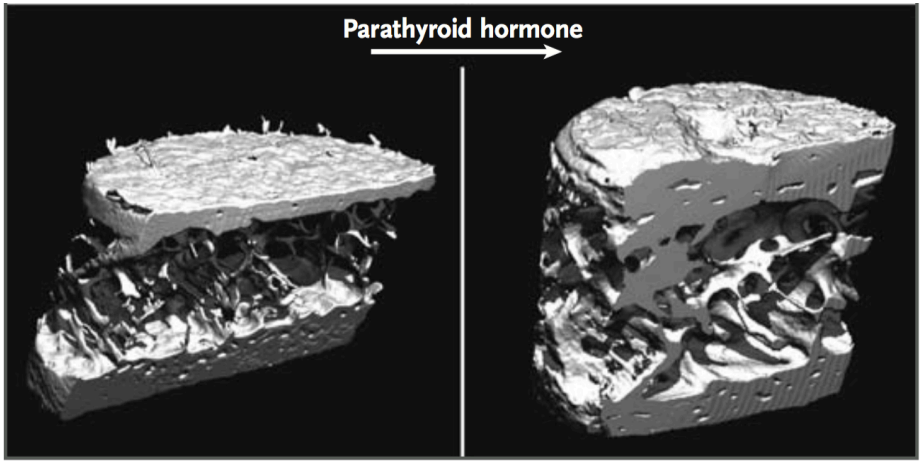
- Limitations
  - *Areal* BMD
  - Body-size dependent
  - No separation cortical/trabecular compartments

Current Pharmacological Treatments

Antiresorptive drugs:
slow down bone resorption



Anabolic drugs:
stimulate bone formation



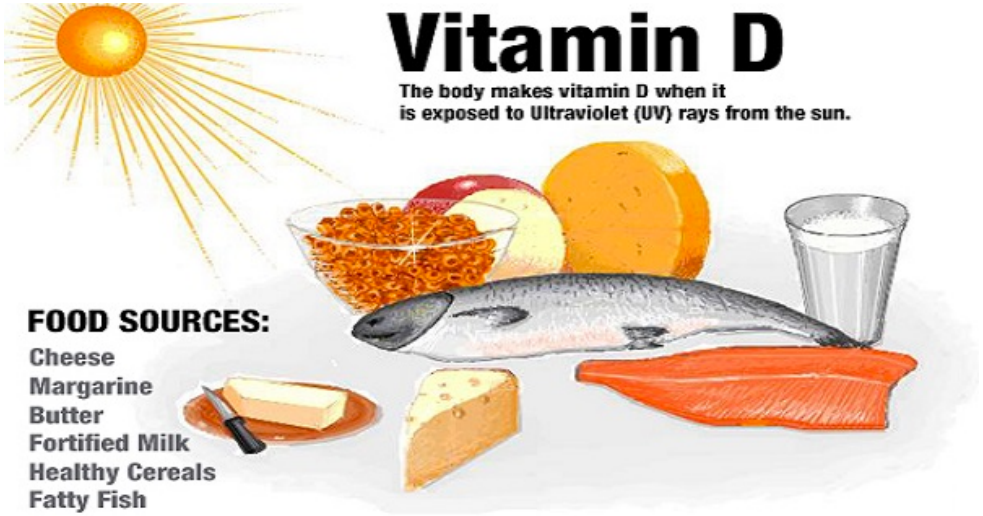
Combination of antiresorptive + anabolic drugs:

- BMD outcomes depend on the timing and drugs used
- Spine studies show no benefit with combination therapy vs. monotherapy

Seeman et al. 2006; Cosman 2014

Calcium and Vitamin D Supplementation

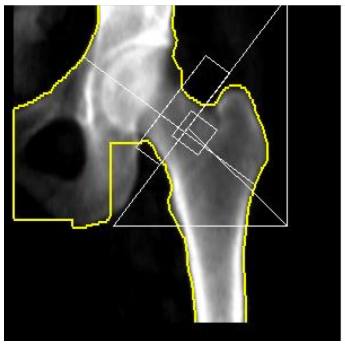
- Calcium
  - 99% of calcium is in the skeleton stored as hydroxyapatite
  - It is only available to the body through dietary intake (dairy)
  - In the elderly there is inadequate intestinal absorption of calcium
- Vitamin D 25(OH)D
  - It is derived from the diet (fortified dairy or fish oils) or synthesized in the skin – sunbath!
  - It helps calcium intestinal absorption
  - It maintains and controls calcium serum level

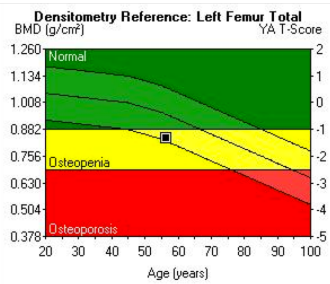


Bone Quality

- *Bone quality* is the sum of all characteristics of bone that affect fracture except bone mineral density (BMD) [Hernandez et al. 2006]

- BMD is the gold standard assess osteoporosis
- BMD does not fully explain fracture risk
- BMD should be used as one of several factors to assess fracture risk





- Other factors should be used

Factors Affecting Bone Quality And Strength

Intrinsic	Extrinsic	Environmental
Bone Mass	Age	Mechanical Loading
Geometry (and Architecture)	Sex	Diet
Material Properties (Tissue Composition)	Disease	
	Genetics	

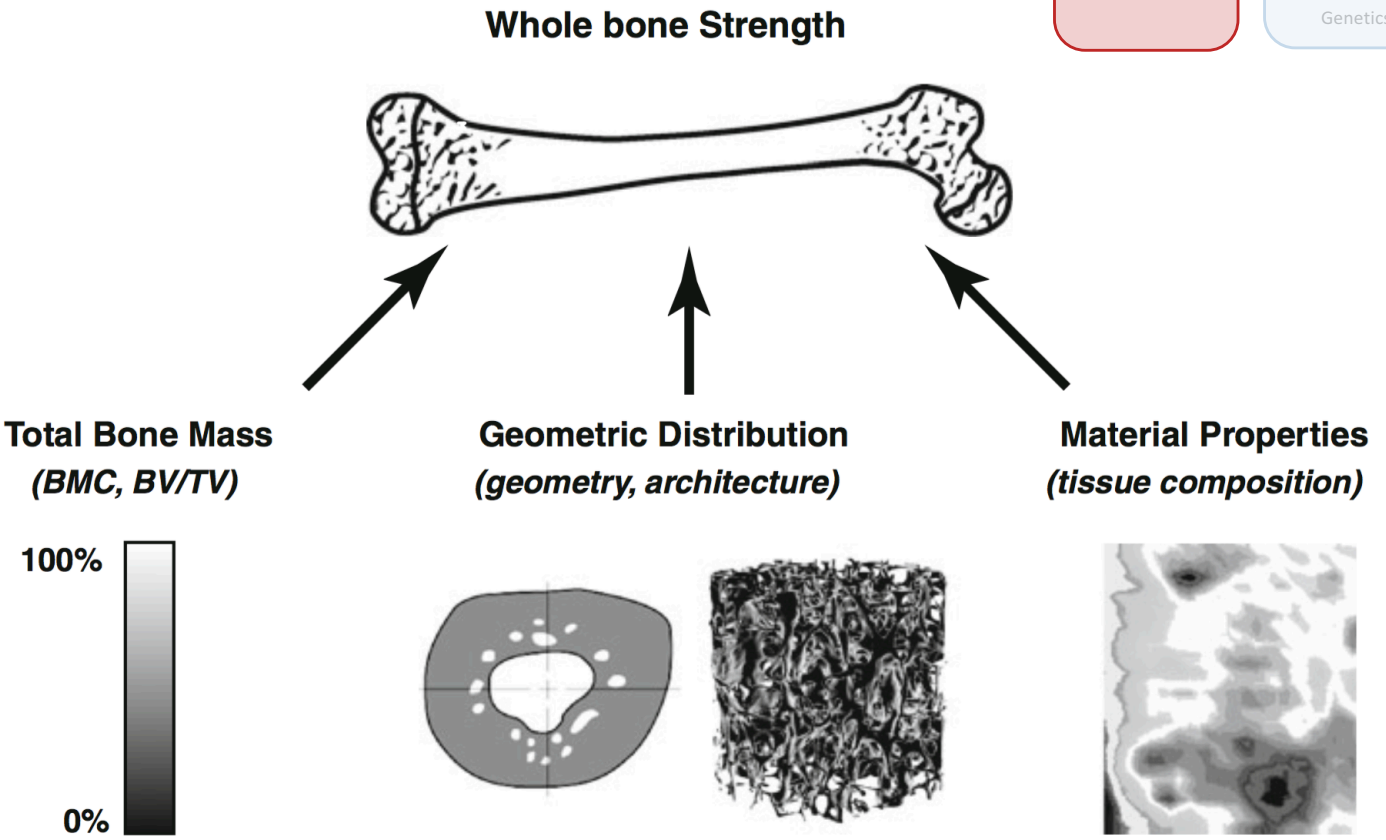
Cole et al., 2011

Intrinsic Factors

Intrinsic
- Bone Mass
- Geometry (and Architecture)
- Material Properties (Tissue Composition)

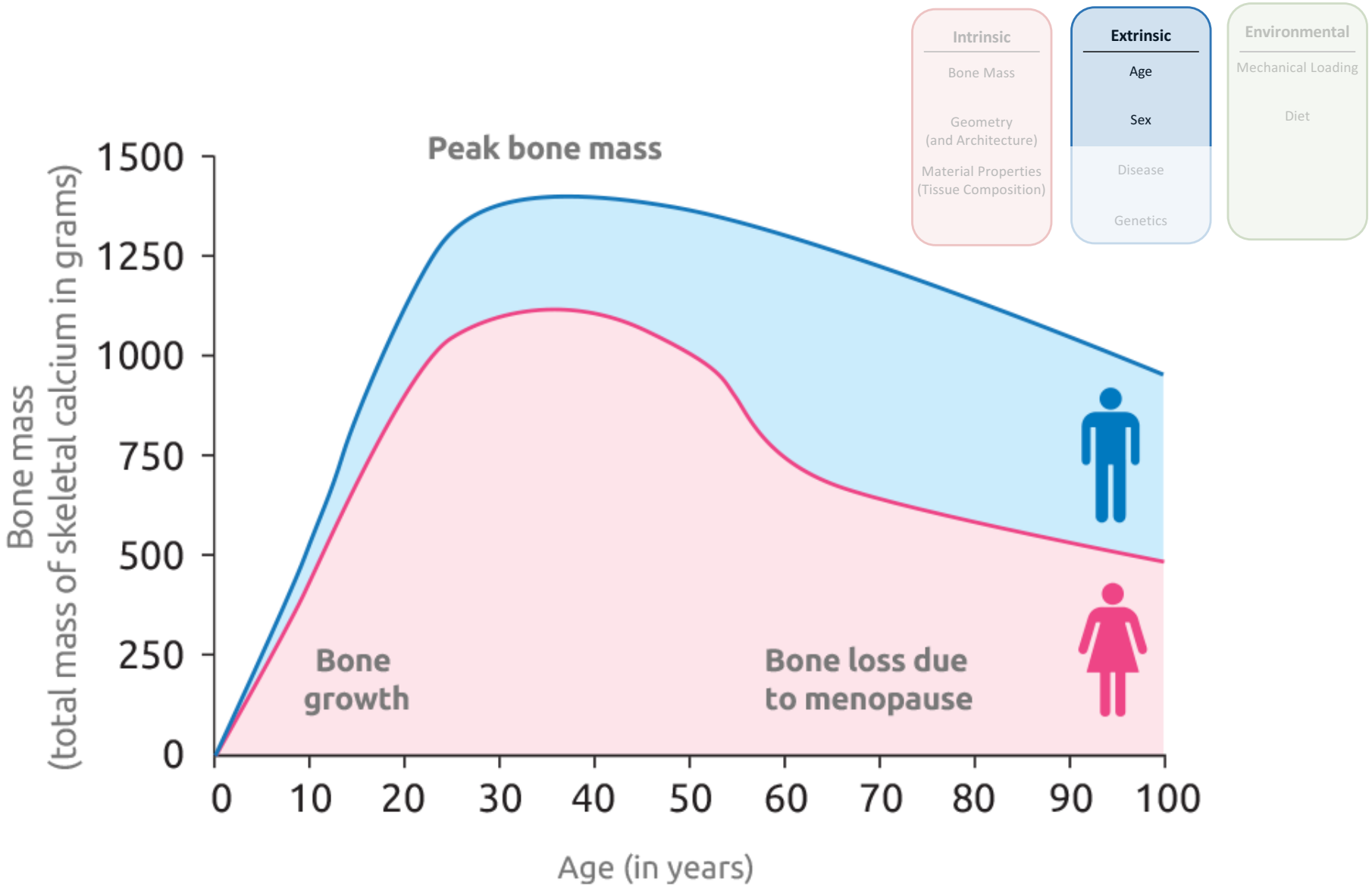
Extrinsic
- Age
- Sex
- Disease
- Genetics

Environmental
- Mechanical Loading
- Diet



Cole et al. 2011

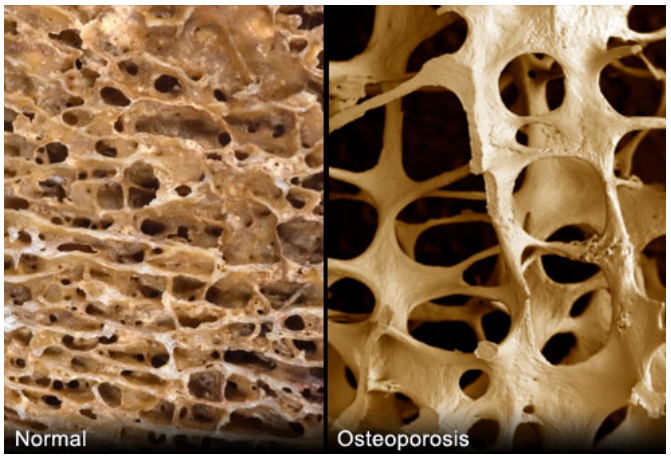
Extrinsic Factors - Age and Sex



- Compressive strength decreases by 50% to 75% in whole vertebra, vertebral trabecular bone and distal femoral trabecular bone [Cole 2011]

Extrinsic Factors – Disease and Genetics

Osteoporosis



Intrinsic	Extrinsic	Environmental
Bone Mass	Age	Mechanical Loading
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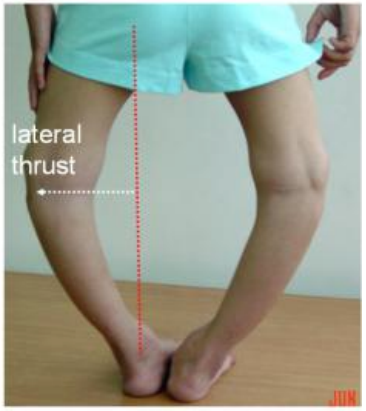
Osteomalacia (Rickets)

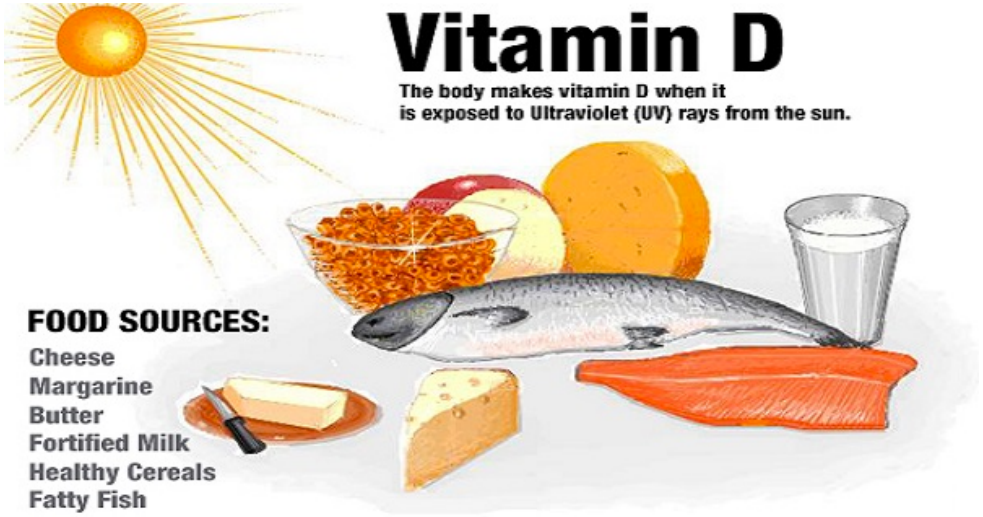


6 year old /c
Hypophosphatemic rickets

Osteogenesis Imperfecta

Environmental factors – Mechanical Loading and Diet

Intrinsic	Extrinsic	**Environmental**
Bone Mass	Age	Mechanical Loading
Geometry (and Architecture)	Sex	Diet
Material Properties (Tissue Composition)	Disease	
	Genetics	



Bone Fractures and Fixation

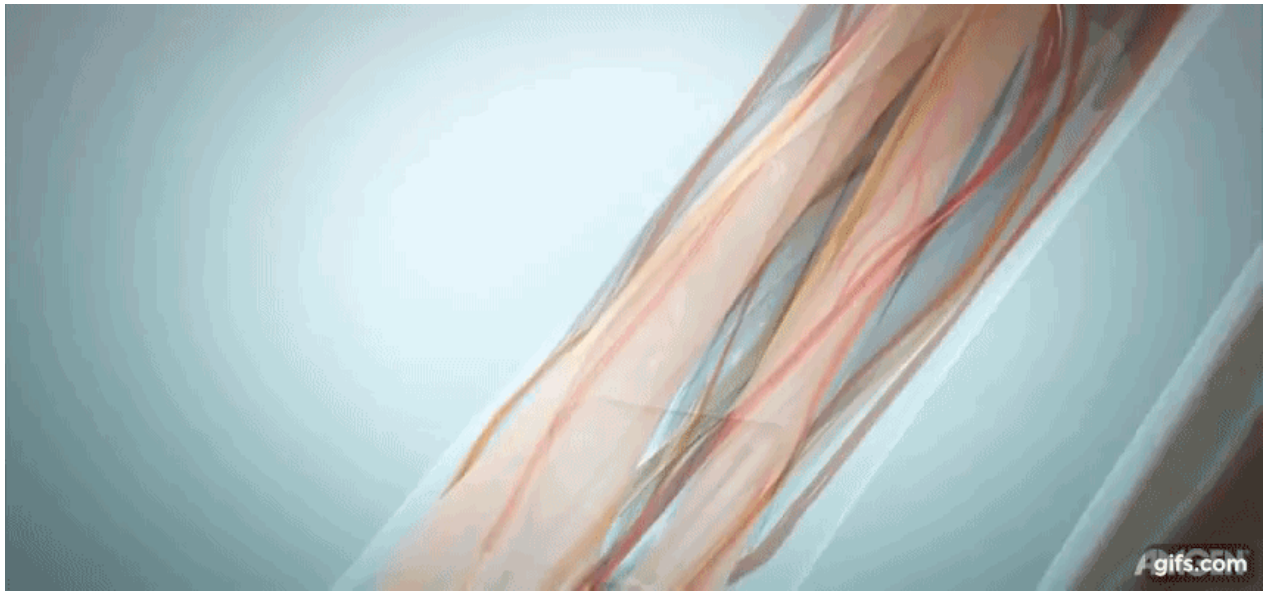
When Does a Fracture Occur?

- A bone fracture occurs when a bone cannot withstand the applied force

- Causes of bone fractures:
  - Disease: e.g. osteoporosis
  - Trauma
  - Bone tumor

Fracture Repair

- The healing process is constituted by three main phases:
  - Inflammatory phase
    1. Fracture and generation of hematoma



Fracture Repair

- The healing process is constituted by three main phases:
  - Inflammatory phase
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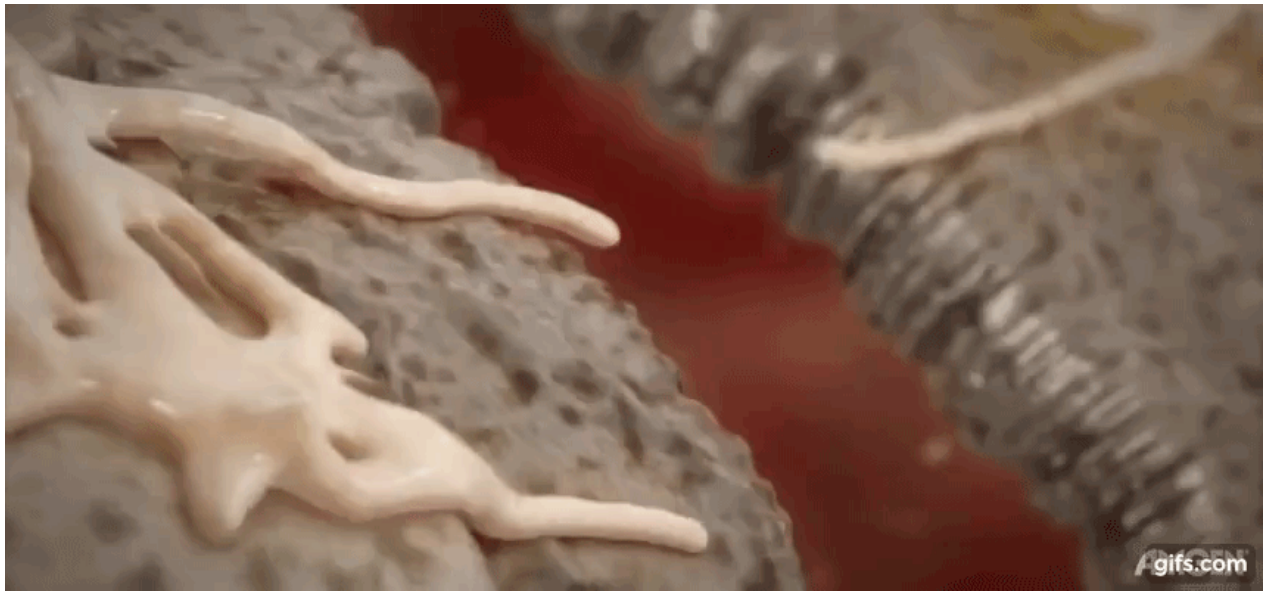
  - Reparative/Granulation phase
    2. Creation of a cartilaginous soft callus



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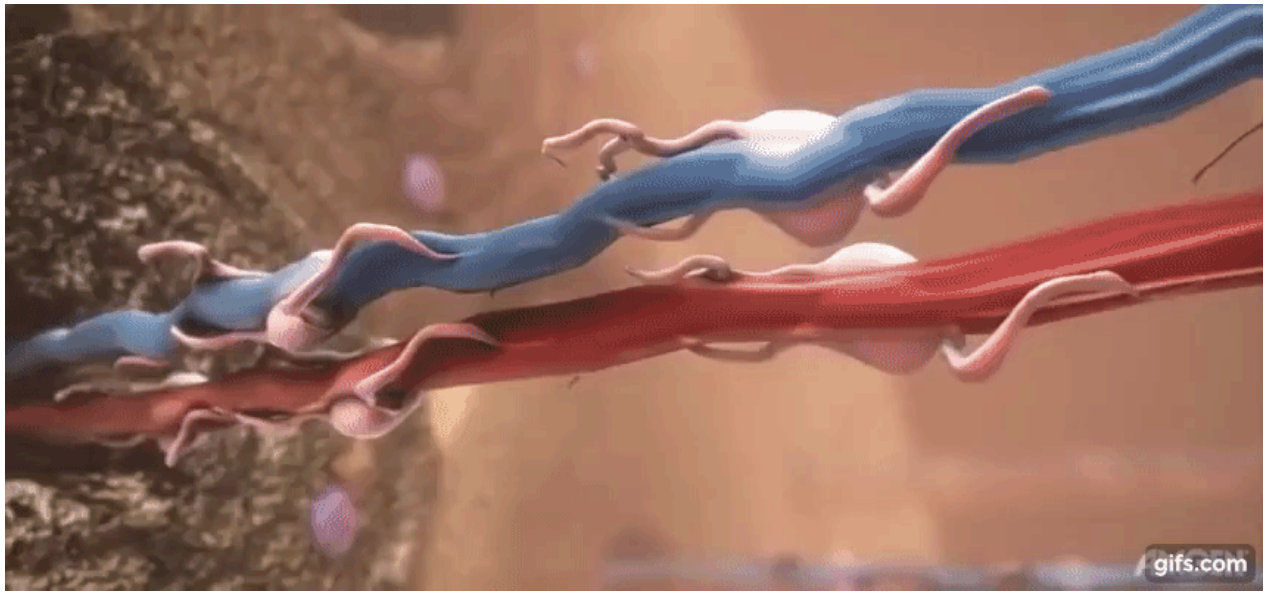

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    3. Transformation to a bony callus
  - Remodeling phase
    4. The woven bone is replaced by lamellar bone

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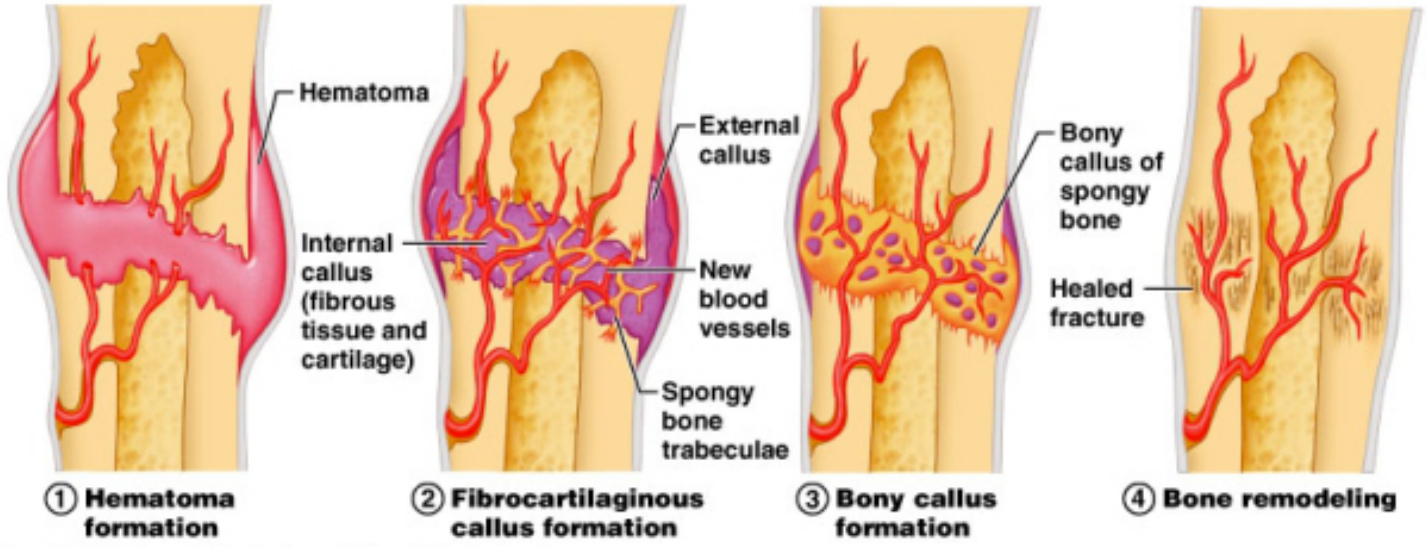
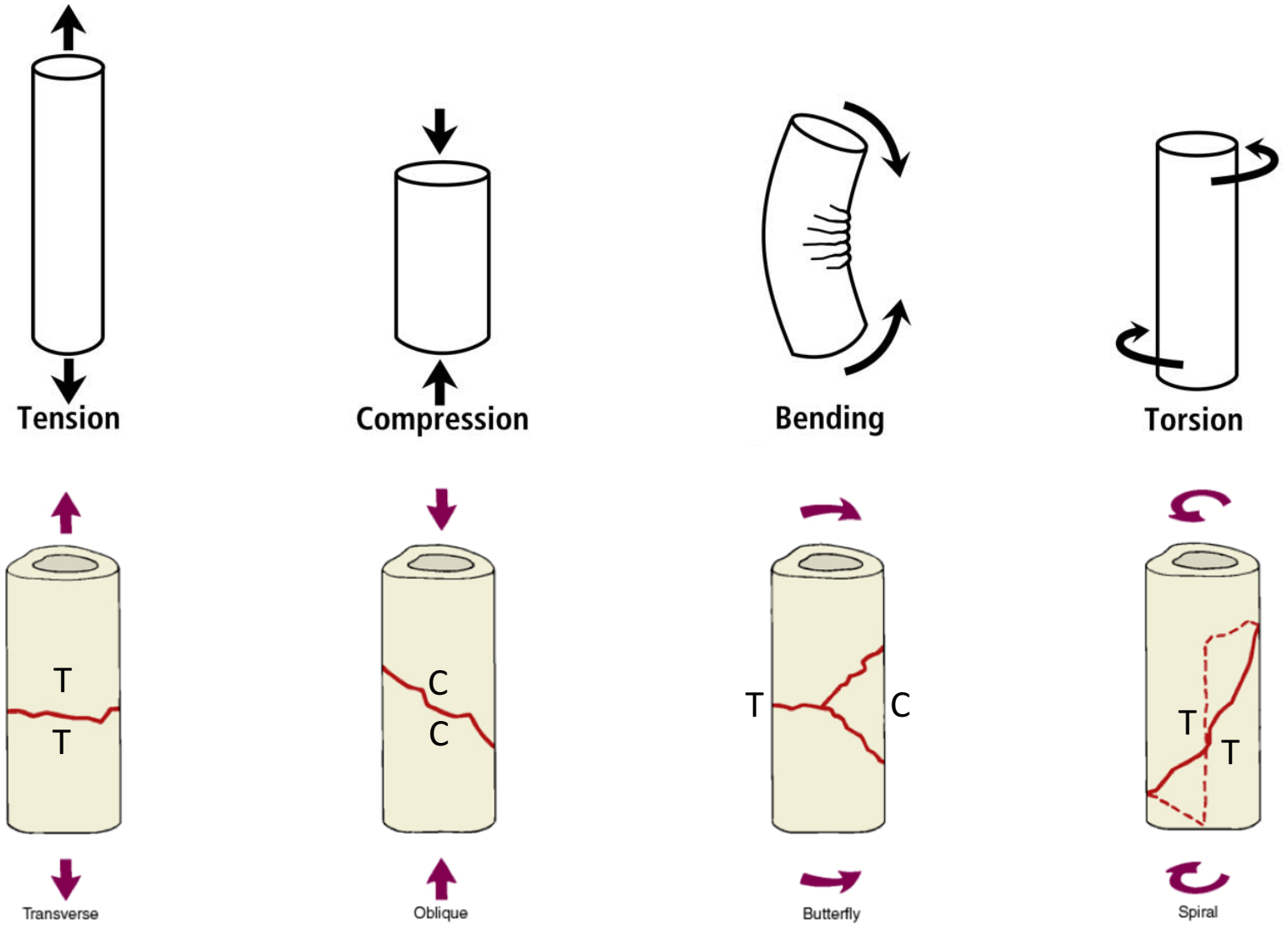
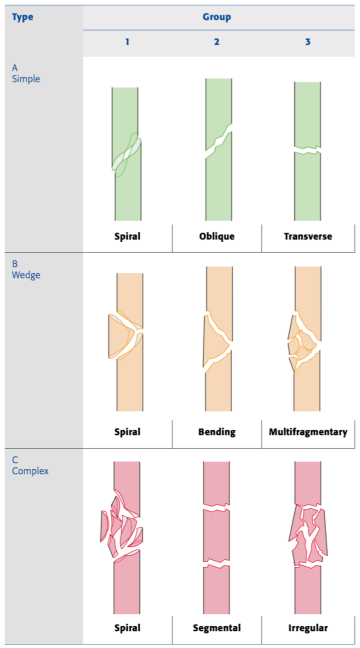
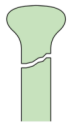
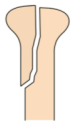
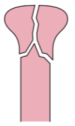
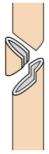
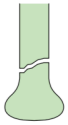
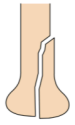
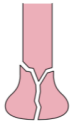


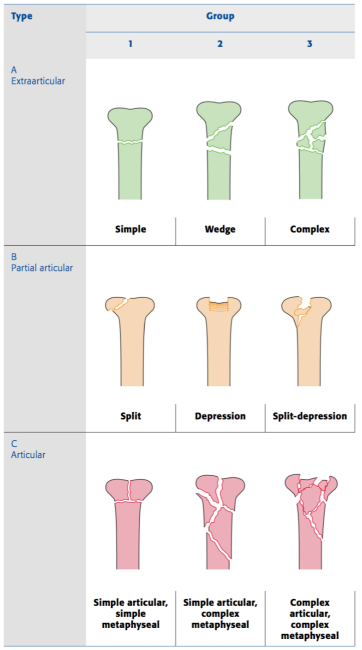
Forces Causing Fractures



Bone Fracture Classification (AO Foundation)



Segment	Type		
	A	B	C
1 Proximal	 **Extraarticular** No involvement of displaced fractures that extend into the articular surface	 **Partial articular** Part of the articular component is involved, leaving the other part attached to the meta-/diaphysis	 **Complete articular** Articular surface involved, metaphyseal fracture completely separates the articular component from the diaphysis
2 Diaphyseal	 **Simple** One fracture line, cortical contact between fragments exceeds 90% after reduction	 **Wedge** Three or more fragments, main fragments have contact after reduction	 **Complex** Three or more fragments, main fragments have no contact after reduction
3 Distal	 **Extraarticular** No involvement of displaced fractures that extend into the articular surface	 **Partial articular** Part of the articular component is involved, leaving the other part attached to the meta-/diaphysis	 **Complete articular** Articular surface involved, metaphyseal fracture completely separates the articular component from the diaphysis



https://aotrauma.aofoundation.org

Bone Fracture Classification – Femur (AO Foundation)

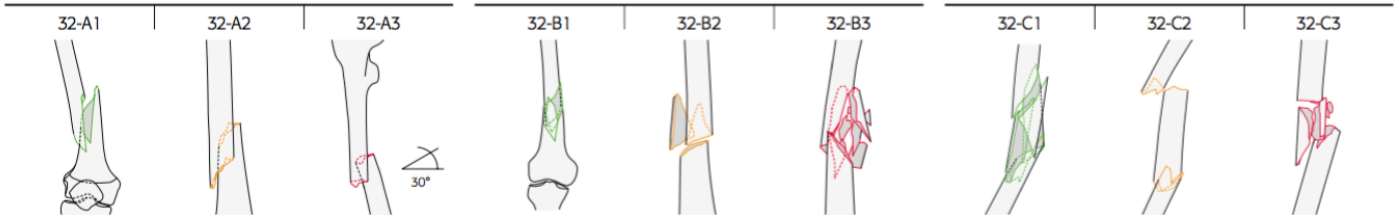
31 proximal (defined by a line passing transversely through the lower end of the lesser trochanter)

31-A extraarticular fracture, trochanteric area
31-A1 pertrochanteric simple
31-A2 pertrochanteric multifragmentary
31-A3 intertrochanteric

31-B extraarticular fracture, neck
31-B1 subcapital, with slight displacement
31-B2 transcervical
31-B3 subcapital, displaced, nonimpacted

31-C articular fracture, head
31-C1 split (Pipkin)
31-C2 with depression
31-C3 with neck fracture

32 diaphyseal

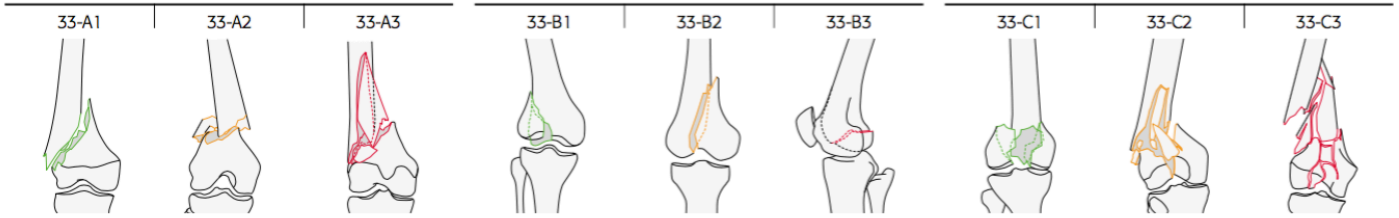


32-A simple fracture
32-A1 spiral
32-A2 oblique (≥ 30°)
32-A3 transverse (< 30°)
32-A(1–3).1 = subtrochanteric fracture

32-B wedge fracture
32-B1 spiral wedge
32-B2 bending wedge
32-B3 fragmented wedge
32-B(1–3).1 = subtrochanteric fracture

32-C complex fracture
32-C1 spiral
32-C2 segmental
32-C3 irregular
32-C(1–3).1 = subtrochanteric fracture

33 distal



33-A extraarticular fracture
33-A1 simple
33-A2 metaphyseal wedge and/or fragmented wedge
33-A3 metaphyseal complex

33-B partial articular fracture
33-B1 lateral condyle, sagittal
33-B2 medial condyle, sagittal
33-B3 coronal

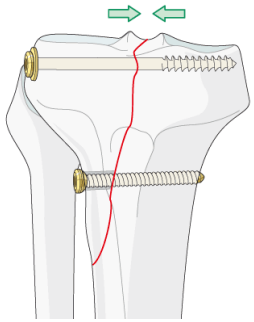
33-C complete articular fracture
33-C1 articular simple, metaphyseal simple
33-C2 articular simple, metaphyseal multifragmentary
33-C3 articular multifragmentary

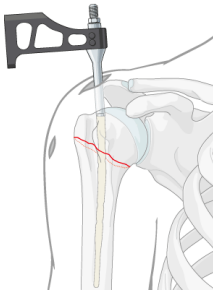
https://aotrauma.aofoundation.org

Fracture Treatments

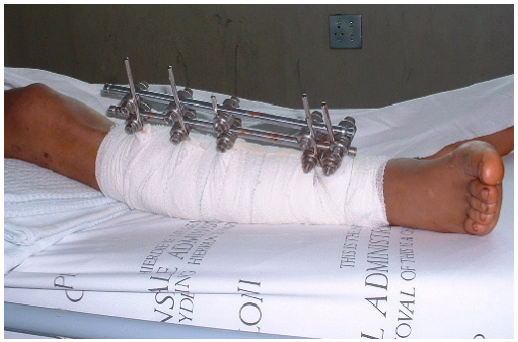
Non-operative

Internal Fixation



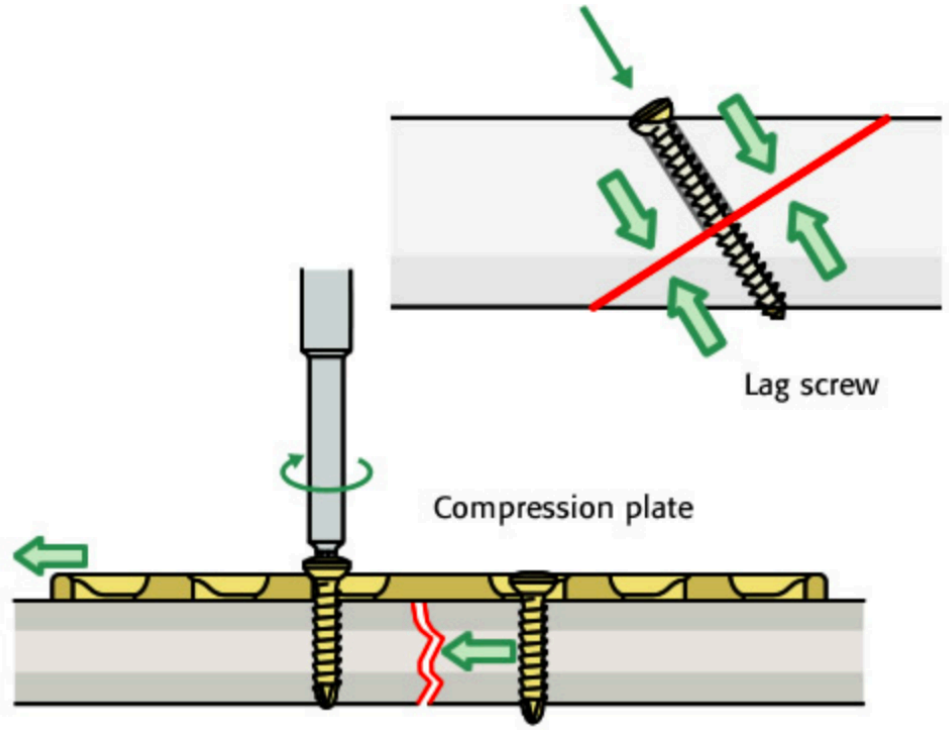


External Fixation



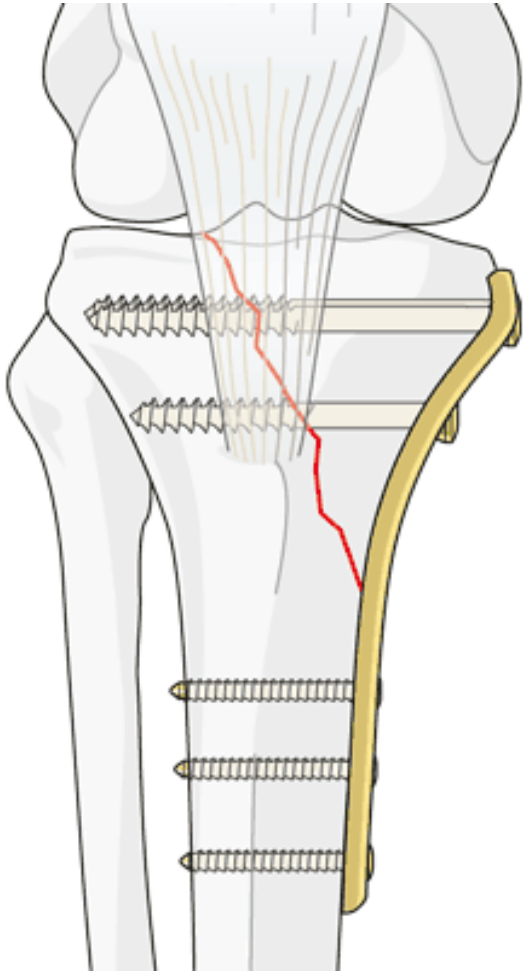
Internal Fixation

- Restore bone anatomy
- Produce bone stability – No callus formation
- Load bone as soon as possible to avoid massive resorption



https://aotrauma.aofoundation.org

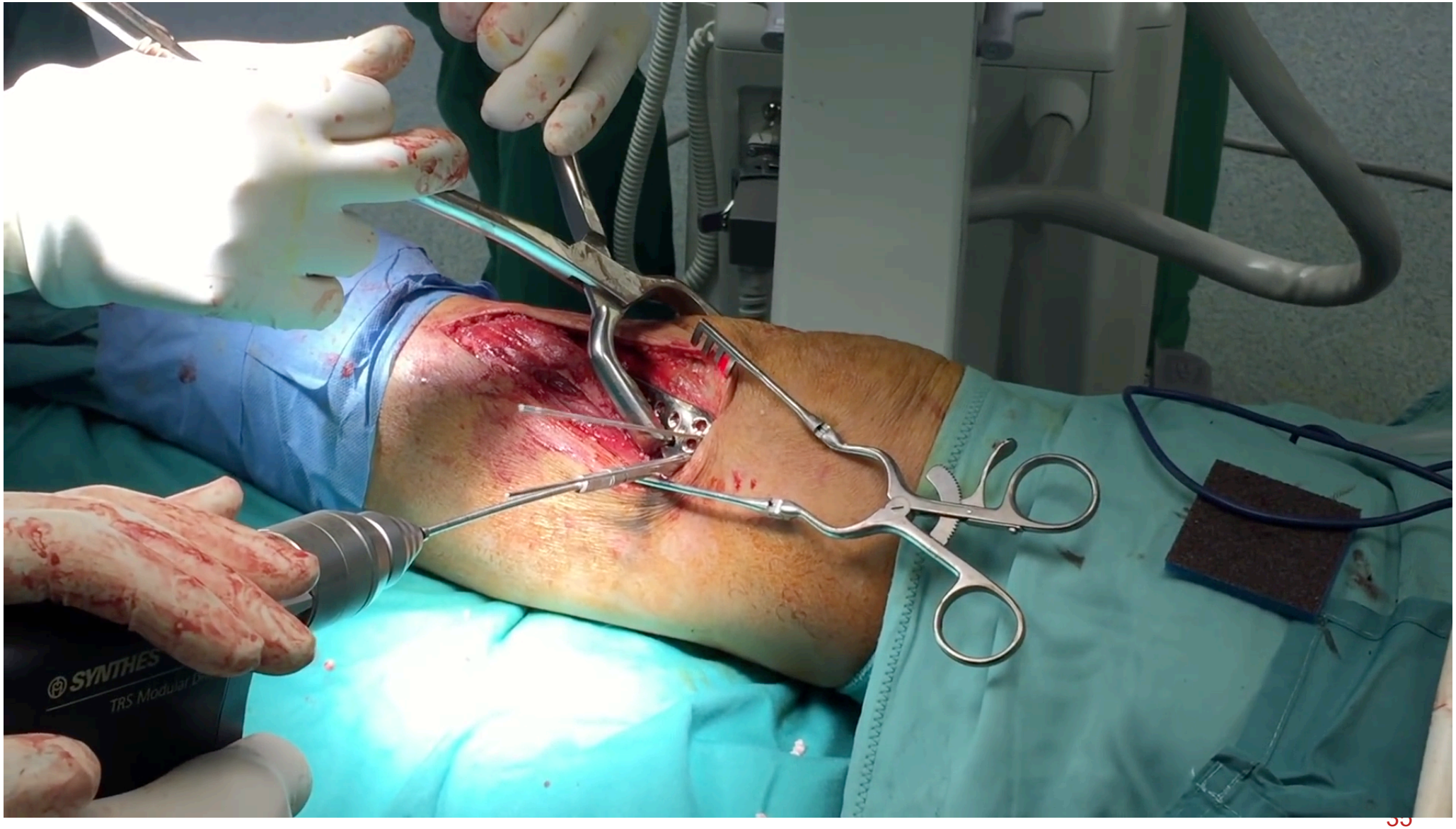
Fixation of Lateral Tibial Plateau Fracture



Fixation of Lateral Tibial Plateau Fracture

https://www.youtube.com/watch?v=CN-t4xjMqAQ

Fixation of Lateral Tibial Plateau Fracture



https://www.youtube.com/watch?v=CN-t4xjMqAQ

Implant Design

- Biocompatible materials
- Fit a wide anatomical range of patients
- Maintain mechanical fixation under cycle loading
- Offer a functional range of motion
- Provide the required kinematic stability